Designing for Safety: A Team Sport

White Paper

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Summary: From engineering, owner, architectural, legal, and academic perspectives, a team of professionals offer some critical considerations and proven, practical approaches to establishing and promoting a Design for Safety program.

Disclaimer

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Introduction

When designing a product, structure, facility, or process, it is critical to instill that design with considerations for safety. This becomes not only a sign of an experienced engineer, architect, or project manager, it is simply the right thing to do – especially in consideration of preventing accidents, injuries, and fatalities long after the design and construction phases of a project have ended. We call this Design for Safety (DfS). Because the various stakeholders in a project (architect, engineer, contractor, owner, and so forth) must interact with each other to achieve this safety objective, it can be likened to a team sport.

By integrating Design for Safety early in the conceptual and design phases of a project, benefits can be reaped through construction and owner/operation phases. Conversely, the longer the project team waits before introducing safety considerations into the design and construction planning of a project, the less the project team as the ability to impact overall safety. This concept is aptly illustrated by Szymberski, shown below in Figure 1.

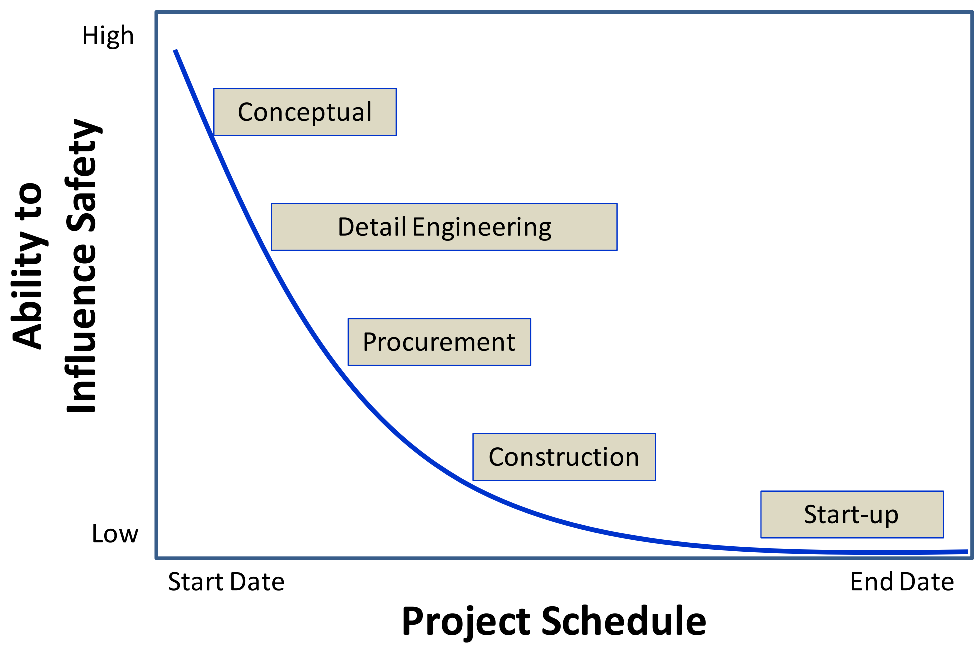


Figure 1. Time/Safety Influence Curve (Szymberski 1997)

Design for Safety has been recognized as one of the product design practices (that is, “Design for X”) along with constructability, quality, reliability, maintainability, usability, and others. These design-for practices are all desirable, but how to implement them in specific product types (for instance, in design of structures) has been an on-going debate for the past 50-60 years dating back to the original edition of the National Safety Council’s Accident Prevention

Manual For Industrial Operations (1st ed., Chicago, National Safety Council, 1946) and the origins of systems engineering of products.

While weighing the fundamentals of cost, risk, schedule, and quality as well, we believe safety should be paramount across all the roles in a project:

- Owner Concerns: How to ensure that my Architect/Engineer and/or construction contractor are providing me a product that is safe to operate and maintain?
- Architect/Engineer (A/E) Concerns: How to improve the design such that it is safer to construct in the field and safer for the owner to operate?
- Contractor Concerns: How to ensure worker safety during construction while also mitigating post-construction claims?
- Insurance Concerns: What elements of the design could potentially lower insurance costs for the owner, designer, and constructor?
- Legal Concerns: How to limit loss and liability in the future by investing in safety now?
- Academic Concerns: How to instill the DfS concepts used by the professionals listed above into the curriculum of students who will soon be entering the workforce as young professionals?

This paper offers some critical considerations and proven, practical approaches to establishing and promoting a Design for Safety program.

Defining Terms

In Safety and Health For Engineers, Roger Brauer defines safety as "the state of being relatively free from harm, danger, injury, or damage" and safety engineering as "the application of engineering principles to the recognition and control of hazards." More specific to the design process, NIOSH has defined the concept of Prevention though Design (PtD) on its web site to be "addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment." The application of PtD to construction is also known as Design for Construction Safety (DfCS), the process of addressing construction site safety and health during the design of the project. A synonym for DfCS one sometimes encounters is Safety Constructability. An earlier version of PtD was called Safety through Design. There was an Institute for Safety through Design established by the National Safety Council (NSC) from 1995-2005. The application of PtD to the facility being constructed is part of the more general practice of Design for Safety (DfS), which is concerned with the facility and equipment user's and maintainer's health and safety.

Owners

> Formal DfS Programs

Owners should evaluate the need for and benefits of implementing a DfS program on the "next" project. Owners should also adopt a total project cost mindset with respect to DfS, recognizing the costs may be reduced because the safer and more constructible design has the potential to:

- Lower workers compensation insurance costs.
- Improve quality, potentially reduce total project cost.
- Reduce job site injuries and fewer delays due to injuries.

Construction productivity should be higher and construction duration should be shorter because some risks have been designed out of the project. Furthermore, maintenance costs over the life of the facility should be lower because the DfS process designed out or reduced maintenance workers hazards.

The owner organization and A/E firm can implement their own DfS program. If there is not a DfS program in the owner's organization or the A/E firm already, the owner should request a DfS program be created and used on projects.

Most employees in owner organizations will not understand the DfS concept unless the owner manages a formal DfS program. The owner should communicate and demonstrate its commitment to safety by placing a higher priority on personal safety than on quality, cost, and schedule.

> Creating a DfS Program

A new DfS program could be modeled after a successful Prevention through Design, Design for Construction Safety, or a Design for Safety program implemented by Southern Company, a southeast-region utility company.

Design for Safety (DfS) teams should consist of representatives from these areas:

- Owner's safety professional and/or contractors safety professional;
- DfS team leader (someone with DfS training, education or construction experience).
- Constructability coordinator.

- Representative for each design discipline (architecture, structural or civil, mechanical or piping, electrical and instrumentation and controls.

This team will do most of the work in creating the DfS program. The Owner's DfS program may consist of creating a DfS goal, a DfS checklist, a DfS database, a DfS method to identify hazards and implement constructability, and a DfS procedure. Owners should require design professionals to have access to discipline-specific DfS checklists. Such checklists could be created in-house or secured from external sources, such as from the Construction Industry Institute (CII) or the Australian government's Construction Hazard Assessment Implication Review (CHAIR) tool. Design managers should also consider providing their employees with reference tools and websites to increase knowledge of construction safety in general. Description of the DfS tools used by Southern Company may be found in Attachment 1.

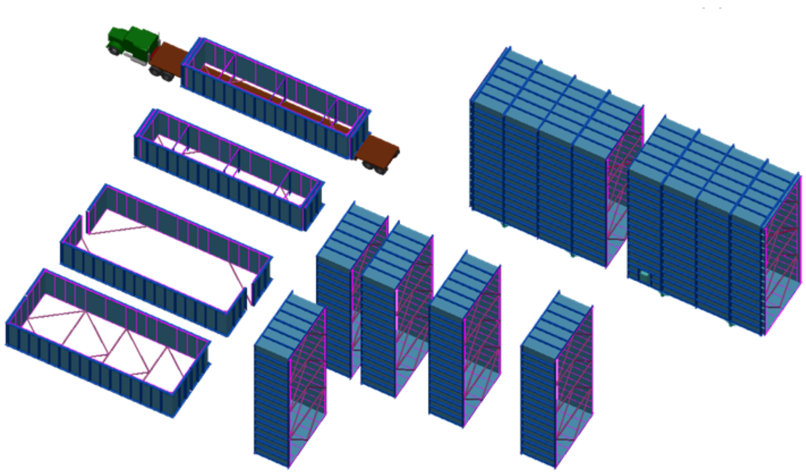
One-project DfS programs may consist of project review meetings focusing on identifying and documenting job site and maintenance hazards needing to be designed out. Also, document the hazards that could not be designed out and transmit this information through the project manager to the owner and contractor. Also, identify and document constructability ideas and best practices that will be implemented on the project.

Owner, A/E firm, and contractor personnel must be able to easily access draft design drawings, specifications, project models and share DfS-related and other constructability comments.

> Selection of A/E Firm and Contractor

Having one contract with a Design-Build Contractor makes it easier to implement the DfS program on a project requiring architects/engineers and a contractor. If an owner uses the traditional Design-Bid-Build process, the owner may need the services of key trade contractors as consultants to review the design on a regular basis if DfS is implemented. The owner should ensure these team players are supportive of a DfS and constructability process.

To avoid excessive DfS implementation costs to the owner, cost-Plus contracts with an A/E firm that include a guaranteed maximum price (GMP) are preferable to fixed price contracts if the firm does not already have a DfS program. Sometime the design costs are a little higher but the costs are offset by lower cost for the contractor. Design firms submitting proposals for the project must be fully aware of the owner's requirements for DfS to be performed on the project. The owner inquiry documents should include requirements for the company to submit information detailing previous DfS implementations and previous DfS experience of key personnel assigned to the project. The inquiry document should outline the DfS expectations. The owner should require the use of Computer–Aided Design (CAD) on the project. CAD can show the user the design in three dimensions to expose design conflicts and space issues. One example: The design team can present the recommended erection sequence and make recommendations for steel fabricated panels, modules and stair towers. Southern is using this approach quite successfully with pre-fabricated duct sections. By shop fabricating, assembling, and shipping the duct prior to arrival on the jobsite, the safety and constructability of the entire job was positively impacted.



The content of the Request For Proposal (RFP) for constructors should be similar to that of the contract.

> DfS-related Duties of Owner

Improving construction site safety requires attention and commitment from all parties involved. This is accomplished by addressing safety issues for each project on a project-specific basis.

Some duties of an owner with respect to Design for Safety are:

- Select the A/E firm and contractor
- Clearly communicate the owner's commitment to safety. The owner's goal is to create an injury-free project.
- Assign overall project safety responsibility and authority to a specific organization or individual.
- Develop a coordinated project safety plan and monitor construction safety.
- Assign responsibility for approval of shop drawings.
- Encourage the Design team to consider DfS in all design activities.
- Consider the vehicular and pedestrian traffic during all project phases.
- Consider the project's need for maintenance, spare parts, and safety and health files.
- Consider the project's impact on existing plant workers and facilities.
- Assign someone to monitor the injuries and near misses for construction and plant worker. Items of a design nature should be passed to the A/E firm.
- Evaluate the need for a safety recognition program.
- Participate with the project team when they have hazards, safety, constructability and project reviews/meetings.

The owner should require the contractor to provide the following information with proposals, after award, or during the construction of the project: Contractor's project safety plan, a job hazard analysis, and evidence of regular safety meetings with supervisory personnel.

Owners that are aggressive in safety should use proactive criteria to evaluate and select contractors. These criteria include the Total Recordable Incident Rate (TRIR) on past projects, qualifications of the contractor's safety staff, qualifications of the contractor's project management team, and the assessed quality of the contractor's overall safety program.

Post-award, contractual safety requirements should clearly convey the Owner's emphasis on safety and the owner's expectation of a safe project. Huang (2003) lists four additional contractual requirements identified as being leading indicators:

- Contractor shall have at least one full-time safety professional on the project.
- Contractor shall submit with the proposal the résumés of key safety personnel.
- Contractor shall provide minimum training, drug screening, and safety orientation for the workers.
- Contractor shall submit a safety policy signed by one of the firm's executive officers.

Architect/Engineering Firms

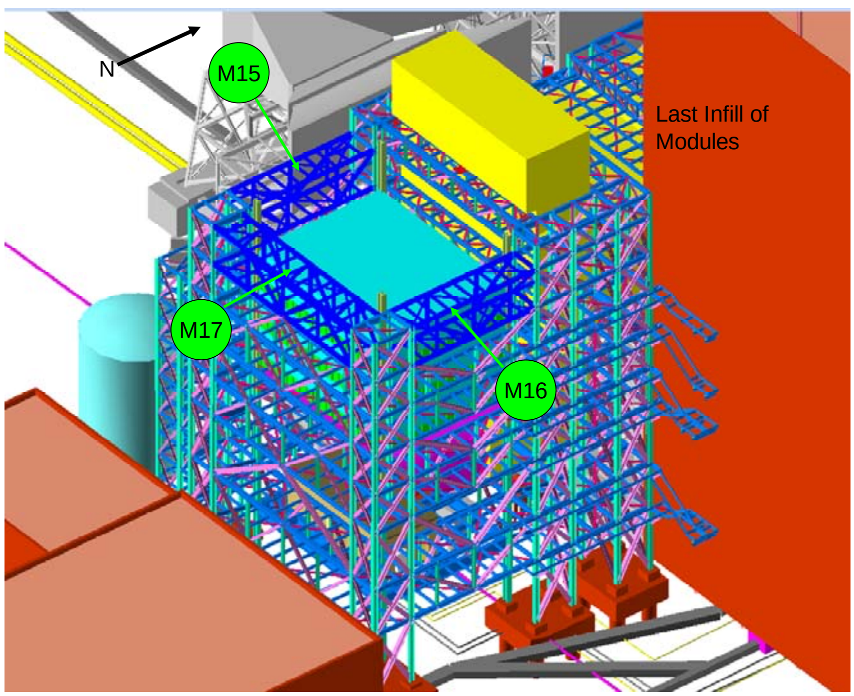
> Engineering in Industrial Projects

In the United States the role of the design professional has traditionally been to design with the end user in mind while considering engineering practices, local building codes, and public safety with the safety of the construction workers left up to the contractors. Following our team sport analogy, this can prove as ineffective as a coaching staff investing all their practice time building a potential winning team, while an entirely different team actually plays the game. Consider:

- In 1985 the International Labor Office (ILO) recommended that designers give consideration to the safety of workers who will be involved in erecting buildings.
- In 1991 the European Foundation for the Improvement of Living and Working Conditions concluded that about 60 percent of fatal accidents in construction are the result of decisions made before the site work begins.
- In 1994 a study of the United Kingdom's construction industry found a causal link between design decisions and safe construction.

There are a number of design aids available to design professionals, and the Construction Industry Institute (CII) has developed over 400 design suggestions that can be used by design professionals. These design practices have been incorporated into a computer design toolbox that can be purchased from CII. Teams consisting of contractors, A/E firms, owners as well as other project stakeholders who communicate before, during and after a project have proven that increased safety, quality and profitability go hand in hand.

DFS should be considered during the conceptual phase of the project. As soon as the conceptual design team is assembled, this is a good time to begin the "kickoff" of the DFS effort. For example, Southern Company's structural conceptual team considered using shop-fabricated pre-assembled steel modules well before the detailed design phase of the project. The illustration below shows just three of the modules (M15, M16, and M17) as they are being planned. Shop-assembled modules, panels, and towers reduce the number of individual steel members by approximately 65%. This reduction in the steel erector's labor not only improves safety during construction, but also reduces cost and positively impacts the construction schedule compared to Southern's previous practice.



Some large industrial and utility companies have their own in house engineering staff and construction services group, facilitating a team approach. Southern Company primarily uses engineering services from its in-house organization. However, sometimes it needs to use the services of outside A/E firms and design build companies. Southern Company's Design for Safety effort is led by Design. When outside engineering services are required, Southern Company requires the A/E Firms to use their own or the Southern Company's DfS program. Southern Company includes its own DfS requirements when issuing an inquiry for engineering services. The company's DfS Goal is to have all engineering drawings and specifications prepared with a consideration for safety and constructability. Southern Company's DfS procedure requires all mid- to large-size projects to follow this process, including the use of APEX, a MS SharePoint-based tool incorporating hundreds of DfS considerations across the design disciplines. APEX may be sorted by title, discipline, system/topic, department, description, modified date, and checklist display. APEX can generate a custom DfS checklist that can be used by each discipline design lead.

APEX has a form for design personnel to submit new DfS ideas. A DfS team reviews each submitted item before adding it to the APEX database. Additionally, this team reviews Incident Notification Reports submitted from construction projects to determine if the project design contributed in any way to the injury or near-miss incident. The design leads are responsible for ensuring design documents such as calculations, drawings, and specifications have incorporated the appropriate DfS items from APEX and the project-specific checklists. The project engineer (coordinator of design disciplines) ensures that safety was appropriately factored in to the design. Applying the Design for Safety process, conducting constructability reviews, implementing best practices, and designing out hazards has improved the quality, budget, schedule and safety on projects constructed over the last 5 years.

Per ASCE-CI Policy Statement 350, Design engineers have responsibility for (1) recognizing that safety and constructability are important considerations when preparing construction plans and specifications; and (2) ensuring specification require that the design or details of critical elements of temporary construction, erection and lifting schemes, complicated form work and scaffolding be prepared by a professional engineer. Often the simplest of decisions by the engineer up-front can save a great deal of effort on the construction effort. For example, these include: considerations of stair/platform locations, valve orientation, or even specifying the use of squirter washers for indicating proper fastener tension during assembly onsite.

A/E Firms should implement good practices, code requirements; and industry standards into their design. For example, the structural engineer could specify the steel design drawings and shop drawings should meet the OSHA 29CFR Subpart R 1926.750 though 761 mandatory requirements. The Steel Erectors Association of America and National Institute of Steel Detailing jointly wrote “Detailing Guide for the Enhancement of Erection Safety”. This book contains sketches of how to implement the mandatory and good practice (suggested) requirements of Subpart R. Some of the mandatory sketches are: tipping hazards, fall-through-deck protection, column protection, column anchorage, perimeter, protection, column splices, double connections, joist/joist girder stability, and fall protection. Some of the good practice sketches are: erector friendly column, self supporting connections, deck support, beam connections and bracing.

> Architectural Projects

A line has been drawn as a barrier between architectural and engineering design and construction safety in the built environment. That barrier has its origin in our traditionally set roles, contractual language, and professional liability concerns about managing risks. However, as we turn to the next page of development as a design and construction industry, the line will inevitably begin to blur. Safety in construction has to become a team sport to protect our most treasured assets – the men and women who build and maintain our constructed environment.

On U.S. construction sites each year there are nearly 200,000 serious injuries and 850 deaths (Department of Labor, 2009). Even though it incorporates only 7% of the United States' work force, construction accidents account for 18% of our workforce fatalities (Department of Labor, 2009). Construction is a serious and dangerous business, making it difficult to attract young workers who want to make it a career. As our experienced construction force ages, improving safety becomes all the more important to attracting young workers. Improving safety in construction is important to everyone. Architects and engineers who are concerned about achieving higher quality want the most experienced and capable workers building their projects.

Admittedly, architects and engineers have had limited involvement in designing for construction site safety due to a variety of reasons, but paramount among them is the risk management concern about professional liability - and for good reason. The design and construction industry has carefully developed contractual language and case law that for decades has clearly defined the domain of the designer as in the studio and the domain of the contractor as on the jobsite. On a daily basis, neither the designer nor the contractor wants to venture outside their domain, which could subject him/her to litigation and cause the insurance carrier to deny a claim. This is serious business, especially given the highly litigious environment prevalent in the United States.

Clearly, the designer should feel a moral obligation to design for safety, but he/she should be able to do so through a professional concern, rather than a contractual obligation for safety on the jobsite. Even so, that may change in the future, and, through the use of Integrated Project Delivery (IPD) methodology using Building Information Modeling (BIM) software, it already has. According to a white paper by the Victor O. Schinnerer & Company, one of the largest professional liability insurance carriers, with IPD we will be seeing a change – a sharing – of construction safety responsibility arising because of integrated project delivery and shared design and construction responsibility. However, how the responsibility is handled has not yet been sorted out. It has also not stopped IPD Teams from pursuing the sharing of responsibility. A commonly used IPD contract already states two provisions of interest regarding responsibility of the IPD Team, including at a minimum the owner, architect, and contractor:

- The IPD Team shall be fully responsible for all construction means, methods, techniques, sequences, and procedures for construction.
- The IPD Team shall be responsible for initiating, maintaining and supervising all safety precautions and programs in connection with the work.

In the future, IPD is projected to become common-place. While IPD is yet to be prevalent, Design-Build (D/B) is a current and potentially low impact project delivery venue for learning to Design for Safety. Working in the team sport mode, early in a D/B project, the owner, contractor, and Architect/Engineer have the opportunity of establishing a "culture of safety", that would permeate throughout design and construction. In this mode, each entity would contribute knowledge and expertise toward preparing a Design for Safety program, outlining the specific goals and requirements for safety. Included would be the owner's criteria for safely maintaining the project after construction is completed. See Attachment 1: The Southern Company DfS Program, as an excellent example. As the project is designed, an analysis should be performed to determine how each requirement is met or satisfied during the process. It should be clarified contractually that the A/E is not responsible for jobsite safety, as that is the domain of the contractor, but the A/E can be expected to work as a team with the owner and contractor throughout design and construction to eliminate potential accidents to the extent practical.

Once the architect or engineer recognizes his/her value and expertise in designing for safety, the knowledge gained will most likely be easily transferred to other project delivery methodologies, such as design/bid/build, allowing for review and concurrence or adjustment by the successful contractor.

Spending more time and expending more resources in design by adding safety components should result in appropriately adjusted compensation to the A/E, but it could also easily result in an overall life-cycle cost reduction to the owner. Figure 1 indicates that the ability to influence safety is high during design and lower during construction. The converse should also be true when it comes to cost, that safety measures incorporated during design cost less than adding them to the project during construction or after the project is completed, resulting in a net savings to the owner. See Figure 2.

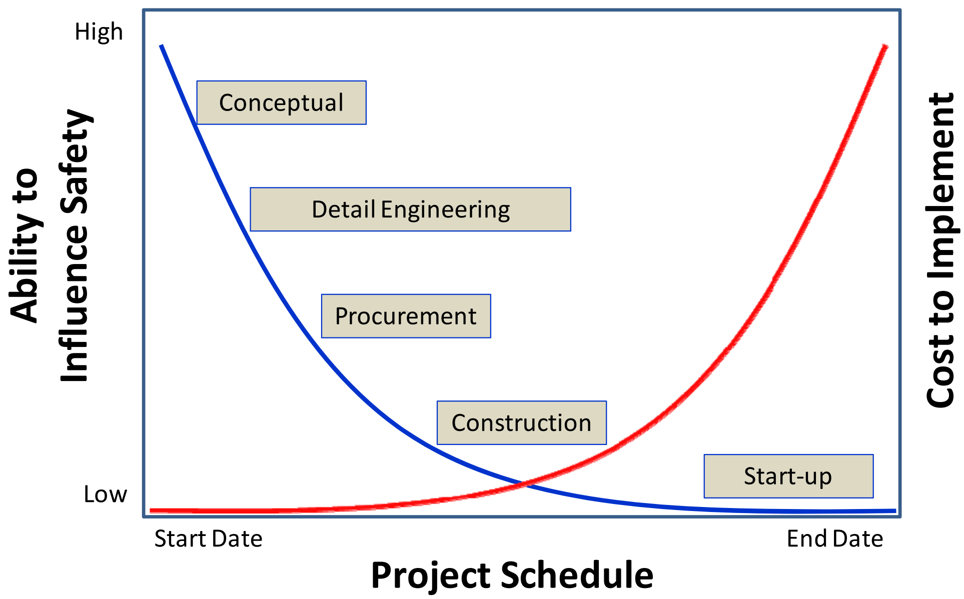


Figure 2. Time/Safety Influence Curve (Szymberski 1997) with Cost Curve Overlaid

The following are examples of Design for Safety practices:

- Roof Edge Fall Protection: When parapets are incorporated into the design of a building, they should be 42" above the roof surface, eliminating the need for additional fall protection either during construction or in maintaining the building throughout its life. If parapets are not provided or they cannot be at the 42" height, additional fall protection will be required in the form of temporary or permanent rails at the 42" height or tie-backs anchored into the building structure.

- Service Clearances: Building equipment, such as boilers, air handlers, chillers, switchgear, generators, and electrical panels can be installed so that they are functional, but difficult or potentially dangerous to maintain. Designing equipment layouts should take into consideration proper maintenance and future replacement. Examples of maintenance activities requiring safe clearances include pulling coils on major air handlers, rodding chiller tubes in a water-source cooling system, changing out motors and filters.

- Perimeter Fall Protection: Perimeter fall protection requires barriers at 21" and 42" and these are frequently made of wood and may be movable. While these may meet OSHA requirements, they are often inadequate for positively providing fall protection because of their construction or they are moved out of position. During design of steel or concrete structures, provisions for effective fall protection barrier cables can be easily made by designing holes in columns (while avoiding the neutral axis). The cables can be recycled from project to project.

- Equipment Guardrails: Where servicing equipment requires working in an area within 6 ft of a roof edge or otherwise raised 30" or greater above adjacent grade, design permanent guardrails at 21" and 42" to prevent the danger of falling during maintenance.

- Roofing Systems: Select roofing systems that are appropriate for design conditions, but that are less damaging to the environment and to workers health and safety. Many of the single membrane systems available are largely manufactured under controlled conditions and then jobsite assembled with less use of VOCs than hot kettle systems, which can be dangerous and unhealthy to install.

- Prefabrication: Prefabrication of various building components in a controlled manufacturing environment and erection on the jobsite means less time is spent in performing potentially dangerous activities at the site. The prefabricated elements may also be constructed to a higher level of quality and at a reduction in overall cost to the owner. Examples include: Steel stairs, prefabricated concrete stairs, precast concrete walls and other components, equipment racks, piping systems, ductwork assemblies, and glazed curtainwall, among others.

Consider prefabricated formwork where possible: for example, prefabricated formwork for concrete stairs.

There is also the possibility of prefabricating specialized rooms in buildings with repetitive elements such as toilets or dorm rooms to substantially eliminate onsite construction, reducing the time workers are exposed to potentially dangerous or unhealthy working conditions.

- Specify Low Hazard Products: DfS can easily include specifying products that must be incorporated on the jobsite so that they do not adversely affect worker health or safety. Examples include low volatile organic compounds (VOC) such as paints, glues, and sealers which are less likely to harm initial installers, occupants or future maintenance workers making repairs or replacements.

- Equipment Handling: DfS should incorporate an understanding of how major equipment is placed in or on a building. Pathways for installation and replacement should be determined as part of the design process. Beams should be designed to allow hoisting where needed and inserts should be cast or attached to the building structure to allow winching loads into place.

- Facility Maintenance Program: DfS does not end with construction activities. In any coordinated safety program, the owner should receive, pay for and follow a recommended procedure for properly maintaining the building and associated equipment. The maintenance program should specifically address the safety features that have been designed into the building, how those safety features were intended to be used, and how to properly maintain the features so they can perform as intended.

Architects and engineers should become more familiar with the process and terminology of DfS. An American Institute of Architects (AIA) approved course, "Overview of Construction Prevention through Design", is being offered by East Carolina University through a grant from the Virginia Tech Occupational Safety and Health Research Center. This course provides 1 Learning Unit /HSW credit.

Contractors

As mentioned in other sections of this paper, DfS is indeed a team sport. Once construction begins, safety is to a great degree the responsibility of the contractors and other site professionals. Without the proper pre-game foundation being laid, far too often the contracting community views safety as something they must do at an additional cost of both time and dollars with no measurable return. Thankfully, not all contractors hold to that view. In reality countless profitable and safe projects now stand as testimony to the falsehood of this myth. Many studies have shown that sound safety practices are indeed good business practices.

Contractors must provide appropriate safety training for their employees on specific hazards they may encounter, and inform employees of work-related hazards. The contractors' competent persons must truly be competent in the anticipation of hazards and aggressively interrupt unsafe practices. Site workers, after proper training, should assume personal responsibility and accountability for their actions, including knowing and observing safety rules and safe work procedure; wearing and using the required clothing, equipment and protective devices; and being free from drugs and alcohol. This proactive safety culture decreases the numerous construction incidents that result from basic causes such as lack of proper training, deficient or inconsistent enforcement of safety, unsafe equipment, unsafe methods or sequencing, unsafe site conditions, not using the safety equipment that was provided, and a poor attitude towards safety.

The proactive contractor who desires to obtain the maximum return of the safety dollar can and should positively influence safety in the pre-game design process. The Construction Industry Institute (CII) references the use of design, fabrication, and construction knowledge and experience in planning, design, procurement, and construction to achieve objectives of the project. Pre-construction meetings are held with the owner, A/E, and safety representatives for planning and visualization of the construction process. These meetings should be in the early stages of the project design.

The contractor's knowledge will be useful in the designer's effort to implement DfS and constructability. The constructability meetings focus on simple, economical design and short construction schedule, while considering the site conditions, code restrictions and owner's requirements. The team that includes the constructor's and designer's knowledge will facilitate more informed decisions.

Constructability DfS meetings can be beneficial when performed prior to establishment of a defined scope and during early planning and design phases. In the early state of the project there is more flexibility to consider alternate designs that could have a positive impact on the quality, cost, schedule and safety of the project. In contrast, when a contractor is faced with devising methods to overcome safety-related design hurdles once the game begins, schedule delays occur, and increased manpower demands and worker risk are typical, thus increasing cost.

Just as any championship team conducts detailed post-game analysis, DfS extends to post-project analysis as well. After-action contractor feedback to the A/E firm and entire design team should result in an ongoing quality and safety improvement loop feeding directly into future designs. The typical practice of immediately moving on to the next job without looking back at potential DfS lessons learned simply results in the same costly methods being employed again and again. One cannot imagine a coach saying, "We lost that game, now let's go out and do exactly the same thing again."

Insurance/Risk Management

> Insurance Considerations

From an insurance perspective, controlling losses controls costs. This is easily said, but not easily done. Incorporating DfS initiatives in the preplanning stage provides the best opportunity for reducing the possibility of loss not only at the time of construction but also after the project is completed.

Imagine using automobiles today without seatbelts or tempered safety glass or airbags or speedometers or any number of safety-related features. These items were built into the design to help achieve improved results from a safety standpoint, a marketing standpoint and yes, also from a legal liability standpoint.

Improvements are not always mandated by laws or regulations which are typically intended to provide only a minimal degree of protection. Taking a proactive approach to use the best technology available drives the continual improvement process and also provides the greatest return on investment by keeping losses to a minimum. This is the best method in the long run, as retrofitting construction is much more costly than including technology features at the beginning.

From a property insurance standpoint, it is much less costly to insure a building with a sprinkler system than one without this protection. It is also much less costly to provide firewalls before rather than after construction. These features also improve life safety considerations.

From a workers' compensation standpoint, with the average cost of a lost-time accident of over $20,000 per claim, fall risk control features such as 42 in high parapets or using built-in anchorage points capable of holding 5000 lbs helps reduce the possibility of a claim during construction and facility maintenance. Workers and maintenance employees will be much safer if Design for Safety features are preplanned and incorporated. Workers compensation losses drive the development of the Experience Modification Rate (EMR) which is a measure of claim performance vs. others in similar industries. Having a single workers compensation loss appears in the EMR calculation in 3 consecutive years until it ages its way out of the formula. In other words, a company typically pays for a single loss 3 times as far as the EMR is concerned. The EMR is the largest insurance industry premium adjustment factor in driving premiums charged for this coverage. Also, many larger companies participate in insurance programs where that company pays the first deductible amount of a claim (in many cases up to $250,000 per claim) and this cost must be paid out of corporate profits. While reducing unsafe acts is very important in controlling losses, so is reducing unsafe conditions. Also, incorporating DfS initiatives helps keep employees performing the job

functions and tasks that they were originally hired to do. In other words, incorporating DfS procedures is just part of an overall effective business management plan.

> Risk Management Considerations

General liability, also referred to as third party liability, is a concern for any business that has people other than their own employees working or present on the premises. Examples include outside contractors onsite or visitors, etc. Incorporating DfS considerations such as slip-resistant flooring is another example of controlling slip-and-fall type exposures.

Environmental Impairment Liability is also similar to general liability in that it involves damages to third parties. Again, incorporating DfS features such as diking to contain the volumetric capacity of an above ground storage tank reduces these types of claims.

From a professional liability standpoint, including design features that keep losses from occurring keeps the claim from occurring in the first place and thus avoids the subsequent costly lawsuit. Many times litigation costs are staggering even if subsequently found not liable. Therefore, in debunking the myth of DfS being too expensive, think in terms of both "during" and "years after" construction (life cycle costs).

Legal Considerations

> Limiting Liability

Form a legal point of view, the concept of DfS presents a number of interesting questions, primarily relating to liability. From a risk standpoint, DfS is a recognized method to control liability by reducing risk in active construction zones. Common sense dictates that preventing accidents means there is less opportunity for litigation and liability. There are consequential concerns that must be addressed when designers, architects, and engineers undertake to remove safety risks from a jobsite.

During the construction phase, the benefits are obvious to the contractor. Architects and designers consider the methods and means of construction, and they design the physical features of a building in such a manner that it can be constructed safely. This may involve prefabrication of certain elements of the project, such as stairwells or suspended cat walks, reducing the amount of time that workers have to construct permanent items at suspended heights.

> Contractors: Two examples

The concern for contractors, however, includes issues that may arise after projects are completed. Without fail, personal injuries from building or facility maintenance happen, at least in part, to conditions which could have been designed in a manner to protect the worker that has to access the area. Consider the following examples that help demonstrate the control of risk through DfS.

In the first situation, a crew was removing material from a roof on a warehouse facility. The warehouse had translucent skylights built into the roof. The skylights, however, matched the profile and were a similar color as the corrugated roofing material. Even though the crew was not working in the area of the skylight, one member carried debris in a path that took her in its vicinity. When returning from dumping material, she fell through the skylight.

As in most lawsuits, there were a number of potential OSHA violations onsite relating to the failure to identify and cover the skylight, as well as the failure to use fall protection, the case demonstrates that both workers and employers make mistakes. If DfS and hazards identification had been used, such as the raised skylights in the photo, the accident would be far less likely to occur.

In another situation, a millwright was working around the motor at the top of the enclosed conveyor system. While the worker was wearing a harness, he did not have each hook secured, and one of his lanyards fell into the exposed drive shaft of the motor. The machine pulled him in by his lanyard, resulting in serious injury before power was cut to the drive. Again, while there are questions about proper fall protection, lock–out/tag-out, and OSHA questions on the part of the worker and employer, an access platform built beside the motor would best serve to prevent the accident.

While each of these factual scenarios demonstrate errors that were made in workplace conduct, they also demonstrate examples of potential accidents that could be prevented through DfS initiatives that consider the long term maintenance needs and safety-related issues for a facility.

> Architects, Designers, and Contractors

A larger concern, however, is the fear that a designer or contractor is taking on additional potential liability by adopting a design for safety standard. Normally, an architect does not have a legal duty to a contractor or its employees to make sure that the project he designs can be carried out in a safe manner, much less to ensure the safety of workers that may maintain the building for the decades following its completion. Where an architect undertakes such a mission, however, a legal duty may be created, for which liability can be assessed if there is an accident that the architect could have or should have foreseen.

Where a designer is attempting to create a construction process that limits potential exposures, the question arises of whether a designer is doing everything he/she can to make a site safe. Does adopting a safer standard for construction create a duty to take every possible foreseeable step to make a safe jobsite? This is often the grey area that is the subject of costly litigation with hired experts asking the question, “Did the designer do everything in his power to make the job safe?” versus “Did the designer take reasonable steps within his power to make the job safe?”

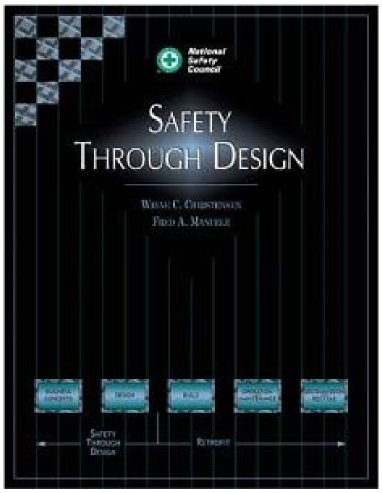
An additional concern relates to the need for the contractor to transfer liability to the owner. For instance, although permanent safety features in the building such as permanent anchor points for fall protection may be used by subcontractors during construction, the contractor will not likely have control over the building once the project has been turned over to the developer or owner. During use of the facility, the condition of the anchor points may deteriorate or may be misused by a subsequent contractor, causing injury. In short, the original installer is potentially creating a condition for which it may be liable for the life of the building.

The risk of such liability can unfortunately have a chilling effect on a contractor’s willingness to leave such permanent safety features. One manner to deal with such risk is through statutes of repose, which would limit potential liability for contractors to accidents that occur within a set number of years. Another method would be to shift liability for incidents relating to the use of permanently installed safety features to the owner of the building, or the party responsible for maintenance, by contract.

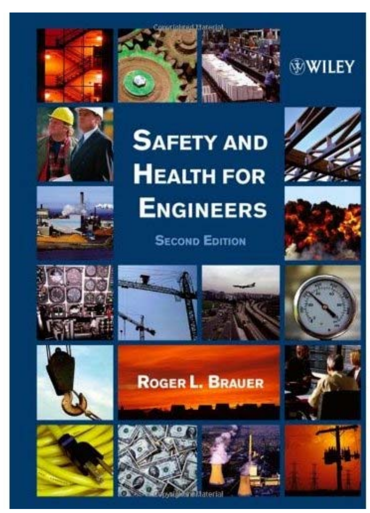
Academia

> Options for "Design for Safety" Course Content

Who has not heard a coach encourage his players to "focus on the fundamentals"? In the same way, we believe the focus of DfS should begin at the undergraduate, not the professional level.



Engineering course content is a mix of theory, methodology (processes to follow in design or analysis), tools (typically mathematical or computational), and case studies. This content is drawn from textbooks, handbooks, and other published literature on the subject in question. One searching for such DfS material could start very broadly, looking at textbooks on the design process for their discipline, the systems engineering process in general, and perhaps books on Design for X or the more recent movement known as simultaneous or concurrent engineering. Organizational processes that bring together designers with representatives from later stages of the product life-cycle (e.g., constructors, operators, maintainers) in concurrent design teams have been shown effective in influencing the design decisions toward products that are easier and safer to construct, operate, and maintain. Success with such processes is probably better illustrated with case studies than with process diagrams and descriptions. Design-build project delivery certainly enhances the probability of concurrent engineering in a construction project. Another practice that is more prevalent than concurrent design is the use of checklists, which in some sense try to remind the designer about lessons learned and what the representatives would have said about design decisions, if they were consulted. Checklists are often found in handbooks, articles, or the architectural/design company's own design standards and reference files.



The DfS book most often referenced in magazine and journal articles is Safety through Design (Christensen and Manuele, 1999). Textbooks on Safety and Health written for engineers will have either a chapter or at least a section on DfS, but less likely a section on DfCS. For instance, the textbook Safety and Health for Engineers (Brauer, 2006) has a chapter on DfS for facilities that actually includes hazards for the site, the facility, the equipment, and the production and logistics operations. Brauer also addresses loss prevention in the context of DfS.

Many articles on the subject have appeared in Professional Safety, the journal of the ASSE, and the Journal of Safety Research, a journal of the NSC published by Elsevier. The latter journal had a special edition dedicated to PtD in April 2008. There is a NIOSH website on PtD at www.dcd.gov/niosh/topics/ptd and a DfCS website www.designforconstructionsafety.org. These contain reference lists and links to other resources. The Health and Safety Executive in the United Kingdom (the equivalent of OSHA) developed several documents that help designers comply with the requirement that they design for construction safety. There are consensus standards for DfS in certain countries, for instance Western Australia's Safe Design Code of Practice (2008) and Singapore's DfS Guidelines (2009), but none yet in the U.S. Professors who teach design of structures, power systems, HVAC systems, and so on typically use the consensus standard as a supporting document to their classroom textbook in such courses. A consensus standard on DfS is needed from each of the several societies that promulgate such standards for engineering designers in the United States.

In summary, enough reference materials available for a professor of engineering (any discipline) in any design-content course, or directing a capstone design course, to introduce lectures or outside reading on DfS and/or DfCS. A mix of "good practice" processes, guidelines or checklists, tools, and case studies can be integrated into lectures. This information can be extracted and incorporated into courses from the many references mentioned earlier, putting the responsibility on the professor. If instead outside reading is used, the responsibility for reading and integration shifts more to the student. Finally, a guest lecturer who has practical experience with DfS or DfCS could perhaps make a lasting impression on the students.

> Alternatives to Incorporate Design for Safety into Engineering Curricula

To those experienced with the introduction of new topics or courses into established engineering curricula, there are five obvious alternatives to increase the DfS knowledge of degreed engineers:

A. **In all engineering courses, as hazards naturally arise and are noted to the students by the instructor as the subject matter progresses.** This alternative requires a broad array of modules be developed, one for each course, and disseminated. The engineering professoriate broadly defined would have to be educated and convinced to cooperate. Chances for success: Unlikely.

B. **In all engineering design courses only.** Courses that have design content usually refer to multiple criteria, including safety, and instructors would likely be receptive to either written or electronic information on DfS in their particular design focus (e.g., steel structures, masonry, power systems, mechanical systems, etc.) Reference to design standards or guidelines would help promote the relevance of safety to the course of study. Because of already squeezed time to cover current subject matter, safety topics should take no more than one week out of a fifteen week course, and would perhaps best be exposed as case studies or special topics for students to read and report on. <u>Chances for success: Good.</u>

C. **In all senior capstone design courses, as a criterion each design team must address in data collection, analysis, creation of alternatives, and evaluation of alternatives.** Requiring DfS on all senior capstone design projects, whether the project involves design of a system, component, or process, is an excellent approach to familiarize the students with the concepts and practical aspects of DfS (most likely in architectural, mechanical, or electrical engineering programs) or DfCS (most likely in civil, construction, or industrial engineering programs). It would expose the students to the subject in a realistic design environment. The responsibility could be shared among the team members, or assigned to one of the team playing the role of the safety engineer in the design team. <u>Chances for success: Excellent.</u>

D. **In a course on safety engineering.** Including DfS in courses with titles such as Safety Engineering, Safety and Health Management, or Construction Safety is a common practice. In the CE 464 Safety Engineering course at the University of Alabama, students continue from Brauer's presentation into the last four weeks of the course devoted to the OSHA 10-hour Construction Industry Outreach Course, which includes many new insights for the senior civil engineering student on DfS. So, at least in this University of Alabama implementation, essentially one-third of this fifteen week course will be DfS and DfCS material for the civil engineering students enrolled. <u>Chances for success: 100% - already proven.</u>

E. **In a course on Design for Safety.** A course on DfS would most likely be offered as a senior elective cross-listed with a masters-level course, with Safety Engineering as a prerequisite. It assumes the student understands his/her discipline's design process, wants to extend his safety training, and wants to consider this topic as a possible master's thesis theme. Ideally, there would be a textbook that captures the aspects of PtD, DfS, and DfCS that we have discussed in this section, and presented theoretical background, best practice processes, methods and tools, perhaps cases, and most definitely exercises. Such a textbook will be written by a committed author or author team, backed by an interested editor and publisher. <u>Chances for success: Unknown—future development.</u>

We recommend the academician interested in incorporating DfS/DfCS in his/her department's undergraduate curriculum consider Alternative D first. This is an easy route, following what has worked at other institutions and using proven materials already published. The only drawback is someone on the faculty has to have the academic or professional background to develop the course, and the desire to teach it regularly. Next, we recommend Alternative C. Those who teach capstone design often have PE licenses and can educate their design teams on the ethical and practical aspects of including safety as a criterion in their design and evaluation of alternatives. This is admittedly more of a brief exposure than a full course in DfS/DfCS, but it can be implemented by the design project instructor within his authority over the projects, with excellent chances of making an impression and having the students leave campus with knowledge of available written and electronic resources. The habit of thinking about safety aspects of design will hopefully have been planted. Alternative B has a good chance of succeeding if the faculty members responsible for design in the curriculum view safety (as they should) as the number one obligation of the engineer, and design for safety as simply bringing consideration of safety from something done during operations or retrofit/redesign as a corrective procedure, back into planning and design as a preventive procedure.

> Continuing Education

Employers of engineers and those engineers with professional development hour (PDH) requirements to maintain their Professional Engineer licenses look to their local universities for continuing education courses on topics pertinent to current engineering practice. The DfS/DfCS materials mentioned above for use with degree-seeking engineering students could certainly be adapted to the continuing education arena, whether those learners are attending in person or via distance education technology. Those writing standards for engineering societies and handbooks or textbooks are often in the best position to convert materials into continuing education presentations and course notes. Professors teaching safety engineering to degree-seeking students often find it relatively easy to combine some of their campus course materials with case studies and practical experience to create a continuing education course for practicing engineers. Finally, when faculty members are reluctant or not qualified to teach DfS/DfCS topics to practicing engineers, nationally-recognized experts (e.g., consultants, authors, industry authorities, or professors at other institutions) can be hired as continuing education instructors, with the local institution providing the facility, equipment, registration services, catering, etc. to hold the course. On-line options for DfS continuing education should be considered, as practicing professionals could more easily fit the training into their busy schedules. Continuing education in DfS fundamentals for the professional is as critical as regular physical training for an athlete.

Conclusion

We believe a team approach to DfS is critical to the success of a project and to the ultimate users of the finished facility, equipment, or process.

- Owners promote safety by establishing a design for safety mindset with all parties involved, preferably through their own DfS program. This includes making allowances in the total project cost for DfS activities and ensuring that safety-conscious A/E firms and contractors are selected.

- Contractors promote safety by having a project safety plan, by avoiding shortcuts that deviate from the architect or engineering plan, and by ensuring a clear turnover of safety considerations (and therefore liability) to the owner.

- Architects and Engineers – promote safety by eliminating from their designs identified hazards and by integrating construction knowledge into the design, procurement, and construction of the project. They should consider the owner's needs for operation and maintainability.

Additionally, communication and collaboration between each of the players – architect, engineer, contractor, owner, and insurer – is important while the project is ongoing. Without this, each party views safety only in a limited performance-of-job sense.

Designing for safety needs more emphasis in both undergraduate courses for students and in continuing education for professionals. It should enhance the technical coursework and be welcomed as an opportunity to communicate a practical approach to design and construction. If the project team players are truly acting as a team, they do not need to neglect the fundamentals of safety.

Designing for Safety is, after all, a team sport.

Attachment 1: The Southern Company DfS Program

As an example of a DfS program having been in place for a number of years already, the Southern Company process is formalized though procedural directives and is enabled by three tools: the DfS checklist, the APEX software, and the Constructability & Hazard Identification model design reviews.

Table 1 describes the process:

When	Who	What
No later than the start of detailed design	Each Design discipline lead on the project	Complete their discipline DfS checklist. At this point, a lot of the items will be marked as "Will be incorporated . . . ."
At some point early in the detailed design ("before 25%")	Each Design discipline lead on the project	Review the items in APEX to see if there's a DfS item that could be incorporated into the design.
During detailed design	Each Design discipline lead on the project	Over the course of detailed design, model reviews may reveal site hazards and/or constructability issues. If so, add them to the DfS Checklist and/or APEX.
Before Project Closeout	Each Design discipline lead on the project	Finalize the Design for Safety checklist and send to the Project Engineer. To quote the procedure: "In its final form, all items on the checklist shall be dispositioned in one of the following ways: • Item "has been addressed," including a short description of how. • Item "will not be addressed," including a short explanation of why.
As part of Project Closeout	Project Engineer	Place the finalized checklists in the project file.

Table 1. Summary of the Southern Company DfS Process

Design For Safety Checklist

Southern Company created a generic DfS checklist for each of the four Design disciplines: Civil/Structural; Mechanical/Piping; Electrical; and Instrumentation and Controls. The DfS checklist contains a representative selection of DFS database items. Figure 3 is an example . . . . .

Design For Safety Checklist

Electrical

THIS HAZARD OR CONCERN NEEDS TO BE ADDRESSED ON THIS PROJECT? Y=YES; N=NO

THIS HAZARD OR CONCERN:

HAS BEEN ADDRESSED IN OUR DESIGN

WILL BE ADDRESSED IN OUR DESIGN

OTHER

Design Lead:	
Project No.:	
Plant:	
Date:	

Place X in column				Item No:	Description And Resolution
				216	**Description** - Electrical: General **Resolution** - Project Engineer has communicated "HAZCOM" project information required for design engineering personnel making site visits. (Each person that is sent to the job site must be informed of any potential hazards.)
				217	**Description** - Electrical: General **Resolution** - A constructability meeting has been held with representatives from Plant, Construction Services, and Power Engineering to discuss safety-related items.
				218	**Description** - Electrical: General **Resolution** - Underground hazards (electrical duct banks and cables, buried pipes, etc.) and reference drawings locating any potential hazards are identified.
				220	**Description** - Electrical: General **Resolution** - Applicable codes and standards have been reviewed for requirements impacting the design of a safe facility.
				221	**Description** - Electrical: General **Resolution** - All potentially hazardous areas have been defined per Chapter 5 of the National Electrical Code. Hazardous areas have been identified and boundaries located.

(continued)

Figure 3. Design for Safety Checklist (excerpt)

APEX

The APEX Design for Safety software tool is a Microsoft SharePoint site containing hundreds of items focused on safety in construction, operations and maintenance, constructability, code requirements, and best practices. These items assist in identifying and eliminating project hazards from the design thereby helping Southern achieve their safety goal, "Target Zero".

Hazards Identification and Constructability Consideration

> Hazard Identification

Hazard Identification is the process to identify project construction worker and plant maintenance worker hazards early in the design process and take actions to design out the hazards or communicate to management of impacted workers the unavoidable hazard that can't be designed out. Hazards that the Engineering Design department at Southern Company look for include, the following:

- caught-in-between situations
- falls
- struck-by-objects situations
- cave-in,
- fire
- toxic substances
- fiberglass
- worker issues
- on-line equipment
- confined spaces
- heavy equipment vehicular traffic
- electrical shock
- lighting
- work area
- environmental/climate
- obstructions
- explosions

Hazard Identification meeting(s) are held with representatives from Southern Company's own construction services representatives, safety professional; design firm or A/E firm, and plant operations and maintenance representatives. Representatives from equipment suppliers, fabricators and others may be invited to attend the meetings. These meeting can occur as part of regular project design review meetings or as a separate meeting. The meeting facilitator uses general arrangement drawings and/or plant 3D model or model snapshots as a visual aid to encourage all meeting attendees to identify and communicate project hazards. The meeting agendas are prepared by the facilitator or someone trained in Design for Safety. Documentation of the results of the Hazard Identification meeting is distributed to attendees and managers who are impacted.

> Constructability Considerations

Constructability Consideration meetings are separate meetings or combined with the Hazard Identification portion of design review meetings. Southern Company uses the broad Construction Industry Institute (CII) for the definition of Constructability: "Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and field operation to achieve overall project objectives." Examples of employing constructability considerations include:

- Showing the sequence of installation of new bracing and removal of existing bracing on the design drawings when the rework will affect the stability of the building.
- Planning the sequence of steel and duct work erection onsite. Identifying the steel shop assemblies and modules and erection sequence during the conceptual phase of the project so procurement and construction personnel can plan their work.
- Improving a design by eliminating most field welds and moving assembly of large steel sections to the fabricator's shop. Such a redesign reduces cost, improves quality, shortens the construction field schedule, and makes a construction jobsite safer.

Maximum benefits occur when people with construction knowledge and experience become involved at the very beginning of a project. Ensuring constructability is not merely ensuring important aspects of a project such as efficiency gains, document control, interfaces between engineering and construction, and modular preassemblies – they are only a part.

Only through the effective and timely integration of construction input into planning and design as well as field operations will the potential benefits of constructability be achieved. Industry tends to separate the individual functions involved in capital projects. Design tends to place emphasis on minimizing its cost. Construction focuses on minimizing field cost. Fine-tuning the individual parts, however, does not yield the most successful project. Constructability integrates these parts and is one of the most powerful tools owners can use on their projects.

Attachment 2: Design for Safety Resources and References

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