Design for Safety and the Triple Bottom Line in Construction Projects

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OVERVIEW

- Triple Bottom Line and Social Sustainability
- Improving Site Safety requires Integrated Design and Construction
- DfS Concept and Benefits
- Examples
- Processes and Tools
- Moving forward with DfS

Prevention through Design
= Design for Safety
= Safety by Design
“All businesses can and must help society achieve three goals that are linked – economic prosperity, environmental protection and social equity.”

SUSTAINABILITY AND THE TRIPLE BOTTOM LINE

- Environmental
- Economic Viability
- Social Equity

Sustainability
SOCIAL SUSTAINABILITY


- Focus on people as much as on the environment
  - Meet the needs of people who can’t speak for themselves
Sustainable Development

Design and construction that doesn’t unfairly affect people who are not at the table

Further reading:
SOCIAL SUSTAINABILITY ISSUES

How will we convince all stakeholders that our project will not unfairly affect people who are not at the table during the concept development, design and construction planning?

- Building occupants
- Nearby residents
- Politicians and regulators
- Our employees
- Construction workers
- Maintenance workers
ANNUAL CONSTRUCTION ACCIDENTS IN U.S.

- Nearly 200,000 serious injuries
- 1,000+ deaths
DESIGN-SAFETY LINKS

- 22% of 226 injuries that occurred from 2000-2002 in Oregon, WA, and CA\(^1\)
- 42% of 224 fatalities in US between 1990-2003\(^1\)
- 60% of fatal accidents resulted in part from decisions made before site work began\(^2\)
- 63% of all fatalities and injuries could be attributed to design decisions or lack of planning\(^3\)

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\(^2\) European Foundation for the Improvement of Living and Working Conditions
\(^3\) NSW WorkCover, CHAIR Safety in Design Tool, 2001
“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.”

(http://www.cdc.gov/niosh/topics/ptd/)
DFS IN CONSTRUCTION IS...

- Explicitly considering construction and maintenance safety in the design of a project.
- Being conscious of and valuing the safety of construction and maintenance workers when performing design tasks.
- Making design decisions based in part on a design element's inherent safety risk to construction and maintenance workers.

“Safety Constructability and Maintainability”
INTEGRATED DESIGN AND CONSTRUCTION

- Project success requires that design reflects input from all stakeholders, including:
  - Users/occupants
  - Owner facility management personnel
  - Contractors

- Constructability feedback must start early in the design process
5. **Definitions.** Biddability, Constructability, Operability, Environmental and Sustainability (BCOES) Considerations.

   a. **Biddability** is defined as the clarity of the acquisition documents, the soundness of the government’s evaluation and selection criteria for negotiated acquisitions, and the ease of bidders or proposers to understand the government’s requirements, allowing the submission of a competitive bid or proposal that is responsive to the government’s requirements.

   b. **Constructability** is defined as the ease of constructing a specified or designed project according to the government’s requirements, including the proposed construction duration, and the ease of understanding and administering the contract documents during their execution.

   c. **Operability** is defined as the ability to efficiently operate and maintain a facility or facilities over their life cycle when the facility or facilities are built according to the project’s plans and specifications.
## BENEFITS OF INTEGRATED DESIGN AND CONSTRUCTION

- **Accepted:** Cost, Schedule, Quality
- **Accepted:** Environmental sustainability
- **Emerging:** Prefabrication
- **Emerging:** Safety
DESIGN HAS MAJOR LEVERAGE

- Ability to influence key project goals is greatest early in the project schedule during planning and design (Szymberski, 1997)
HIERARCHY OF CONTROLS

Elimination
Eliminate the hazard during design

Substitution
Substitute a less-hazardous material or form during design

Engineering Controls
“Design-in” engineering controls, Incorporate warning systems

Administrative Controls
Well-designed work methods & organization

PPE
Available, effective, easy to use

Prevention through Design
WHEN SAFETY IS NOT DISCUSSED DURING DESIGN

1. Users/Occupants can be hurt.
   Example: Kansas City Hyatt

2. Designs are unconstructable.
   Example: high school masonry wall collapse

3. Designs are more hazardous to construct than they need to be.

4. Designs are more hazardous to maintain than they need to be.
   Examples: skylights, access to light bulbs, valves...

ECONOMIC BENEFITS OF DFS

- Reduced site hazards
  - Fewer worker injuries and fatalities
- Reduced workers’ compensation premiums
- Increased productivity and quality
- Fewer delays due to accidents
- Improved operations/maintenance safety
DFS AND PROFESSIONAL ETHICS

- NSPE Code of Ethics:
  - Engineers shall hold paramount the safety, health, and welfare of the public.

- ASCE Code of Ethics:
  - Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering decisions ....
SOCIAL SUSTAINABILITY ISSUES

- Do not our duties include minimizing all risks (especially to people) that we have control over?
- Do not we have the same duties for construction and maintenance workers as for the “public”? 
WHAT DO YOU THINK?

What do you think about the Triple Bottom Line concept?

Do codes of ethics apply to construction and maintenance workers?

What do you think about the Prevention through Design concept?

What are your experiences in design for safe construction and design for safe maintenance?
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Prevention through Design
= Design for Safety
= Safety by Design
EXAMPLE OF THE NEED FOR DFS

- **Design spec:**
  - Dig groundwater monitoring wells at various locations.
  - Wells located directly under overhead power lines.

- **Accident:**
  - Worker electrocuted when his drill rig got too close to overhead power lines.

- **Engineer could have:**
  - specified wells be dug away from power lines; and/or
  - better informed the contractor of hazard posed by wells’ proximity to powerlines through the plans, specifications, and bid documents.
DFS EXAMPLE: ANCHORAGE POINTS
DFS EXAMPLE: STRUCTURAL STEEL DESIGN

Detailing Guide for the Enhancement of Erection Safety
Published by the National Institute for Steel Detailing and the Steel Erectors Association of America
The Erector Friendly Column

+ Include holes in columns at 21” and 42” for guardrail cables and at higher locations for fall protection tie-offs
+ Locate column splices and connections at reasonable heights above floor

Photo: AISC educator ppt
Provide enough space for making connections

- Allow enough space for torque guns or erection wrench.
- Solution 1: Clip outstanding leg.
- Solution 2: Increase take-off distance.
- Solution 3: Clip to allow more space.

Problem is not enough space for torque guns.
Know approximate dimensions of necessary tools to make connections.

Photo: AISC educator ppt
DFS EXAMPLE: ROOFS AND PERIMETERS

Skylights
Upper story windows
Parapet walls
DFS EXAMPLE: PREFABRICATION

- Steel Stairs
- Concrete Wall Panels
- Concrete Segmented Bridge
- MEP Corridor Racks
PREFABRICATION: THE LINK BETWEEN ENVIRONMENTAL SUSTAINABILITY AND SAFETY

- Prefabricated construction is inherently safer than “stick-built”
- Work is shifted from dangerous work environments to engineered work environments and processes.
  - at height
  - in trenches
  - in confined spaces
  - exposed to weather (wind, water, ice, mud, lightning)
- Prefabricated construction has
  - lower construction waste
  - lower embodied energy
  - lower embodied greenhouse gases
ANSI/ASSP Z590.3-2011(R2016)

Prevention through Design Guidelines for
Addressing Occupational Hazards and
Risks in Design and Redesign Processes

This standard pertains principally to the avoidance, elimination, reduction or control of occupational safety and health hazards and risks in the design and redesign process.
DESIGN FOR MAINTENANCE SAFETY

- Provide safe access for recurring maintenance/preventive maintenance
  - Light Bulbs, Air Filters, Belts, Valves
  - At height, confined space, awkward ergonomics

- Provide safe clearance for replacing units
  - Blower Units, Boilers, Compressors, Pumps
  - Isolation, Material handling, Path out and in
To incorporate systems safety engineering and management practices into a facility life cycle process used in the conceptual phase, planning stages, construction of facilities, and facility reduction (demolition).
Facility Systems Safety
Program Manager 256-895-1583

The Facility Systems Safety (FASS) program is designed to incorporate system safety into the facility design process as prescribed in Military Standard 882E (Standard Practice System Safety), AR 385-10 (Army Safety Program), DA Pam 385-16 (System Safety Engineering and Management), and new UFC 1-200-01 General Building requirements. The FASS process is used in the conceptual phase, planning stages, construction of facilities and facility reduction (demolition) to examine the specifics of the hazards involved, the level of risk, and the potential effectiveness of existing codes and standards. The FASS program is structured to guide designers toward elimination and control of hazards during criteria development and design of facilities. The U.S. Army Engineering and Support Center, Huntsville, is a Technical Center of Expertise for FASS for the Army.

The FASS process first examines specific hazards involved, the level of risk and the potential effectiveness of existing codes and standards. Following this discovery and analysis process, the FASS engineer works with the construction team and customer to implement solutions to either eliminate or reduce the risk through the use of controls set forth in codes and standards, specially designed controls or a mix of both control types.

The U.S. Army Corps of Engineers is responsible for the development and implementation of the Facility Systems Safety Program Plan (SSPP), which details the designer’s plan for executing the systems safety program for a specific project from the concept design phase to the acceptance of the completed facility. The plan describes in detail how each applicable element of FASS is to be implemented. Each Facility SSPP will address the proposed approach to the requirement, the content, and format of the deliverables, and indicate the level of effort for each area. An individually tailored approach based on the contract requirements, the anticipated hazards and the level of risk involved with the specific facility, the SSPP describes how each applicable safety element is to be implemented.

Defining safety and occupational health requirements at the earliest possible time through the FASS process is critical for both the customer and the design/construction team. Identifying issues early can result in cost-savings for the customer, increase customer satisfaction and reduce post-construction project rework/retrofitting to resolve safety issues.

For Example:
The Army Safety Program lists “dredging” as an initial HIGH risk project. Great Lakes dredging PDT have included safety into their risk management plan by engaging the Safety Office. When the PDT documented the hazards which were present, they were able to mitigate residual safety risk to the project.
UNIFIED FACILITIES CRITERIA (UFC)

GENERAL BUILDING REQUIREMENTS
FACILITY SYSTEMS SAFETY
PATH FORWARD

FY 2004
- FASS Budget Established

FY 2007 - Present
- FASS Training SOH/Designers

FY 2011 - 2012
- FASS #2 Goal for USACE

FY 2012
- Create FASS Program Manual

FY 2013
- Create FASS Procedures (QMS)

FY 2013
- Review Design Draws with FASS

FY 2014
- Create a FASS Pilot Program at one Districts

FY 2015
- Create a Second FASS Pilot Program

FY 2015
- Review Progress with FASS Pilot Programs

FY 2015
- FASS Mandatory Training to all Employees

FY 2016
- Implement a FASS Contract to conduct reviews

FY 2016/2017
- Implement FASS Across USACE

FY 2017
- Implement FASS Across USACE
The Vision:

“To ensure the safety and well-being of construction workers, motorists, truck drivers, pedestrians and their families by making transportation project sites worldwide zero-incident zones.”

“The Safety Certification for Transportation Project Professionals” (SCTPP) program – identification of the target audience, core competencies to test, and the exam itself – was developed by leading executives and safety professionals in the transportation infrastructure industry. Thus, the SCTPP credential shows your employer and peers that you can identify common hazards found on transportation project sites and correct them to prevent safety incidents that could result in deaths or injuries. Earning the professional certification also provides you with a competitive edge in the workplace because it demonstrates your command of internationally-recognized core competencies for safety awareness and risk management on transportation projects.
Why should a state or local transportation department support their managers, inspectors and designers earning the Safety Certification for Transportation Project Professionals™?

- Because as custodians of the public’s tax dollars and trust, project safety is the top priority for transportation agencies and your personnel. Having SCTPP recipients on your team demonstrates that commitment.
- It shows your employees that project safety is the agency’s top priority.
- Having professionally certified personnel involved at all stages of a project—from inception through completion—should help reduce safety incidents, thus saving lives and preventing disabling injuries.
- Because safety incident mitigation can be worked into transportation project plans and designs, if designers know what causes safety incidents on project sites.

https://puttingsafetyfirst.org/
LEED PTD PILOT CREDIT

- Identify and document the items found for the following two stages:
  - Construction
  - Operations and Maintenance
- For each stage, complete three stages of analysis:
  - Baseline (design prior to safety constructability review)
  - Discovery (hazards posed by design)
  - Implementation (hazards reduced by design changes)
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DFS DESIGN REVIEW

- **Hazard identification**
  - What construction safety risks does the design create?
  - What maintenance safety risks does the design create?

- **Risk assessment**
  - What is the level of safety and health risk associated with each hazard?

- **Design option identification and selection**
  - What can be done to eliminate or reduce the risk?
  - Remember the hierarchy of controls...
DFS PROCESS

Get the right people talking about the right things at the right time!
DFS PROCESS

**Concept** (Owner, AE, GC/CM)
- Establish PtD process
- Identify PtD checklists, other tools
- Select primary materials
- Identify opportunities for prefab./modular.

**30% Design** (Owner, AE, GC/CM, Key trade contractors, Key equip. manufact.)
- Finalize design aspects to facilitate prefabrication
- Review design checklists
- Perform preliminary hazard analysis
- Apply multi-attribute decision tools
- Select secondary materials

**60% Design** (Owner, AE, GC/CM, Key trade contractors)
- Use design checklists
- Draft erection plans
- Communicate critical hazards on plans and specs
- Identify needed anchorage points, work platforms

**90% Design** (Owner, AE, GC/CM, All trade contractors)
- Review safety constructability of all plans, specs
- Identify safety expectations in all contract docs
- Identify safety parameters for subcontracts

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<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Structural Framing</td>
</tr>
<tr>
<td>1.1</td>
<td>Space slab and mat foundation top reinforcing steel at no more than 6 inches on center each way to provide a safe walking surface.</td>
</tr>
<tr>
<td>1.2</td>
<td>Design floor perimeter beams and beams above floor openings to support lanyards.</td>
</tr>
<tr>
<td>1.3</td>
<td>Design steel columns with holes at 21 and 42 inches above the floor level to support guardrail cables.</td>
</tr>
<tr>
<td>2.0</td>
<td>Accessibility</td>
</tr>
<tr>
<td>2.1</td>
<td>Provide adequate access to all valves and controls.</td>
</tr>
<tr>
<td>2.2</td>
<td>Orient equipment and controls so that they do not obstruct walkways and work areas.</td>
</tr>
<tr>
<td>2.3</td>
<td>Locate shutoff valves and switches in sight of the equipment which they control.</td>
</tr>
<tr>
<td>2.4</td>
<td>Provide adequate head room for access to equipment, electrical panels, and storage areas.</td>
</tr>
<tr>
<td>2.5</td>
<td>Design welded connections such that the weld locations can be safely accessed.</td>
</tr>
</tbody>
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Welcome to Prevention through Design!

News:
It is recognized that many design professionals lack the necessary knowledge of construction safety and site operations to adequately design for construction safety. Fortunately, researchers, government offices and practitioners have developed tools that assist designers in designing for construction safety.

**SliDeRulE** (Safety in Design Risk Evaluator) assists building designers with assessing the construction safety risk associated with their designs.

The Sustainable Construction Safety and Health (**SCSH**) rating system helps evaluate construction worker safety and health on construction projects.

Alan Speegle (The Southern Company) compiled a **1600 item Prevention through Design list**, mostly from the process (i.e., industrial) construction sector.
DFS TOOLS – BIM AND VISUALIZATION
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THREE STEPS TOWARDS DFS

1. Establish a lifecycle safety culture
2. Establish enabling processes
3. Team with organizations who value lifecycle safety
ESTABLISH A LIFECYCLE SAFETY CULTURE

- Secure management commitment to safety and to a life cycle approach
- Instill the right safety values
  1. Professional Codes of Ethics (right thing to do)
  2. Payoff data (smart thing to do)
- Training
ESTABLISH ENABLING PROCESSES

- Designer training and tools
- Enabled safety constructability and maintainability input
  - Design-Bid-Build with Design-Assist
  - Design-Build
  - Construction Management
- Collaborative decision processes
CHOOSE YOUR PARTNERS WISELY

- Commitment to safety and to a life cycle approach
- Open to change
- Collaborative culture and experiences
- Enabled safety constructability input
- Negotiated or Cost-Plus contracting
SUMMARY

- Our clients and others are increasingly demanding that we deliver integrated design and construction and proactively consider the triple bottom line on our projects.
- Design for Safety is a promising way to achieve economic, social and environmental sustainability.
- USACE can become a leader in moving DFS forward in appropriate ways.
- Management commitment, personnel training and stakeholder engagement are necessary first steps.
WHAT DO YOU THINK?

What aspects of the PtD concept or examples are unclear?

What experiences related to PtD have you had?

What aspects of the PtD process are unclear?

How might the PtD process work on your projects?
WHAT DFS IN CONSTRUCTION IS NOT

- Having designers take an active role in construction safety **DURING** construction.
- An endorsement of future legislation mandating that designers design for construction safety.
- An endorsement of the principle that designers can or should be held partially responsible for construction accidents.
WHAT DO YOU THINK?

What experiences have you had in implementing a similar innovation on a project or in your organization?

What ideas do you have for moving PtD forward?
See May 2015 *PE* magazine article entitled “Safety by Design”