Production System Design for Accident Prevention: Lessons from High Reliability Foremen

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Research Areas

Production system design for accident prevention
- Production practices of High Reliability foremen
- Organization of production and workers’ task demands
- Teamwork for accident prevention
- Learning mechanisms to improve work design & safety

Lean Production Systems
- Production control
- Work Structuring
Overview

Research overview:

• Production system design for accident prevention: Lessons from High Reliability foremen

Implications for BIM:

• How can BIM contribute to better production system design?
Dynamic & Hazardous Processes

Chart 2. Number and rate of fatal occupational injuries, by industry sector, 2011*

- Transportation and warehousing: 733 (15.0)
- Construction: 721 (8.9)
- Agriculture, forestry, fishing, and hunting: 557 (2.2)
- Government: 495 (2.2)
- Professional and business services: 424 (2.9)
- Manufacturing: 322 (2.1)
- Retail trade: 266 (1.9)
- Leisure and hospitality: 224 (4.9)
- Wholesale trade: 189 (2.9)
- Other services (exc. public admin.): 177 (2.2)
- Mining: 154 (0.8)
- Education and health services: 151 (1.1)
- Financial activities: 95 (2.0)
- Information: 58 (4.2)
- Utilities: 39

Total fatal work injuries = 4,609
All-worker fatal injury rate = 3.5

*Data for 2011 are preliminary.
Industry Challenge

Design the production system & develop the work teams, so that we consistently achieve high production AND high safety
Safety Research Paradigms

Normative
- Emphasizes safe rules of conduct and compliance though training, motivation, enforcement, values, etc.

Human error
- Human “malfunction” is the source of errors and violations.

Cognitive
- Complex systems involve trade-offs between multiple irreconcilable goals.
- The features and demands of the task and context shape the work behaviors and can lead to errors & accidents.
Rasmussen (1994): Migration to accidents model of work behavior
Research Approach

How do the High Reliability foremen organize and manage the work and consistently achieve high productivity, speed and safety?

A HR foreman is one who consistently achieves very high levels of BOTH productivity and safety.
Research Methodology

In-depth field case studies and comparative analysis of exceptional and average foremen in high risk trades: framing, masonry, concrete (blg), roofing, concrete (heavy)
Research Methodology

1. Identify High Reliability foremen
2. Analyze operations and accidents
3. Document & compare production practices
4. Analyze effect on workers task demands and performance

<table>
<thead>
<tr>
<th>Production Practices</th>
<th>Safety Practices</th>
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<tbody>
<tr>
<td>Foreman priorities</td>
<td>Management policies</td>
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<td>Process design</td>
<td>Safety resources</td>
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<td>Mgt of high-risk tasks</td>
<td>Safety enforcement</td>
<td>Frustration</td>
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Identify HR Foremen

Safety performance:
Foreman’s incident rate over 3 years.

Production performance
over 3 years
Document Work Practices

**Production practices**
- Foreman priorities
- Work process design
- Activity management
- Production pressures
- Mgt of high-risk tasks
- Resource management
- Performance control

**Crew management**
- Crew requirements
- Crew planning
- Task assignment
- Cross-monitoring

**Safety Practices**
- Management policies
- Safety resources
- Safety training
- Safety planning
- Safety audits
- Safety enforcement
Task Demand and Work Difficulty

Dear Respondent;

Please think about your current work (task), and give a score to each of the following factors based on the difficulty you have experienced during performing the task.

### Mental Demand
- How much thinking, deciding, calculating, remembering, looking, or searching was required to do the task?

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### Physical Demand
- How much physical activities like pulling, pushing, lifting, turning and controlling were required?

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### Temporal Demand
- How hurried or rushed was the pace of the task? How much time pressure did you feel?

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### Performance
- How successful were you doing the task you were asked to do? How satisfied were you with your performance?

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### Effort
- How hard did you have to work (mentally and physically) to accomplish your level of performance?

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### Frustration
- How unsecured, discouraged, irritated, stressed, and annoyed did you feel during the task?

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Findings

Practices of High Reliability foremen
Practices of High Reliability Foremen

1. Focus on preventing rework & incomplete work
2. Design the activities to reduce task complexity, physical demands and time pressures
3. Manage the time pressures to prevent rushing
4. Organize the process for speed
5. Crew management to prevent errors
6. Close & cross-monitoring to detect problems and prevent /correct errors
7. Varying emphasis on safety management
1. Focus on Preventing Errors

- Identify & manage complex / difficult areas
- Extensive preparations: check all material, double check layout, and work area
- Work on fewer areas to provide effective support
- Multiple checks before “set” (layout, walls, etc.)

➤ Task predictability: Reduce surprises & interruptions
2. Activity design

Simplify the work methods:

- Use fewer components, fewer steps, less variety
- Reduce measure & cut, use templates
- Use lighter components
- Raise scaffold more frequently
- Decouple tasks, perform tasks ahead of time.

• Material management:
  - Pre-layout complex block patterns for masons
  ➔ Control / mitigate task complexity, physical demands and time pressures
3. Manage Production Pressures

- Adequate (and reliable) manpower
- Shield crews from “pressures” from following activities/crews
- Task design strategies (simplify, decouple, etc.)

» Prevent rushing (… and mistakes)
4. Organize Process for Speed

- Reduce batch size
- Overlap operations (but reduce dependencies)
- Use dedicated crews (with some flexibility)
- Manage shared resources
- Provide additional resources
5. Crew Management

- Manpower depending on production needs
- Crew reliability to prevent excessive workload: zero or very low tolerance for absenteeism
- Task assignment:
  - rotate heavy tasks, plan for more rest time
  - specialize accuracy & high-risk tasks
- Focused crew:
  - Crew planning, focus on task.
  - Prevent distractions from task

→ Prevent excessive workload, Reduce fatigue, frustration, errors
6. Close & Cross-monitoring

- Several daily milestones
- Close monitoring & cross-monitoring to identify problems and correct errors
- Clear plan to contain problems: “do not stop work to help, notify foreman”
- Redistribute workload or expertise, resource flexibility

- Identify problems and correct errors fast
- Adaptability
7. Inconsistent Safety Management

Significant differences and emphasis on safety management

- Framing
- Masonry
- Concrete
- Roofing

Safety management system

Weak (high exposure)
Strong (low exposure)

Policies, programs and efforts to control the hazards
- Management commitment to safety
- Safety policies & requirements
- Safety resources
- Safety in Design, safety planning
- Safety training, inspections, enforcement, rewards
Safety Performance Determinants

- Safety Management System
- Production Control

- High
  - F
  - M
  - CR

- Low
  - Weak
  - Strong

Safety Management System
Production Control

Determines the Control of the Production Processes (not the hazards)

- Task complexity and difficulty
- Task predictability: Expected scope and conditions, no surprises.
- Task is well prepared, no interruptions
- Time pressures: allow time for primary & secondary tasks. Prevent rushing, frustration
- Appropriate capability assigned to task demands
- Crew attention focused, fatigue managed
- Adaptability to changing conditions & problems.
Tentative Conclusion

To improve safety outcomes, it is critical to improve the Production Control.
Santa Maria del Fiore, Florence

- 1st cathedral with unsupported octagonal dome
- Dome Architect: Filippo Brunelleschi
- Dome construction: 1420 -1436. 37,000 tons of marble
Implications for BIM

1- Improve the Safety Management System
   • Identify hazards, eliminate hazards (Design for Safety)

2- Improve the Production Control
   • Prevent installation errors
   • Reduce task complexity and difficulty
   • Increase task predictability
Thank you

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