Automation mania in the time of Reason: considerations for complex transportation systems

Stephen Popkin, Ph.D.
Volpe National Transportation Systems Center
U.S. Department of Transportation

18 November 2010
Volpe Center Human Factors

- 35 Federal Staff, 16 holding a PhD
- $13M project work per year
- 4 generation workforce, 2/3 women
- Projects span all modes
- Separate laboratory building
- CRADA with MIT, open to others
Center of Innovation Mission

• Quantitative Analysis of Relationships Between Human Behavior and Transportation Safety, Health and Productivity
  – Human-Systems Interface and Habitability
  – Human-Centered Automation
  – Human Performance Assessment
  – Experimental Design and Statistical Analysis
  – Information Management & Display Evaluation
  – Organizational Behavior

• In Support of Planning, Rule Making, Systems Evaluation and Specification, and Other Federal Agency Requirements
There is no such thing as an unmanned system
Apple Computer Is Usually Good at This

• Ability to design and launch very successful products like the iPhone, iPod, and iPad
  • Tapped into emerging confluence of user needs and developed infrastructure both in creating the foundational technologies and incremental improvements

• Not all products have been a success, however, mostly due to a lack of infrastructure and user needs and/or understanding (Apple Newton)
Growing Concerns with Introduction of Automation/Capability

• Washington Post: Airport 'pat-downs' cause growing passenger backlash

• Web/Facebook Capable Cars
  – “GoCarShare to use Facebook for car sharing”
More Concern Over Automated Systems

- WP: U.S. Power Plants at risk of attach by computer work like Stuxnet (Oct 1)

- WP: Warning labels on cell phones (Sept 22)

- WSJ: Automation Erodes Pilot Skills (Nov 11)
  Reliance on automated systems may be eroding the flying skills of pilots, contributing to about 60 percent of the accidents reviewed by an FAA research team.
  “Operating flight-control computers can distract pilots from ‘managing the flight path of the airplane,’ Abbott said. In addition, ‘pilots sometimes abdicate too much responsibility to the automated systems.’ She added that sometimes pilots don't get enough practice in hand-flying and will hesitate to take control away from the computer in an emergency.”
Living in the Age of Reason

Thomas Paine from the *Age of Reason*:

“Man cannot make principles, he can only discover them”

Successive Layers consider increased safeguards (barriers) within and across different dimensions or levels of the Sociotechnical mode

Adapted from J. Reason
In addition to Reason, One Needs Mores

Socio-technical System Provides Context

Adapted from N. Moray
Goals for Automation Technology

• Safe **Introduction** of New automation Technologies

• **Upgrade** of Existing Technologies Without Compromising Safety

• **Efficient** Implementation of Technology

How we introduce technology can directly affect human error, safety and success.
Thoughts on Automation

- It is improper to think that a system has to be either fully automated or fully manual.
- It is also improper to apply a level of automation uniformly to a whole information processing and control system.
- Most information/control systems may be subdivided into four stages:
  - (1) information acquisition,
  - (2) information analysis,
  - (3) response decision, and
  - (4) response implementation.

(Parasuraman, Sheridan, & Wickens, 2000)
Levels of Automation

1. The computer offers no assistance; the human must do it all.
2. The computer suggests alternative ways to do the task.
3. The computer advises one way to do the task ….or:
4. ….executes that suggestion if the human approves, or
5. ….allows the human a restricted time to veto before automatic execution, or
6. ….executes the suggestion automatically, then informs the human, or
7. ….executes the suggestion automatically, then informs the human only if queried.
8. The computer selects the method, executes the task, and ignores the human.

(Parasuraman, Sheridan, & Wickens, 2000)
Examples

• Positive Train Control (Make It So)
• Operator Impairment Monitors (Good Medicine)
• Quieter Car (Personal Rights)
Train Control: Traditional v. PTC Systems

Source: telephonecomponents.com
Currently there are few PTC system deployments around the country with different railroad employing variety of specifications (vital and non-vital overlay) in many operating modes including development, testing, and revenue service.

469 miles – Revenue service
450 miles – testing
1374 miles – Development
Congressional Mandated PTC Routes

Colored by Railroads
Class I – Mainline
Intercity/Commuter Rail (marked with dark line)
Alertness Monitoring
**PROBLEM:** Pedestrian Safety Enhancement Act 2009 (Jan 2009/April 2009) requires DOT “…to study and establish a motor vehicle safety standard that provides for a means of alerting blind and other pedestrians of motor vehicle operation.”

**OBJECTIVE:** Phase 1 described safety issue, requirements for blind pedestrians’ safe mobility, identified potential countermeasures. Phase 2 developing specifications for synthetic vehicle sound countermeasures while operating in EV mode below 20 mph.

**RESEARCH:** Collected and analyzed vehicle acoustic measurements by ambient noise conditions, developed detectability requirements for synthetic vehicle sounds, conducted human-subjects testing to measure the detectability of synthetic vehicle sounds for specification requirements.
A Way Forward to Support Well Designed and Integrated Automation

- Human Systems Integration
- Evaluation Methodology
Human Systems Integration (HSI) is the formal systems engineering discipline that ensures consideration of the human in operating a system:

- Disciplined, unified, and interactive approach
- Incorporate human considerations into system design
- Domains are interdependent and addressed together
- Improve total system performance not just one element
- Reduce total cost of ownership
- Incorporates processes and structures to improve performance by improving performance of all the parts of the system, including human activities
## HSI Domain Considerations

<table>
<thead>
<tr>
<th>Human Factors Engineering</th>
<th>Manpower</th>
<th>Personnel</th>
<th>Training</th>
<th>Habitability</th>
<th>Personnel Survivability</th>
<th>Safety</th>
<th>Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Performance</td>
<td>Workload</td>
<td>Knowledge, Skills and Attitudes</td>
<td>Skill Development</td>
<td>Physical Environment</td>
<td>Personnel Protection</td>
<td>Accident Avoidance</td>
<td></td>
</tr>
<tr>
<td>Human Interfaces</td>
<td>Normal Operations &amp; Emergency Activity (Quality / Quantity)</td>
<td>Personnel Classification</td>
<td>Individual / Team Training Concepts</td>
<td>Personnel Services</td>
<td>Safety</td>
<td>Environment Health Hazard Avoidance</td>
<td></td>
</tr>
<tr>
<td>Human Error Avoidance</td>
<td>Operators, Maintainers &amp; Support</td>
<td>Selection</td>
<td>Initial &amp; Follow-on Training</td>
<td>Living Conditions</td>
<td>Damage Control</td>
<td>Hazard Avoidance</td>
<td></td>
</tr>
<tr>
<td>Top Down Analysis</td>
<td>All Personnel</td>
<td>Recruiting</td>
<td>Organized Training</td>
<td>Quality of Life</td>
<td>Quality of Work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design for Usability</td>
<td>Workforce Structure</td>
<td>Retention</td>
<td>Simulations / Delivery Systems</td>
<td>Occupational Standards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design for Maintainability</td>
<td></td>
<td>Career Progression</td>
<td>Embedded Training</td>
<td>Distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Skill Mix/ Special Skills</td>
<td>Distance Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occupational Standards</td>
<td>Virtual Environments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distribution</td>
<td>Intelligent Tutoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Human Performance**
- Workload
- Normal Operations & Emergency Activity (Quality / Quantity)
- Operators, Maintainers & Support
- All Personnel
- Workforce Structure

**Knowledge, Skills and Attitudes**
- Personnel Classification
- Selection
- Recruiting
- Retention
- Career Progression
- Skill Mix/ Special Skills
- Occupational Standards
- Distribution

**Skill Development**
- Individual / Team Training Concepts
- Initial & Follow-on Training
- Organized Training
- Simulations / Delivery Systems
- Embedded Training
- Distance Learning
- Virtual Environments
- Intelligent Tutoring

**Physical Environment**
- Personnel Services
- Living Conditions
- Quality of Life
- Quality of Work

**Personnel Protection**
- Damage Control

**Environment Health Hazard Avoidance**
- Accident Avoidance
- Safety
- Hazard Avoidance
- Ergonomics
- Risk Mitigation
- Medical
HSI End Results

HSI Is the Component of Systems Engineering That Focuses on the HUMAN

- Manpower/Personnel: Recruiting, Retention
- Training
- Environment, Safety, Occupational Health
- Human Factors: Quality of Service
- Personnel Survivability
- Habitability: Quality of Life
HSI Process

User Needs & Technology Opportunities

- Process entry at Milestone A, B, or C
- Entrance criteria met before entering phase
- Evolutionary Acquisition or Single Step to Full Capability

A  B  C

APB (Program Initiation)

IOC  FOC

Concept Refinement  Technology Development  System Development & Demonstration  Production & Deployment  Operations & Support

Pre-Systems Acquisition  Systems Acquisition  Sustainment

Concept Decision  Design Readiness Review  LRIP/IOT&E  FRP Decision Review
• Department of Defense
  – US Army (MANPRINT)
  – US Navy
  – US Air Force (HSI Brooks AFB)
• Department of Transportation
  – FAA
  – Maritime Administration
  – FHWA
• Department of Homeland Security
  – Public Safety Architectures
• HSI is A Big Part of Investigations by NTSB
Case Example

• USCG Deepwater Program
  – VUAV Development and Fielding
Coast Guard Considered

- Design and HFE
- Personnel (Aviators or Not, Intell Specs, etc.)
- Manpower (How Many to Operate? CG-Wide?)
- Training
- Safety (Collision Avoidance, National Airspace)
- Other
FRA HSI Research Priorities

• Moving-map applications

• Crew station/Control and Display configurations

• CTIL will serve as evaluation test-bed for the integration of new cab technology in ways that maximize human capabilities.
Evaluation Methodology

- Evaluation Utilization Framework Context
  - Implementation evaluation
  - Impact evaluation
  - Sustainability evaluation
  - Stakeholder involvement
• **Utilization**
  – How can/will X use this system or program

• **Implementation**
  – What kinds of organizational structures are in place to support implementation?

• **Transfer**
  – How will knowledge transfer from the introduction or pilot site to other sites?

• **Diffusion**
  – What methods can be used to communicate about the system or program to the public or industry?

• **Translation**
  – How can system or related communications be shaped to make them more accessible to the target audiences?

Generic Logic Model

Activities

- Funded Activity “Family”
  - E.g.
    - Scientific Research
    - Technology Development

Outputs

- Deliverables/Products
  - Technical Report(s)
  - Forecasting Model(s)

Outcomes

- Application of Research
- Data Use
- Adoption of Guidelines, Standards or Regulations
- Changing Practices
- Unintended Consequences

Impacts

- Reduced Accidents & Injuries
- Improved Safety Culture
- Positive Knowledge Gains
- Negative Environmental Effects
Shared values, actions, and norms that demonstrate a collective commitment to emphasize safety over competing goals and demands

Psychological
“How people feel”
Values, Attitudes & Perceptions

Behavioral
“What people do”
Actions & Behaviors

Situational
“Organizational factors”
Policies, Procedures & Management Systems
<table>
<thead>
<tr>
<th>Program</th>
<th>Department</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rules Revision</td>
<td>All Operating</td>
<td>30% reduction in reportable injuries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drop in liability claims</td>
</tr>
<tr>
<td>EAGLES</td>
<td>Station Services</td>
<td>80% drop in injury rates</td>
</tr>
<tr>
<td></td>
<td>(Hi Supervision)</td>
<td>76% drop in reportable injuries</td>
</tr>
<tr>
<td>ISROP</td>
<td>Mechanical</td>
<td>50% drop in injury rates (all injuries)</td>
</tr>
<tr>
<td>CAB</td>
<td>Road</td>
<td>72% drop in L.E. decertification rates</td>
</tr>
<tr>
<td></td>
<td>(Lo Supervision)</td>
<td>69% drop in HF derailment rates</td>
</tr>
<tr>
<td>STEEL</td>
<td>Switching</td>
<td>62% drop in yard derailment rates</td>
</tr>
<tr>
<td></td>
<td>(Moderate Supervision)</td>
<td></td>
</tr>
</tbody>
</table>
• The Department of Transportation is a cabinet-level executive department of the United States government that took 92 years to establish; it was first considered in 1808.

• DOT’s mission was to develop and coordinate policies that will provide an efficient and economical national transportation system, with due regard for need, the environment, and national defense.

• DOT is the primary agency in the federal government with the responsibility for shaping and administering policies and programs to protect and enhance the safety, adequacy, and efficiency of the transportation system and services.

• The Office of the Secretary oversees eleven independently funded Operating Administrations

1 US DOT Office of the Historian Web Page
Safety Council Process Model

- Needs assessment
- Design
- Implementation
- Impact / Outcome
- Sustainability
Safety Council Conops

Executive Team
- Secretary Ray LaHood
- Deputy Secretary John Porcari
- Under Secretary Roy Krenitz
- Administrator Randy Babbitt (FAA) | Administrator Victor Mendez (FHWA)
- Administrator Anne Ferro (FMCSA) | Administrator Joe Szabo (FRA)
- Administrator Peter Rogoff (FTA) | Administrator David Matsuda (MARAD)
- Administrator David Strickland (NHTSA) | Administrator Peter Appel (RITA)
- Administrator Cynthia Quarterman (PHMSA) | Administrator Terry Johnson (SLSDC)

Action Teams
- Safety Culture
- HOS/Fatigue

Implementation Team

Technical Team
Current Mission, Vision and Strategic Goals

• Vision
  – To be widely recognized as the world’s leader for safety in transportation.

• Mission
  – To serve as DOT’s safety advocate and to bring together each part of DOT in addressing transportation safety as a critical national health issue.

• Strategic Goals
  – To identify, prioritize and address top current safety issues in DOT.
  – To encourage the development, implementation, and evaluation of proactive initiatives that improve safety and safety culture in transportation.
  – To share data, best practices, and strategies for continuous improvement of DOT’s safety programs.
  – To provide a forum for anticipating and addressing top emerging safety issues in DOT.
## Developmental Evaluation Approach and Results

### Evaluation Approach

- Establish V.1 Safety Council Principals and principles
- Conduct interviews with Principals
- Feed back results for validation
- Empower Principals
- Incorporate results into Safety Council implementation (formalize Roadmap)
- Regularly check in with Principals and chair informally
- Periodically provide opportunity for formal feedback
- Constantly provide feedback on results and actions

### Major Themes / Issues Identified To Date

- Hours of Service/Fatigue
- Operator Impairment / Distraction
- Risk Management (SMS)
- Regulatory Enforcement and Compliance Approaches
- Equipment, Infrastructure and Technology
- Safety Data Management and Reporting
- Aging Operators / Demographics
- Outreach, Communications and Coordination → All Stakeholders
Questions?