To Trust or Not To Trust: 
Factors that Influence Mineworkers’ Trust in Proximity Detection Systems for Mobile Machines

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Human Factors Branch

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Virginia Beach, VA
Presentation Objectives:

- Discuss why appropriate trust in technology is important for mine safety
- Describe proximity detection systems (PDSs)
- Summarize the methods, results, and conclusions from the NIOSH study
- Provide recommendations
Presentation Agenda:

- Background
- Study Methods
- Results
- Conclusions
- Recommendations
Presentation Agenda:
How much do you trust technology?
How much do you trust technology?

Not enough??
How much do you trust technology?

Too much??
How much do you trust __________________________?

1  2  3  4  5  6  7  8  9  10

Never  50/50  Always
Inappropriate trust has the potential to cause safety issues

<table>
<thead>
<tr>
<th>Low Trust</th>
<th>Moderate Trust</th>
<th>High Trust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disuse</td>
<td>Appropriate use</td>
<td>Misuse</td>
</tr>
<tr>
<td>Underutilization</td>
<td></td>
<td>Overreliance</td>
</tr>
<tr>
<td>Ignoring/Defeating</td>
<td></td>
<td>Improper monitoring</td>
</tr>
</tbody>
</table>

- Parasuraman & Riley, 1997
How much do mineworkers trust safety technology?

How much do mineworkers trust proximity detection systems for mobile machines (mobile PDSs)?
Pinning, crushing, and striking accidents involving equipment continue to be a major concern in the mining sector

1984-2013 preventable continuous mining machine injuries
- 238 nonfatal injuries
- 34 fatal injuries

1984-2014 preventable mobile equipment injuries
- 179 nonfatal injuries
- 42 fatal injuries

-Mine Health and Safety Administration, 2015
Underground coal mines adopted PDSs

1984-2014
- Over 400 nonfatal injuries
- Over 75 fatal injuries

2011
- MSHA proposed a rule requiring continuous mining machines to be equipped with PDSs.

2015
- MSHA published a rule requiring continuous mining machines to be equipped with PDSs (installation deadline: March 2018).
- MSHA proposed a rule requiring mobile machines to be equipped with PDSs.

2017
- Continuous mining machine operator fatally injured after activating the emergency stop override function for the PDS.

2018
- SNL Energy Report documented stakeholder concerns related to the adoption and integration of PDSs in underground coal mines.

-Mine Health and Safety Administration, 2015
-Taylor, SNL Energy Report, 2018
Proximity detection systems could improve safety by reducing human-machine collisions

Proximity detection system (PDS) - an automated, collision avoidance technology designed to prevent machine-human collisions.

A PDS can be installed on:
- Continuous Mining Machines
- Mobile Machines
  - Coal hauling machines
    - Shuttle cars
    - Ram cars
  - Scoops
Proximity detection systems could improve safety by reducing human-machine collisions

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    - Ram cars
  - Scoops
Proximity detection systems (PDSs) for mobile equipment help to protect mineworkers

When a worker is in an established warning (yellow) zone or stop (red) zone...

- Worker is alerted by their miner wearable component (MWC)
Proximity detection systems (PDSs) for mobile equipment help to protect mineworkers

When a worker is in an established warning (yellow) zone or stop (red) zone...
  • Worker is alerted by their MWC
  • Mobile machine is slowed or disabled
Presentation Agenda:

- Background
- Study Methods
- Results
- Conclusions
- Recommendations
Study methods and research questions

Study Methods:
- Mixed-methods study (i.e., qualitative and quantitative)
- 7 Underground coal mines
- 208 mineworkers

Research Questions:
- How are mineworkers’ trained on mobile PDSs?
- What factors influence mineworkers’ trust in mobile PDSs?
For this study, trust in a mobile PDS is...

a worker’s “confidence in the system’s ability to prevent collisions while not exposing them to additional risk.”

-Swanson & Bellanca, forthcoming
Mineworkers were asked the following questions

1. How did you learn to use mobile PDS? (qualitative)

2. How confident are you that the system will prevent a collision? (quantitative)

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
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<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
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<td>Never</td>
<td>50/50</td>
<td>Always</td>
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Four of the mines had PDS A and three had PDS B.

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<tr>
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<th>PDS</th>
<th>Mining Method</th>
<th>UG Workers</th>
<th>Hours (annual)</th>
<th>Tons of Coal (annual)</th>
<th>Haulage</th>
<th>Scoop</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>Longwall</td>
<td>598</td>
<td>1,586,445</td>
<td>12,123,618</td>
<td>Partial</td>
<td>Partial</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>Longwall</td>
<td>481</td>
<td>1,391,106</td>
<td>5,352,731</td>
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<tr>
<td>C</td>
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<td>595</td>
<td>1,438,550</td>
<td>9,180,468</td>
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<td>D</td>
<td>B</td>
<td>Room and Pillar</td>
<td>162</td>
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<td>F</td>
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UG = Underground; *National Fatal Incidence Rate = 0.024; **NFDL = Non-Fatal Days Lost; National NFDL Incidence Rate = 3.66
Source: MSHA, Mine Data Retrieval System
Most of the mines were longwall mines

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The mines ranged from 162 to 598 employees

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Presentation Agenda:

- Background
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How are mineworkers trained on mobile PDSs?

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<tr>
<th>Type</th>
<th>Minimal to None</th>
<th>Classroom</th>
<th>Hands-On</th>
<th>Verbal</th>
<th>Written Materials</th>
<th>Not Specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who</td>
<td>Manufacturer</td>
<td>Mine</td>
<td>Not Specified</td>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
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Most mineworkers described receiving hands-on training

- Minimal to none: 39
- Classroom: 75
- Hands-on: 83
- Verbal: 14
- Written: 6

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Most mineworkers reported receiving training from the mine.

- Number of Workers
  - Manufacturer: 45
  - Mine: 91

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Most mineworkers did not learn through practice

Number of Workers

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<td>93</td>
<td>105</td>
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## What factors influence workers’ trust in mobile PDSs?

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<th>Mine</th>
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<td>• Cultural(^2)</td>
<td>• Older adults and overreliance(^4)</td>
<td>• System experience increases trust(^6)</td>
<td>• Performance differences may influence trust(^7)</td>
</tr>
<tr>
<td></td>
<td>• Organizational(^3)</td>
<td>• Young adults and mistrust(^5)</td>
<td>• Experience decreased trust(^7)</td>
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\(^1\) Urata, 2004; \(^2\) Baba, Falkenbrugh, & Hill, 1996; \(^3\) Kramer, 1999; \(^4\) Fletcher & Jensen, 2015; \(^5\) Muir & Moray, 1996; \(^6\) Sanchez, Rogers, Fisk, & Rovira, 2014
What factors influence workers’ trust in mobile PDSs?

Training
- Hands-on training and step-by-step guides

Mine
- Cultural
- Organizational

Age
- Older adults and overreliance
- Young adults and mistrust

Experience
- System experience increases trust
- Experience decreased trust

System Make
- Performance differences may influence trust

Training did not have a significant influence on trust.

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Averages in workers’ trust ranged from about 5 to 8 out of 10

Workers’ Trust in Mobile PDS

Mine A: 6.05
Mine B: 8.04
Mine C: 6.67
Mine D: 5.66
Mine E: 6.1
Mine F: 6.75
Mine G: 7.24

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Statistical differences were found between Mine B and Mine D

![Bar chart showing workers' trust in mobile PDS for different mines. Mine B has the highest trust score of 8.04, followed by Mine G with 7.24. Mine D has the lowest score of 5.66.](image)

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Average trust ratings of the age groups were similar to the overall average

<table>
<thead>
<tr>
<th>Age</th>
<th>Workers (N)</th>
<th>Workers’ Trust (Mean)</th>
<th>Workers’ Trust (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-29 years</td>
<td>43</td>
<td>6.53</td>
<td>2.76</td>
</tr>
<tr>
<td>30-49 years</td>
<td>112</td>
<td>6.42</td>
<td>2.32</td>
</tr>
<tr>
<td>50-69 years</td>
<td>47</td>
<td>6.98</td>
<td>2.32</td>
</tr>
<tr>
<td><strong>All workers</strong></td>
<td><strong>202</strong></td>
<td><strong>6.57</strong></td>
<td><strong>2.42</strong></td>
</tr>
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Age did not have a significant influence on trust.

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Average trust ratings for the experience groups were between 6 and 7

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<th>Worker (N)</th>
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<tr>
<td>0-5 years</td>
<td>44</td>
<td>6.16</td>
<td>2.44</td>
</tr>
<tr>
<td>6-10 years</td>
<td>69</td>
<td>6.68</td>
<td>2.56</td>
</tr>
<tr>
<td>11-20 years</td>
<td>54</td>
<td>6.22</td>
<td>2.39</td>
</tr>
<tr>
<td>21-30 years</td>
<td>12</td>
<td>7.25</td>
<td>1.77</td>
</tr>
<tr>
<td>31 or more years</td>
<td>24</td>
<td>7.29</td>
<td>2.51</td>
</tr>
<tr>
<td>All Workers</td>
<td>203</td>
<td>6.55</td>
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<td>• Young adults and mistrust⁵</td>
<td>• Experience decreased trust⁷</td>
<td></td>
</tr>
</tbody>
</table>

Experience did not have a significant influence on trust.

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What factors influence workers’ trust in mobile PDSs?

<table>
<thead>
<tr>
<th>Training</th>
<th>Mine</th>
<th>Age</th>
<th>Experience</th>
<th>System Make</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hands-on training and step-by-step guides(^1)</td>
<td>• Cultural(^2)</td>
<td>• Older adults and overreliance(^4)</td>
<td>• System experience increases trust(^6)</td>
<td>• Performance differences may influence trust(^7)</td>
</tr>
<tr>
<td></td>
<td>• Organizational(^3)</td>
<td>• Young adults and mistrust(^5)</td>
<td>• Experience decreased trust(^7)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Urata, 2004; \(^2\) Baba, Falkenbrugh, & Hill, 1996; \(^3\) Kramer, 1999; \(^4\) Fletcher & Jensen, 2015; \(^5\) Muir & Moray, 1996; \(^6\) Sanchez, Rogers, Fisk, & Rovira, 2014

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Average trust ratings for system make were around the overall average.

<table>
<thead>
<tr>
<th>Mobile PDS</th>
<th>Workers (N)</th>
<th>Workers’ Trust (Mean)</th>
<th>Workers’ Trust (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System A</td>
<td>128</td>
<td>6.44</td>
<td>2.31</td>
</tr>
<tr>
<td>System B</td>
<td>80</td>
<td>6.73</td>
<td>2.64</td>
</tr>
<tr>
<td>All Workers</td>
<td>208</td>
<td>6.57</td>
<td>2.44</td>
</tr>
<tr>
<td>Training</td>
<td>Mine</td>
<td>Age</td>
<td>Experience</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>• Hands-on training and step-by-step guides&lt;sup&gt;1&lt;/sup&gt;</td>
<td>• Cultural&lt;sup&gt;2&lt;/sup&gt;</td>
<td>• Older adults and overreliance&lt;sup&gt;4&lt;/sup&gt;</td>
<td>• System experience increases trust [28]</td>
</tr>
<tr>
<td></td>
<td>• Organizational&lt;sup&gt;3&lt;/sup&gt;</td>
<td>• Young adults and mistrust&lt;sup&gt;5&lt;/sup&gt;</td>
<td>• Experience decreased trust [29]</td>
</tr>
</tbody>
</table>

System make did not have a significant influence on trust.

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Mine of employment was the only significant factor

**Training**
- Hands-on training and step-by-step guides

**Mine**
- Cultural
- Organizational

**Age**
- Older adults and overreliance
- Young adults and mistrust

**Experience**
- System experience increases trust
- Experience decreased trust

**System Make**
- Performance differences may influence trust

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Mine culture could have influenced the results

- Variations in employee workloads and work practices

- High task loads lead to excessive trust

-Biros, Daly, & Gunsch, 2004
The largest and smallest mine had lower trust ratings

```
Workers’ Trust in Mobile PDS

Largest mine (production, employees)

Mine A: 6.05
Mine B: 8.04
Mine C: 6.67
Mine D: 5.66

Smallest mine (employees)

Mine E: 6.1
Mine F: 6.75
Mine G: 7.24
```

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Mine culture could have influenced the results

- **Social norms** or the attitudes and values of others

  - One employee can shape the trust perceptions of others

  - The initial presentation of the system can influence trust

  -Workman, 2005

  -de Vries & Midden, 2003
Presentation Agenda:

- Background
- Study Methods
- Results
- Conclusions
- Recommendations
Recommendations

- Address behaviors that may indicate **inappropriate trust**
  - Ignoring alarms or alerts
  - Defeating the system
  - Deterioration of awareness or skills

- Consider how **workloads** may be influencing workers’ trust
  - Adjust workloads during implementation

- Select **supervisors with appropriate trust** and a **knowledge of the system** to lead implementation and training efforts
  - Identify leaders with understanding of system strengths and weaknesses

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Feel free to contact me with any questions

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