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Federal Railroad Administration
Fatigue Risk Management Symposium
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Risk Defined

- Risk = Outcome x Probability
  - Any system or operation has multiple possible outcomes, each associated with a probability of occurrence. In addressing system safety, possible hazards are the outcomes of interest.
  - Human Factor accidents caused by fatigue are a hazard for which risk should be determined in the railroad industry.
  - Outcomes are usually classified by severity. Cost in dollars is a convenient metric for accidents.
### Simplified Risk Matrix

**RISK KEY**
- HIGH: A
- MEDIUM: B
- LOW: C

<table>
<thead>
<tr>
<th>PROBABILITY</th>
<th>LOW</th>
<th>MEDIUM</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>LOW</td>
<td>C</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>

**UP Fatigue Management Conference**

5/5/2010
1. Measure fatigue

2. Determine relationship between fatigue and Human Factor Accidents (HFA)
   – Determine critical level of fatigue
   – Conditional probability of a HFA given a critical level of fatigue \[ p(HFA|\text{fatigue}) \]

3. Determine cost of HFAs with a critical level of fatigue

4. Risk = \[ p(HFA|\text{fatigue}) \times \text{Cost} \]
Fatigue Estimation

- Fatigue is assayed from Work and Sleep times using the Fatigue Avoidance Scheduling Software (FAST)
- FAST calculates Effectiveness (E), which is inversely related to fatigue.
- E ranges from 0 (highest level of fatigue) to 100 (totally rested)
Fatigue Profiles

- Amount of exposure to Fatigue Accident Risk for a group in the industry
- Data comes from application of FAST model to diary data or other schedule information
  - Proportion of employee time at various levels of E
  - Diary studies completed to date for Train & Engine crews, Dispatchers, Signalmen, MOW employees.
  - Diary study in progress for passenger service T&E
• FAST Validation study relates fatigue level to odds of human factor accidents
  – At Effectiveness (E) ≤ 70, accident odds are 21% higher than chance
  • Critical level of fatigue
• Effectiveness above 90: well rested; 
  no fatigue
• Effectiveness between 90 and 80: mildly 
fatigued; an acceptable level of fatigue
• Effectiveness below 70: very fatigued;
an unacceptable level of fatigue
  – Lapses 5x more likely than well rested person
  – Equal to being awake for 21 h, awake at 7 am
  – Equal to blood alcohol level of 0.08
### Effectiveness and Accident Odds From Validation Study

<table>
<thead>
<tr>
<th>Criterion Effectiveness Score</th>
<th>Odds of HF Accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 90</td>
<td>0.84</td>
</tr>
<tr>
<td>≤ 90</td>
<td>1.11</td>
</tr>
<tr>
<td>≤ 80</td>
<td>1.14</td>
</tr>
<tr>
<td>≤ 70</td>
<td>1.21</td>
</tr>
<tr>
<td>≤ 60</td>
<td>1.39</td>
</tr>
<tr>
<td>≤ 50</td>
<td>1.65</td>
</tr>
</tbody>
</table>

5/5/2010
Outcomes

- Two outcomes from fatigue
  - Human Factors Accident (HFA)
  - No HFA
- Other outcomes are possible, not considered
  - Fatigue-induced illness (e.g., diabetes)
  - Poor job performance (e.g., fuel use, brake wear)
• Given \( E \leq 70 \), the two outcome probabilities:
  - \( p \ (HFA \geq 1) = 0.21 \)
  - \( p \ (HFA = 0) = 0.79 \)
• \( E \leq 70 \) not acceptable
  - High probability of HFA
  - Equivalent to 0.08 blood alcohol concentration
Cost of HFAs

• Based on validation study data
• Average HFA|E≤70 costs $1,198,396
• Average HFA|E≥90 costs $262,035
  – Cost of a Fatigue-related HFA is 4.57 times the cost of a nonFatigue-related HFA
Fatigue Risk Management: Schedule Changes

• Schedule changes can directly decrease exposure, and are measureable by FAST
  • Schedules with more than 50% of work starts at night (between 2000 and 0300) are most fatiguing
  • Rest days
  • Call windows
  • Scheduled work

• There will always be some exposure to $E \leq 70$
• Schedule changes won’t eliminate all exposure
• Effects not necessarily seen with FAST
• Effect of countermeasures may need to be measured by other means
  – Subjective (e.g., Karolinska Sleepiness Scale)
  – Objective (e.g., actigraph watches)
  – Accidents with fatigue indicators
• Variety of management tools to use
Available Tools

• Napping Policy
• Education/Training
  • Personal
  • Family
• Caffeine use
• Exercise
• Diet and medications
• Supervision
Fatigue Accident Risk

Risk = Probability x Cost

Expected Value (EV) = Sum of risks for all outcomes

• With no Fatigue Management
  – EV = (0.21 x $1,198,396) + (0.79 x $0) = $251,663
    • p(HFA|E<70) x accident cost + p(~HFA) x Fatigue management cost

• With Fatigue Management (hypothetical)
  – EV = (0.1 x $262,035) + (0.9 x $5,000) = $31,203
    • p(HFA|E>90) x accident cost + p(~HFA) x Fatigue management cost
Summary and Conclusions

• Fatigue is a hazard that places railroad operations at risk of accidents
• Fatigue models can be used to estimate the components of that risk: probability and cost
• Fatigue accident risk can be mitigated by Fatigue Risk Management
• Applying concept of Expected Value is means to estimate effectiveness of Fatigue Risk Management
Questions and Suggestions

• Contact
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  (202) 493-6356
• Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, Final Report
• Work Schedules and Sleep Patterns of Railroad Train and Engine Service Workers
• Work Schedules and Sleep Patterns of Railroad Dispatchers
• Work Schedules and Sleep Patterns of Railroad Maintenance of Way Workers
• Work Schedules and Sleep Patterns of Railroad Signalmen
• Work Schedules and Sleep Pattern Survey Data
Fatigue Management Resources

- [Commercial Transportation Operator Fatigue Management Reference](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_81.pdf)
- TCRP Report 81: Toolbox for Transit Operator Fatigue