A Model for Truck Driver Scheduling with Fatigue Management

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Fatigue Related Crashes

- National Academies of Sciences, 2016
- Approximately 4,000 fatalities due to truck and bus crashes occur each year in the United States
- Up to 20% are estimated to involve fatigued drivers
Hours of Service Regulations

- Issued by Federal Motor Carrier Safety Administration (FMCSA)
- Attempt to reduce accidents caused by fatigued drivers by limiting driving/working hours
Truck Driver Scheduling Problem (TDSP) and/or Vehicle Routing (VRP) models with HOS constraints

- Archetti & Savelsbergh (2009)
- Goel (2012, 2014)
- Goel and Vidal (2014)
Introduction

- No model that accounts for fatigue or alertness
- We introduce the Truck Driver Scheduling Problem with Fatigue Monitoring (TDSPFM)
- Accounts for:
  - Time Windows
  - HOS constraints
  - Minimum Alertness Level
Alertness

- How to predict alertness?
  - Several Models:
    - System for Aircrew Fatigue Evaluation (SAFE)
    - The Sleep, Activity, Fatigue, and Task Effectiveness Model (SAFTE)
    - Three Process Model of Alertness (TPMA)
- Prediction vs. Detection
Three Process Model of Alertness (TPMA)

- Builds on the two process model of Alexander Borbély (1982)
- Åkerstedt, Connor, Gray, & Kecklund (2008)
- TPMA Validation: Ingre et al. (2014)
- Karolinska Sleepiness Scale (KSS)
3 Processes of Alertness

- **S**: Homeostatic Sleep Drive
  - S’: Sleep Recovery
- **C**: Circadian Rhythm
- **U**: Ultradian Process

\[ \text{Alertness} = S + C + U \]

Alertness values from 1-21:

- 3: extremely sleepy
- 7: sleepiness threshold
- 14: highly alert
Alertness

S: Homeostatic Sleep Drive
S’: Sleep Recovery
C: Circadian Rhythm
U: Ultradian Process

Time of day

Alertness level
TDSPFM Model

- We are given a sequence of locations
- Objective is to minimize duration:
  - $A_{last} - D_{first}$
- Decision Variables are the rest times at each location ($r_i$) such that:
  - Time Windows are obeyed
  - HOS regulations are obeyed
  - Alertness stays above a minimum threshold while driving ($TPMA^{min}$)
TDSPFM Model

- $\text{TPMA}_{\text{min}}$ is computed along the route and not only at each location $i$
  - $\text{alertness}_{\text{now}} = S_{\text{now}} + C_{\text{now}} + U_{\text{now}}$
  - $\text{alertness}_{\text{now}} \geq \text{TPMA}_{\text{min}}$, $\forall i \in N$

- Each location has optional working times and opening/closing time windows
  - $A_i \leq L_i$, $\forall i \in N$
  - $A_i + r_i + w_i = D_i$, $\forall i \in N$
TDSPFM Model

- Planning Problem
- Genetic Algorithm using Excel/Solver
  - Penalized Time Window, HOS, and $\text{TPMA}^{\text{min}}$ violations
  - Repair function: Force a long rest if continuing resulted in HOS violation
Results

- Created 30 benchmark problems
- Initial alertness: 10.32
- Solved each with varying levels of $\text{TPMA}_{\text{min}}$
  - 0 for baseline (just obey HOS and TW)
  - 7.07: “tired”
  - 8.15: “semi-tired”
  - 9.24: “not tired or alert”
## Results

<table>
<thead>
<tr>
<th>Alertness Threshold</th>
<th>Duration</th>
<th>Minimum Alertness</th>
<th>Worst Case Minimum Alertness</th>
<th>Duration % Increase</th>
<th>Minimum Alertness % Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (0)</td>
<td>99.20</td>
<td>7.9</td>
<td>7.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tired (7.07)</td>
<td>99.22</td>
<td>7.9</td>
<td>7.1</td>
<td>0.02%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Semi-Tired (8.15)</td>
<td>100.37</td>
<td>8.3(^a)</td>
<td>8.2</td>
<td>1.18%</td>
<td>5.13%</td>
</tr>
<tr>
<td>Not Tired (9.24)</td>
<td>104.65(^a)</td>
<td>9.3(^a)</td>
<td>9.2</td>
<td>5.49%</td>
<td>17.94%</td>
</tr>
</tbody>
</table>

\(^a\): Statistically significant difference from Baseline(0) at the 0.05 level
Assumptions

- Ignore caffeine or other drug use
- Ignore noise, sleep disorders, or other factors that may inhibit sleep
- Good, uninterrupted sleep is obtained during rest periods
- Driver is well-rested when they start the work week
Future Work

- TDSPFM validation using naturalistic driving data
- Support for customized sleep and alertness parameters
- Incorporation into scheduling tools or Fatigue Risk Management Systems (FRMS)
- Investigate different levels of starting alertness
Investigating the well-rested assumption (sample log data)

TPMA Alertness as a Function of Stops

TPMA Alertness as a Function of Stops

Min S+C+U

Alertness Threshold

17-March, 2017
FRMS and the well-rested assumption
Future Work

- Would this type of data incentivize drivers to get more (better) rest?
- Would this model (or type of model) work well in conjunction with real time fatigue detection?
Discussion

Questions?
References


References

