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A Model for Truck Driver Scheduling with Fatigue Management

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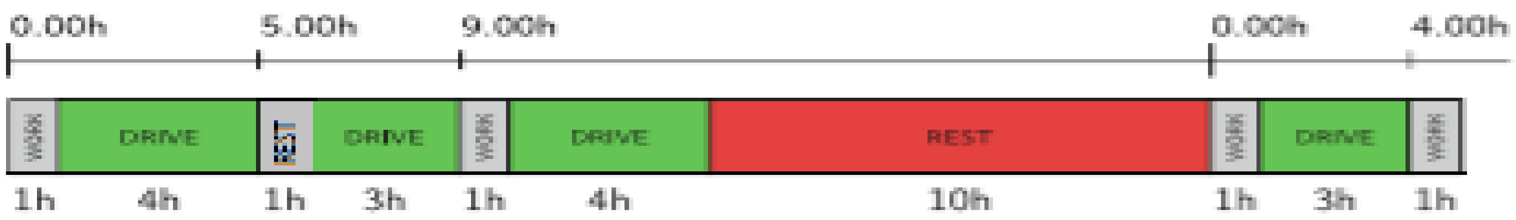
Fatigue Related Crashes

- 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

- Xu, Chen, Rajagopal, & Arunapuram (2003)
- 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)
  - Models Perform Similarly: Van Dongen (2004)
- **Prediction vs. Detection**

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- **Three Process Model of Alertness (TPMA)**
  - Builds on the two process model of Alexander Borbély (1982)
  - Åkerstedt, Folkard, & Portin (2004)
  - Åkerstedt, Connor, Gray, & Kecklund (2008)
  - TPMA Validation: Ingre et al. (2014)
  - Karolinska Sleepiness Scale (KSS)

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3 Processes of Alertness

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

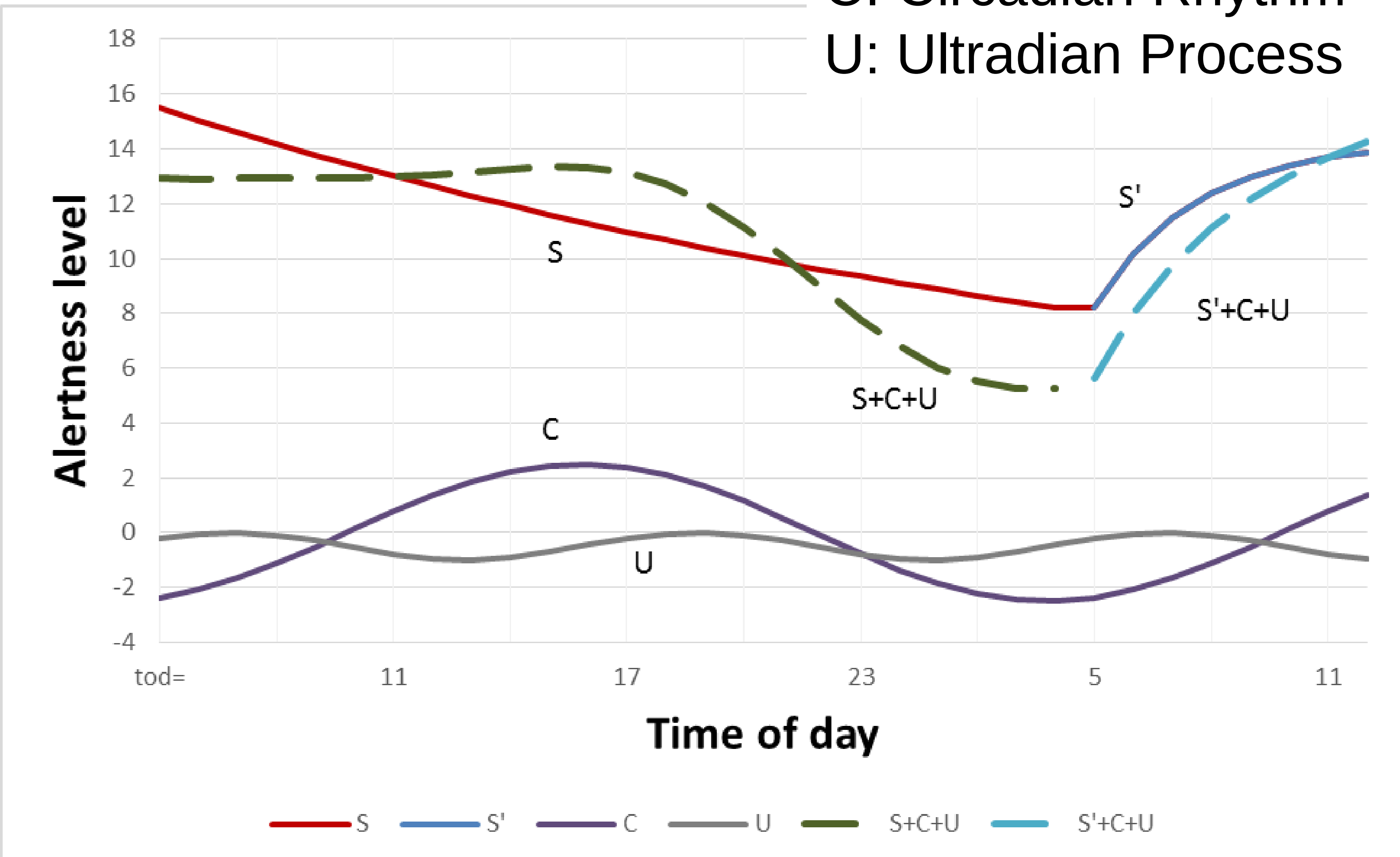
Alertness = S + C + U

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



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 ($TPMA^{min}$)

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TDSPFM Model

- $TPMA^{min}$ is computed along the route and not only at each location *i*
  - $alertness_{now} = S_{now} + C_{now} + U_{now}$
  - $alertness_{now} \geq TPMA^{\min} \quad \forall\, i \in N$
- Each location has optional working times and opening/closing time windows
  - $A_i \leq L_i \ \forall\, i \in N$
  - $A_i + r_i + w_i = D_i \quad \forall\, i \in N$

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TDSPFM Model

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

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Results

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

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Results

Alertness Threshold	Duration	Minimum Alertness	Worst Case Minimum Alertness	Duration % Increase	Minimum Alertness % Increase
Baseline (0)	99.20	7.9	7.0	-	-
Tired (7.07)	99.22	7.9	7.1	0.02%	0.05%
Semi-Tired (8.15)	100.37	8.3[a]	8.2	1.18%	5.13%
Not Tired (9.24)	104.65[a]	9.3[a]	9.2	5.49%	17.94%

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

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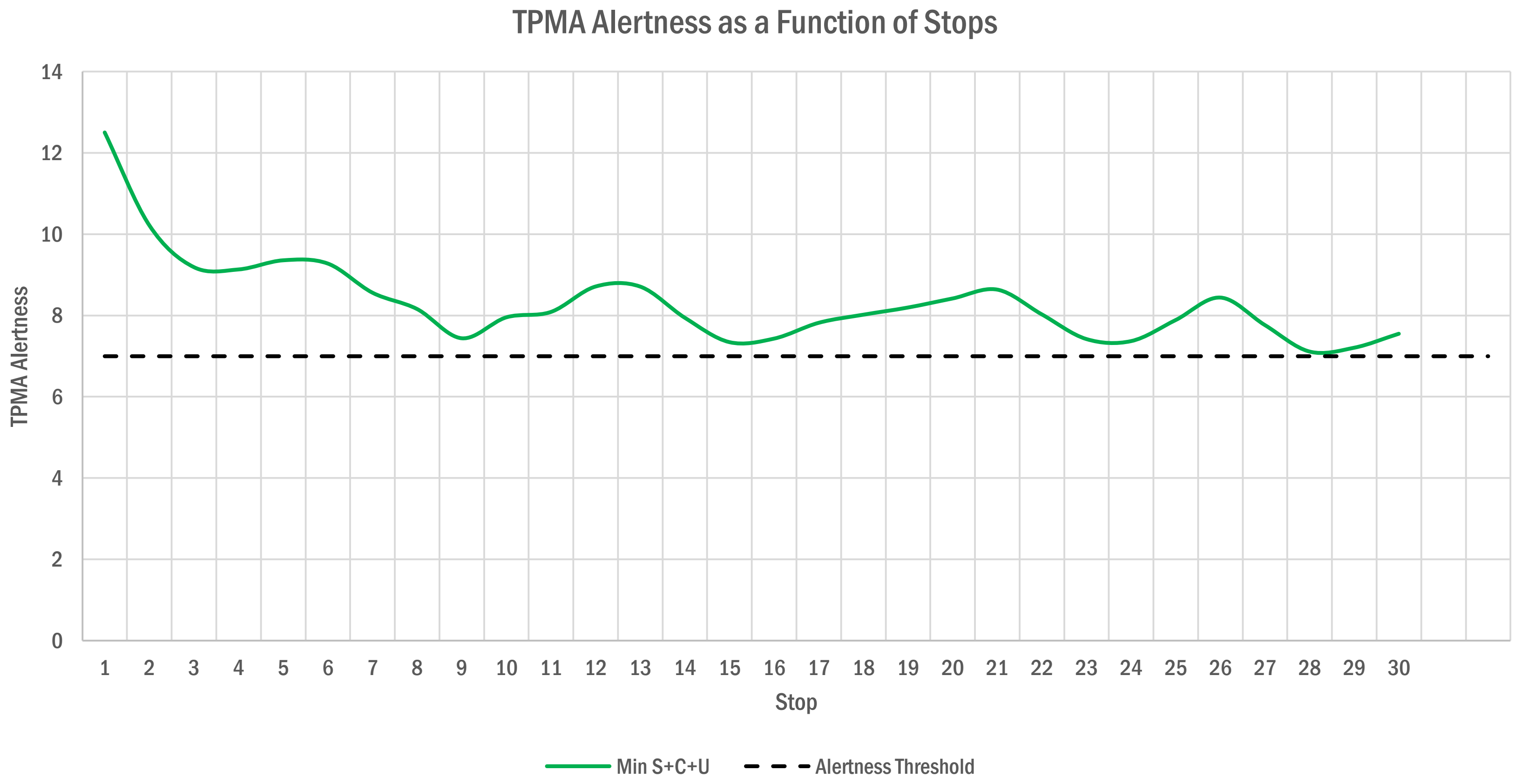
Assumptions

- **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)



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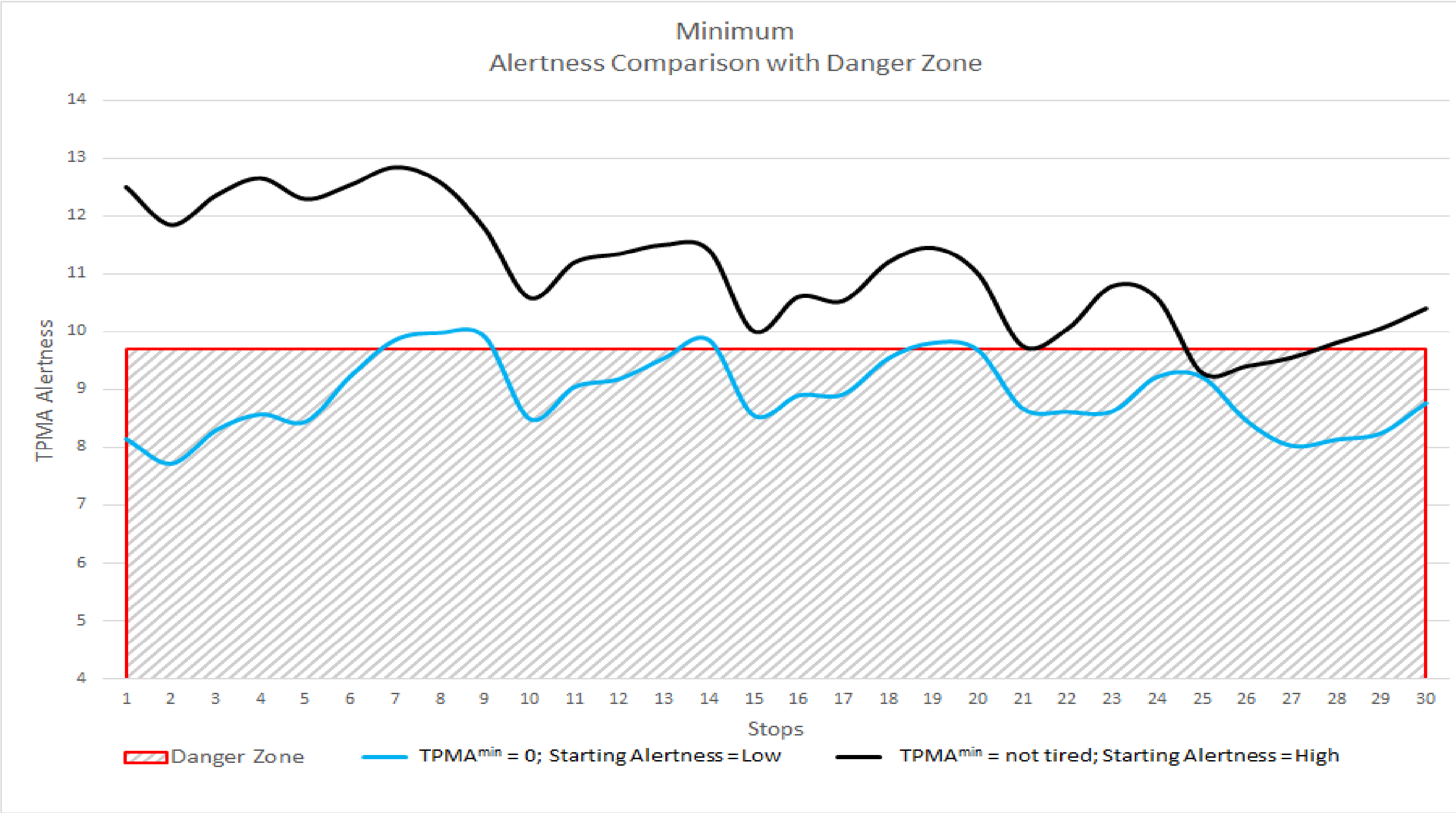
FRMS and the well-rested assumption



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?**

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Discussion

- **Questions?**

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References

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