Automated real-time detection of truck driver non-compliance

Alwyn Hoffman and Pierre Schutte, North-West University

alwyn.hoffman@nwu.ac.za

NORTH-WEST UNIVERSITY FACULTY OF ENGINEERING

Overview

- Introduction and background
- Contribution of trucks to fatal traffic accidents
- Problem statement
- Description of the data set
- Measurement of overload, speed and fatigue compliance
- Comparing behaviour of individual drivers with population behaviour
- Recommendations to fleet owners and road authorities about corrective action
- Conclusions and future work

Introduction and Problem statement

- Trucks contribute disproportionately to fatal traffic accidents
- Overloading, speeding, and fatigue are primary causes of truck accidents
- Speeding is an example of driver inattention to regulations
- Fatigue causes driver distraction due to sleepiness
- Overloading is controlled by weigh-in-motion scales, but driver inattention can result in the evasion of such monitoring systems
- Non-intrusive detection of these behavioural deviations can enable effective action against non-compliant drivers without causing disruption to compliant drivers
- This paper proposes a novel IoT solution that combines data from both road transport operators and the roads authority to detect driver non-compliance in real time, enabling effective action against offenders without negative implications for non-offenders

Literature Overview

- The importance of truck safety has been widely reported (Zhang, Yau, & Zhang, 2014) (Douglas, 2009) (Kemp, Kopp, & Kemp, 2013):
  - In 1997, 98 percent of the fatalities from crashes between a truck and a passenger vehicle were occupants of the passenger vehicle (G.A.O., 1999)
  - According to (Chen, Sieber, & Lincoln, 2015) commercial trucks were involved in 3,464 fatal, 73,000 injury-causing and 241,000 property-damaging crashes in 2012 in the US alone
- Mahaboon (Mahaboon, 2014) found that drivers reported high non-conformance with fatigue regulations, and that speeding violations was a strong predictor of crash involvement
- Batool et al (Batool, Hussain, Kanwal, & Abid, 2018) found that long trucks are involved in fatal accidents because of drivers' risky driving behaviours, speeding and overloading.
- Another finding was that increased monitoring to enforce compliance with work hour rules resulted in increased unsafe driving practices due to speeding (Scott, Balthrop, & Miller, 2020)
- The use of weigh-in-motion technology for overload control was proposed by Jacob et al (Jacob & Feypell-de La Beaumelle, 2010) to allow trucks to be weighed in traffic flow, without any disruptions to operations
- An IoT system for enhancing road safety proposed by Jabbar et al (Jabbar, Shinoy, & Kharbech, 2019) collects trip data, GPS coordinates, average and maximum speed and driving behavior for drivers' risk assessment and to detect extreme road user behaviour

Solutions?

- Combining data from both fleet owners and road authorities to identify offenders
  - WIM (Weight in Motion) scale readings
  - Truckstop transactions
  - GPS crumb trail
- No new infrastructure needs to be added to what already exists on the route
- No extra sensors are required on vehicles
- The intelligent combined interpretation of data sets that are currently managed in silo’s will provide the required insights into trucking operations

Limitations

- Data:
  - Large GPS crumb time intervals
  - Precision of GPS location measurements
  - Discrepancies between the datasets
  - Latency of transactional data may cause incorrect interpretation
  - Accuracy of WIM (weigh-in-motion) scales and ANPR (automated number plate recognition) cameras
- No access to trip plans and driver instructions
- No feedback from drivers for detected offences

High Level Overview

- Focussed on the N3 between Durban and Johannesburg – busiest freight route in Southern Africa
- Uses data from the infrastructure owners and multiple fleets
- Part of the ROUTESecure Initiative of the toll concessionnaire
- Functionality:
  - Creates events for each interaction between vehicles and the infrastructure
  - Determine whether actions completed are compliant with rules
  - Show a warning for non-compliant behaviour
  - Combine events into performance statistics for different fleets

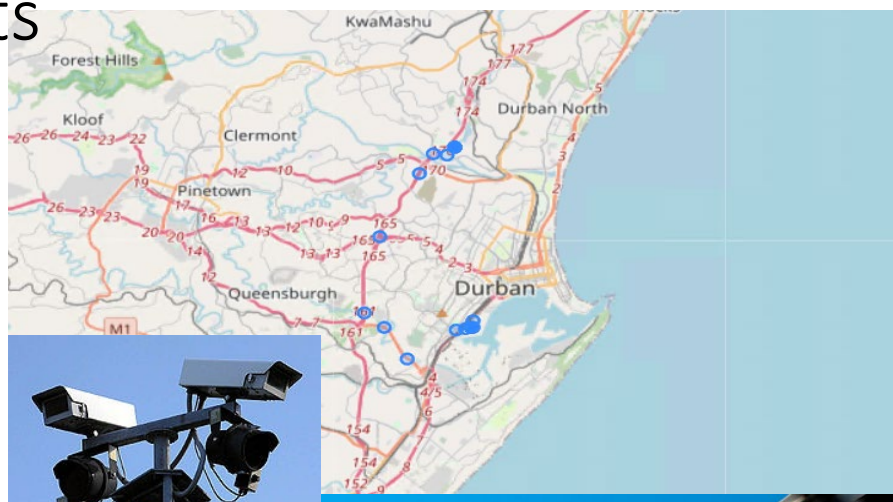
System Design

- Data Collection:
  - Connect to multiple data streams and collect the necessary data
- Archiving
  - Combine data streams into one location to allow the system to access it
  - Save data for later use in statistical analysis
- Analysis
  - Analyse newest data to generate events
  - Generate historical statistics about vehicle compliance based on events
- Presentation
  - Display non-compliance events
  - Display generated statistics for users

WIM (weigh-in-motion) Events

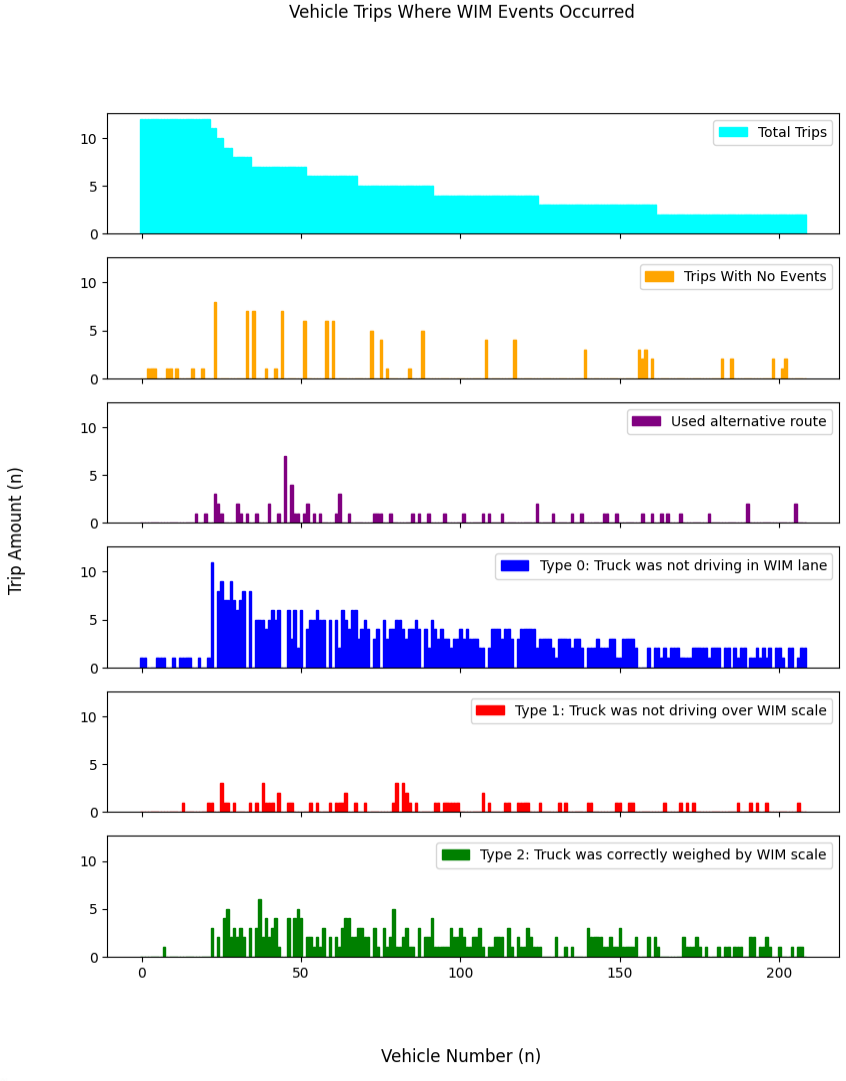
- Weigh-in-motion (WIM) scales are used to detect trucks that are potentially overloaded
- Truck drivers guilty of overloading or of unauthorised removal of cargo tend to evade WIM scales to avoid detection
- WIM scale events:

1. Vehicle deviated from the route onto secondary roads in the vicinity of the WIM scale
2. GPS identified vehicle at WIM scale but it wasn't picked up by the scale's camera
3. GPS identified vehicle at WIM, the scale's camera saw it but it was driving in a non-WIM lane
4. GPS identified vehicle at WIM, the scale's camera saw, it it was driving in the WIM lane but no realistic weight could be measured
5. GPS identified vehicle at WIM scale, it was seen by the scale's camera and properly weighed by the scale



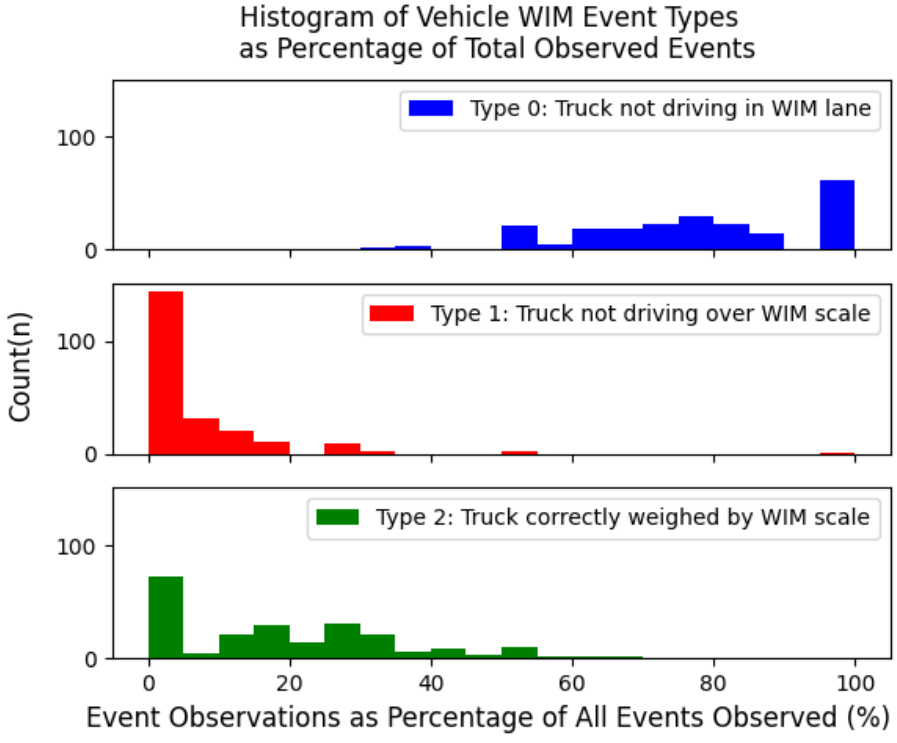
Practical Measurement of Weighbridge Discrepancies

- These graphs divide trucks into different categories based on behaviour at weighbridges
- Some trucks used alternative routes to evade weighbridge
- Many trucks went past weighbridge but did not drive in the correct lane and was therefore not seen by the ANPR camera
- Some of those driving in the correct lane did not drive properly across the WIM scale and therefore did not register a valid weight
- Only a minority of trucks were seen by the ANPR camera and correctly weighed by the WIM scale

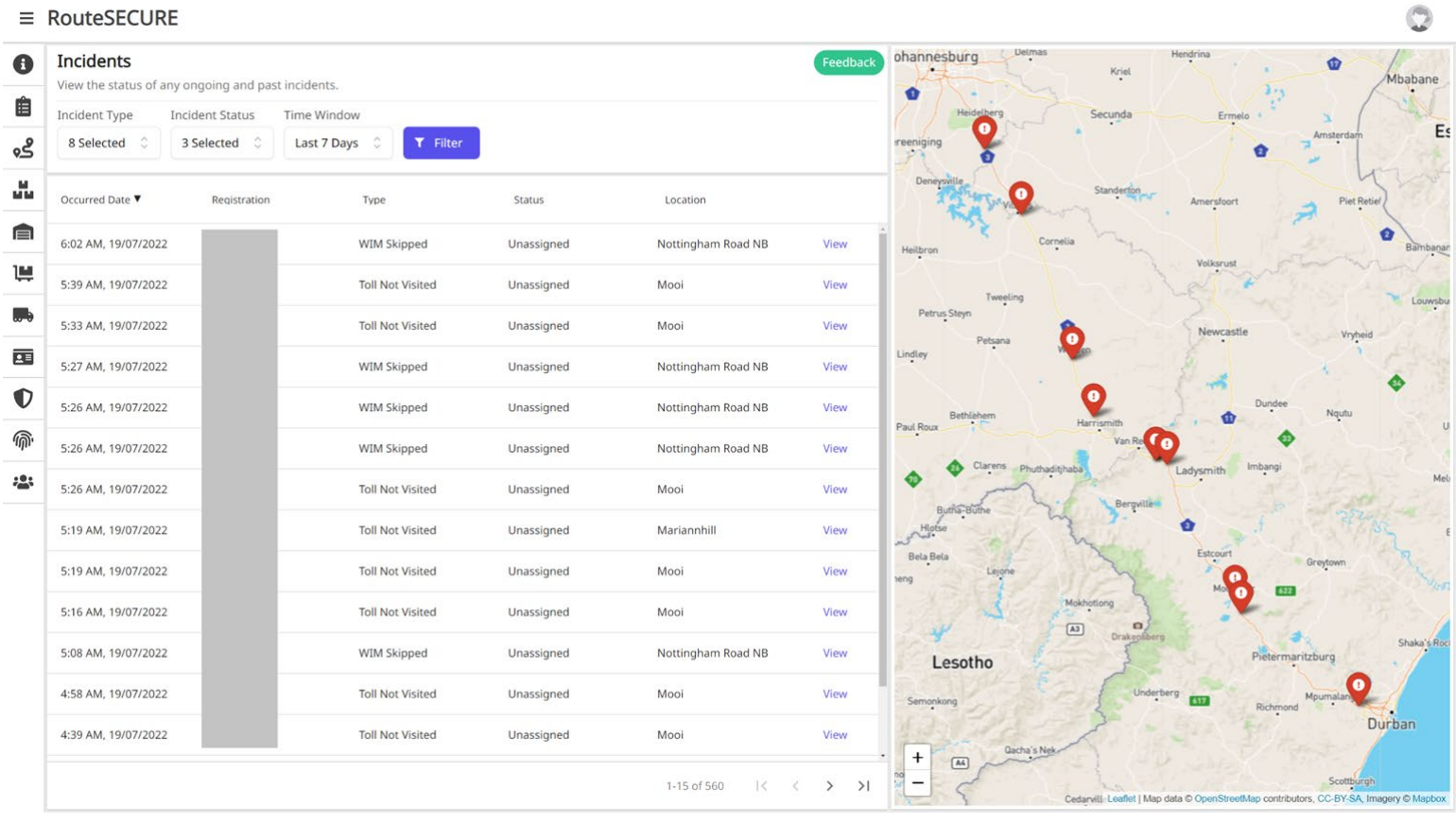


Weighbridge Weight Discrepancies

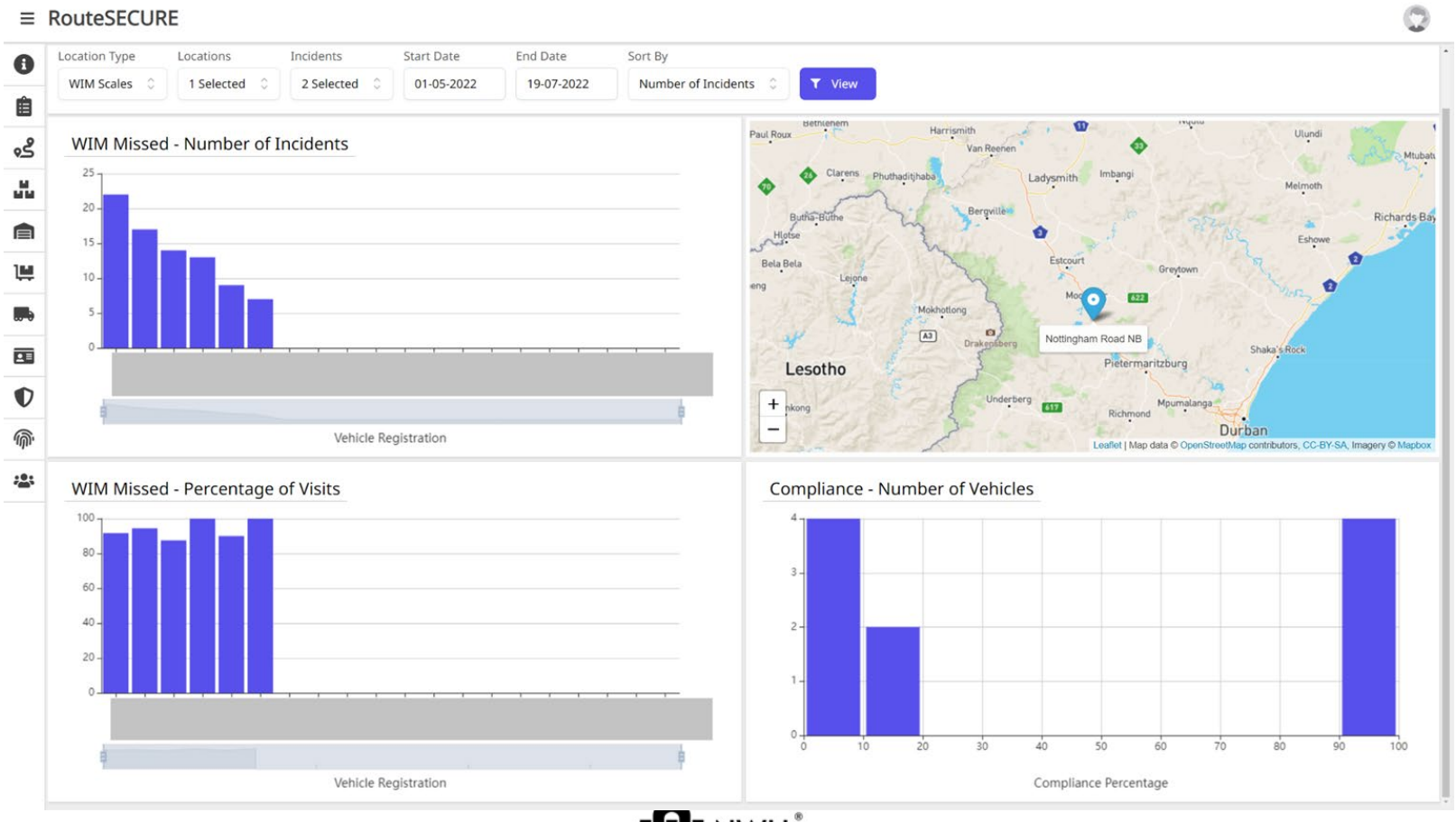
- Drivers involved in Non-Compliant Activities will display higher Weighbridge Weight Discrepancies compared to Legal Drivers
- Drivers evading weighbridges to hide changes in weight due to Non-Compliant activities will have different behavioural profiles from law-abiding drivers



Event Examples:



Statistics Examples



Statistical Results

Non-compliance	WIM	Speeding	Fatigue
Total number of observations	10,718	8,047	8,047
Average observations per vehicle	282	168	168
Total number of incidents	1,552	7,770	298
Average incidents per vehicle	40.8	162	6.2
Incidents as percentage of observation	14.5%	96.6%	3.7%

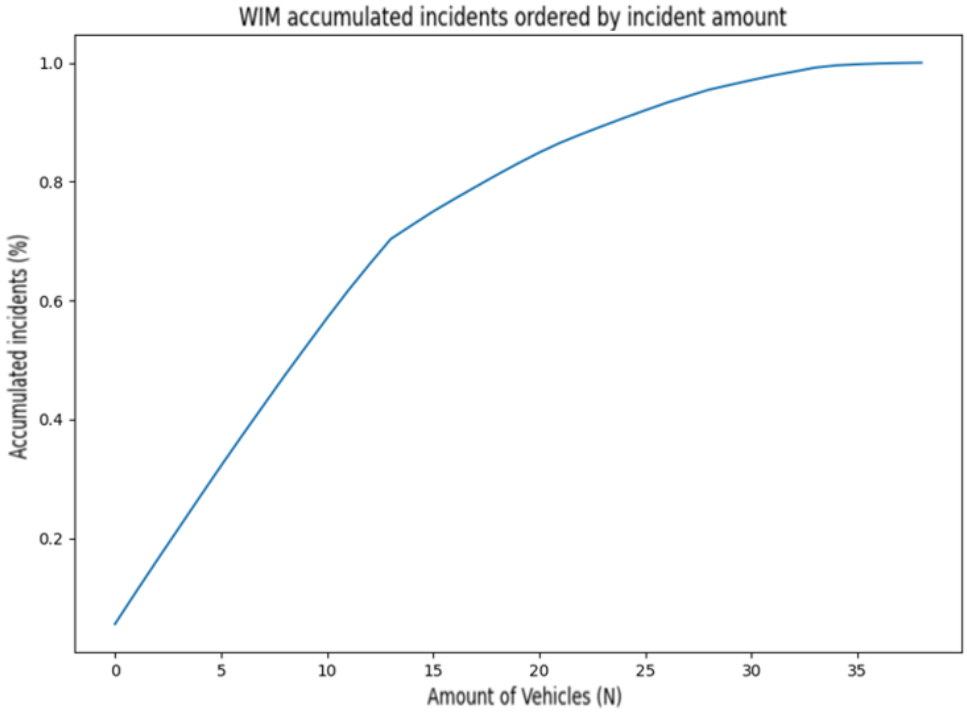
ANOVA Analysis

- ANOVA analysis indicated a clear correlation between the vehicle identity based on number plate and the incidents
- This shows that drivers behave differently and cause differing amounts of incidents
- Results can be used to find outliers that are consistently non-compliant

Incident Type	F-statistic	p-value
WIM non-compliance	8.13	2.99E-54
Speeding	60.5	5.7E-37
Fatigue non-compliance	4.56	7.55E-23

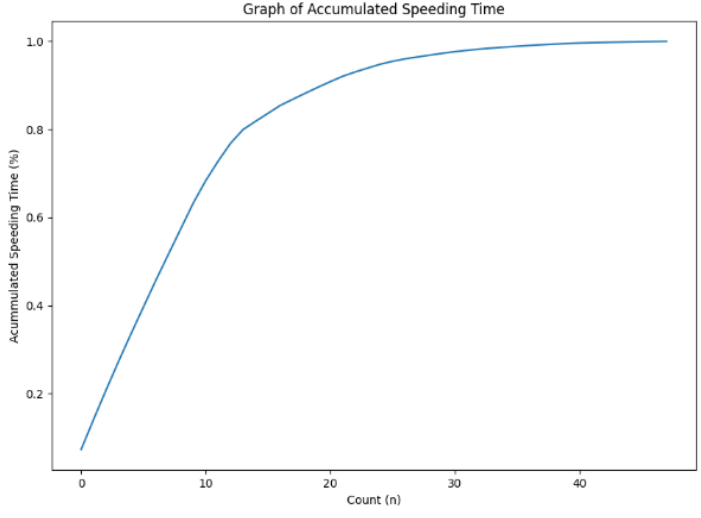
Results: Interpretation

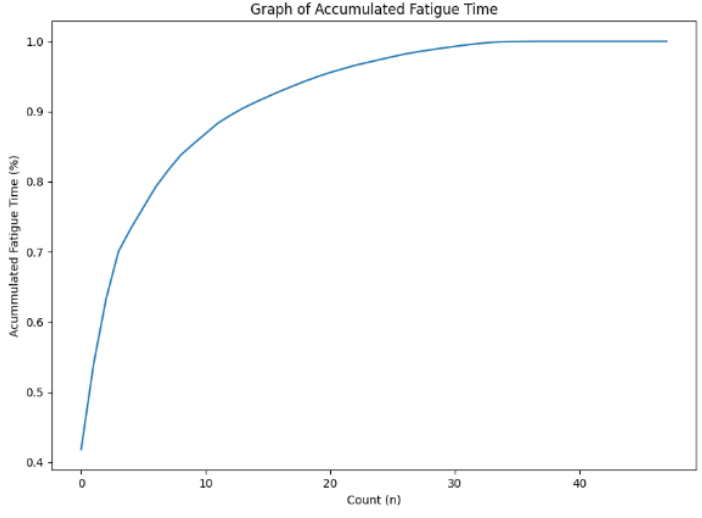
- A small fraction of vehicles caused many safety incidents
- 33% of vehicle (approx. 13 vehicles) were responsible for 66% of incidents
- Identifying these allows the owners to take action against the minority of drivers with high offense levels
- This can decrease the incident rate with minimal impact on normal operations



Results: Interpretation (continued)

- Similar results were obtained for Speeding and Fatigue:
  - 33% of drivers are responsible for more than 80% of over-speed driving time and more than 90% of fatigued driving time





Conclusions

- Truck drivers are involved in a large number of events that have serious safety impacts for other road users
- It is possible to use existing infrastructure to detect such events in real time by combining data from different sources
- As the proposed concept does not require new hardware infrastructure it can be deployed at low cost
- For each aspect of behaviour a variety of event types can be detected, indicating the nature of non-compliant behaviour
- ANOVA provided evidence of a strong relationship between driver identity and non-compliance behaviour. t-statistics indicated that some drivers display extreme non-compliant behaviour
- A minority of drivers are responsible for the majority of detected offenses
- This enables effective action against offenders with minimal impact on commercial operations
- Recommend future work should combine incident data with crash and insurance claims statistics to predict fatalities and insurance losses from observed non-compliant behaviour

Thank you!

Questions and comments welcome…

References

- Anonymous. (2021, July 28). *62% of South African road accidents involve trucks*. Retrieved from South Africa's Freight News: https://www.freightnews.co.za/article/62-south-african-road-accidents-involve-trucks-0
- Batool, I., Hussain, G., Kanwal, N., & Abid, M. (2018). Identifying the factors behind fatal and non-fatal road crashes: a case study of Lahore, Pakistan. *International Journal of Injury Control and Safety Promotion, Vol. 25, No. 4*, 401–407.
- Chen, G., Sieber, W., & Lincoln, J. (2015). NIOSH National Survey of Long-Haul Truck Drivers: Injury and Safety. *Accident Analysis & Prevention, 85(1)*, 66–72.
- Douglas, M. (2009). Commercial motor vehicle driver safety: an application of ethics theory. Texas: University of North Texas.
- G.A.O. (1999). *TRUCK SAFETY: Motor Carriers Office Hampered by Limited Information on Causes of Crashes and Other Data Problems.* Washington, D.C.: United States General Accounting Office.
- *Hijacking of motor vehicles*. (n.d.). (Statistics South Africa) Retrieved February 26, 2022, from http://www.statssa.gov.za
- IET Digital Library. (n.d.). *Author Guide - IET Research Journals*. Retrieved November 27, 2014, from IET Digital Library: http://digital-library.theiet.org/journals/author-guide
- Jabbar, R., Shinoy, M., & Kharbech, M. e. (2019). Urban Traffic Monitoring and Modeling System: An IoT Solution for Enhancing Road Safety. *International Conference on Internet of Things, Embedded Systems and Communications* (pp. 13-18). IEEE.
- Jacob, B., & Feypell-de La Beaumelle, V. (2010). Improving truck safety: Potential of weigh-in-motion technology. *IATSS Research 34*, 9-15.
- Kemp, E., Kopp, S., & Kemp, E. (2013). Six days on the road - Will I make it home safely tonight? Examining attitudes toward commercial transportation regulation and safety. *The International Journal of Logistics Management, 24*(2), 210-229.
- Mahaboon, J. (2014). An Investigation into Factors Influencing Hazardous Materials Truck Crashes in Thailand. *Ph.D. Thesis*. New South Wales, Australia: The University of New South Wales.
- SANRAL. (2017). *SANRAL Annual report 2016.*
- Scott, A., Balthrop, A., & Miller, J. (2020). Unintended responses to IT-enabled monitoring: The case of the electronic logging device mandate. *Journal of Operations Management*, 152-181.
- Zhang, G., Yau, K., & Zhang, X. (2014). Analyzing fault and severity in pedestrian–motor vehicle accidents in China. *Accident Analysis and Prevention, 73*, 141–150.