Investigating the Temporal Evolution of Driving Safety Efficiency Using Data Collected from Smartphone Sensors

Dimitrios I. Tselentis, Eleni I. Vlahogianni, George Yannis
Department of Transportation Planning and Engineering, School of Civil Engineering, National Technical University of Athens, Greece

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Abstract

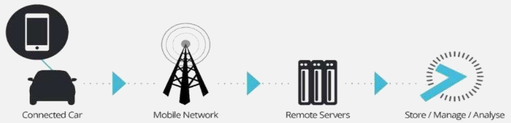
This paper attempts to shed light on the temporal evolution of driving safety efficiency with the aim to acquire insights useful for both driver's and road safety improvement. Data exploited herein are collected from a sophisticated platform that uses smartphone device sensors during a naturalistic driving experiment, at which the driving behavior from a sample of two hundred (200) drivers during 7-months is continuously recorded in real time. The main driving behavior analytics taken into consideration for the driving assessment include distance travelled, acceleration, braking, speed and smartphone usage; these data serve as inputs in the models developed. Various statistical, econometric, optimization and machine learning techniques are applied on data collected to perform the analysis. Initial data analysis results to the most critical components of microscopic driving behaviour, which are used as inputs in the k-means algorithm to perform the clustering analysis. The main driving characteristics of each cluster are identified and lead to the conclusion that there are three main driving groups of the a) moderate drivers, b) unstable drivers and c) cautious drivers.

Introduction

- Driving efficiency is difficult to analyze: We see this as an outcome of a comparative analysis between drivers
- The temporal characteristics of driving efficiency are rarely researched
  - Stationarity
  - Trend
  - Volatility
- Driving profiles identification may link to accident risk
- Far reaching implications to road safety
  - Personal and general feedback to drivers to reduce driving risk
  - Develop insurance pricing schemes (charge premiums based on driving efficiency)

Experiment and data collection

- Continuous recording of driving behavior analytics in real time using a mobile App and a dedicated back-end solution

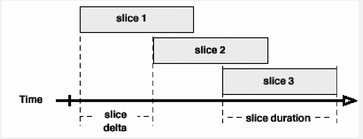


Dataset

- One-hundred (100) drivers
- 8-months driving experiment
- 38,000 trips exploited (60% of trips in urban environment)
- Assessment in each road type separately and in total

Methodology

- Driving safety efficiency is comparatively estimated using the Data Envelopment Analysis technique. The index estimated for each driver represents how risky he was during the period examined.



- Driving efficiency benchmarking in a sliding window
  - driving behaviour changes (volatility measure)
  - driving efficiency time-series analysis
  - time-series decomposition (stationarity, trend, volatility)
  - assessment in each road type separately and in total
- Identifying Driving Profiles with respect to the temporal evolution of driving characteristics with K-means using as inputs:
  - total driving efficiency (aggregately)
  - trend
  - volatility
  - with no accident history

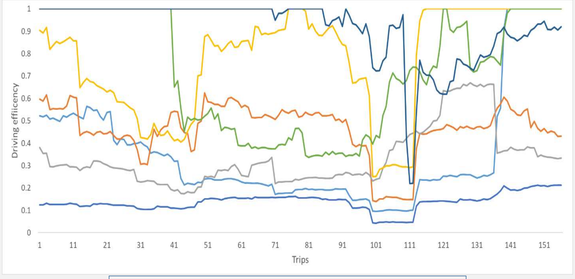


FIGURE 1: Efficiency time series of the anonymous urban sample

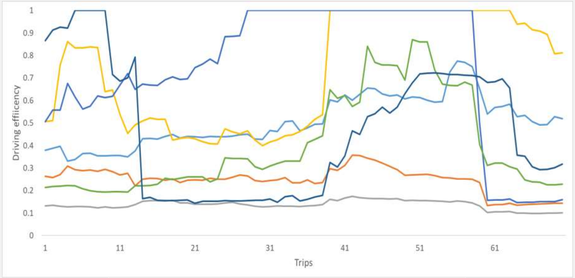


FIGURE 2: Efficiency time series of the anonymous rural sample

TABLE 1: Macroscopic Characteristics of the Drivers' Clusters in urban road

Cluster	Statistical character	Trend (*10-3)	Volatility	Rating
Cluster 1 (79%) (typical drivers)	Min	-1.045	0.066	0.122
	Max	1.686	0.152	0.725
	Average	0.516	0.123	0.340
	Standard Deviation	0.534	0.013	0.108
	Median	0.486	0.124	0.328
	Kurtosis	0.303	4.969	0.944
	Skewness	-0.123	-1.438	0.713
Cluster 2 (13%) (unstable drivers)	Min	2.032	0.066	0.448
	Max	4.085	0.141	1.000
	Average	3.006	0.119	0.673
	Standard Deviation	0.628	0.022	0.206
	Median	3.067	0.125	0.608
	Kurtosis	0.334	-1.815	-2.281
	Skewness	0.209	-1.278	0.732
Cluster 3 (8%) (cautious drivers)	Min	-4.557	0.022	0.367
	Max	0.322	0.122	1.000
	Average	-1.512	0.080	0.746
	Standard Deviation	1.530	0.038	0.263
	Median	-0.937	0.090	0.813
	Kurtosis	-1.027	0.925	-1.154
	Skewness	-1.053	-0.385	-0.237

TABLE 2: Macroscopic Characteristics of the Drivers' Clusters in rural road

Cluster	Statistical character	Trend (*10-3)	Volatility	Rating
Cluster 1 (72%) (typical drivers)	Min	-1.987	0.048	0.127
	Max	3.375	0.228	0.664
	Average	0.764	0.099	0.363
	Standard Deviation	1.040	0.035	0.120
	Median	0.778	0.091	0.356
	Kurtosis	-0.639	2.144	-1.806
	Skewness	-0.252	1.437	0.410
Cluster 2 (12%) (unstable drivers)	Min	-8.785	0.072	0.323
	Max	-1.545	0.379	1.000
	Average	-4.288	0.155	0.716
	Standard Deviation	2.530	0.088	0.246
	Median	-3.811	0.125	0.685
	Kurtosis	0.412	2.323	-0.250
	Skewness	-0.824	1.490	-0.042
Cluster 3 (16%) (cautious drivers)	Min	0.000	0.000	0.483
	Max	8.455	0.306	1.000
	Average	3.904	0.133	0.847
	Standard Deviation	2.573	0.072	0.160
	Median	4.295	0.115	0.880
	Kurtosis	-0.712	1.167	-0.268
	Skewness	0.398	0.789	-0.802

Results

- Least efficient drivers - > least volatile
- Most efficient drivers -> less volatile
- Medium efficiency drivers -> most volatile
- Typical drivers:
  - high number of drivers
  - low total efficiency
  - very low positive trend
  - medium to high volatility
  - low accident frequency (not included in clustering)
- Unstable drivers:
  - medium to high total efficiency
  - medium positive trend
  - high volatility
  - medium to high accident frequency (not included in clustering)
- Cautious drivers:
  - high total efficiency
  - trend
    - medium negative for urban road
    - high positive for express urban road
  - medium volatility
    - low to medium for urban road
    - medium to high for express urban road
  - low accident frequency (not included in clustering)

Conclusions

- Driver Profiles: Typical, Unstable and Cautious drivers
- Temporal evolution of driving behavior with respect to road type:
  - Average volatility is approximately the same in both road types
  - Average trend is approximately the same in both road types
  - Stationarity is similar for all drivers and road types
- Drivers should be continuously monitored and re-evaluated to capture temporal shifts
- Information on driving accident data confirms the conclusions drawn in terms of safety for the clusters formed

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Contact

Corresponding author:
Dr. Dimitrios Tselentis
dtsel@central.ntua.gr