Comparative Evaluation of Driving Efficiency Using Smartphone Data

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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Background

- Driving efficiency evaluation
- Extremely significant in road safety to:
  - identify driving risk parameters
  - quantify their influence on traffic risk
- Several methodologies proposed for driving behavior data collection and analysis
- Most significant parameters associated with driving risk:
  - speeding (SP)
  - mobile phone usage (MU)
  - harsh events (braking, acceleration etc.) (HA, HB)
- Driver's efficiency on a microscopic level has not been studied by making use of DEA techniques

Main objective

- Provide a solid framework for the comparative evaluation of driving efficiency based on Data Envelopment Analysis (DEA)

Research questions

- Is it feasible to measure driver's efficiency?
- How and in how many groups can drivers be categorized based on their efficiency?

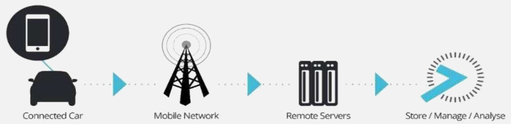
Methodology

- Input-oriented DEA:
  - inputs minimization (recorded driving metrics)
  - maintain the number of outputs (recorded distance)
- Drivers are considered Decision Making Units (DMUs):
  - Provide a relative efficiency measure (Θ_β) to compare different drivers based on driving performance
  - all variables are continuous and quantitative
  - drivers should reduce their mileage and the frequency of driving characteristics
- Python coding:
  - data aggregation
  - DEA models development

Experiment and Data collection

Participants specifications

- > 100 driving hours
- Mileage >0 on all road types (urban, rural and highway)
- Positive input attributes in at least one metric used (i.e. harsh acceleration and braking events, speed limit violation, mobile phone usage)
- Total driving behavior is equal to the sum of the driving characteristics of the period examined
- Continuous recording of driving behavior analytics in real time using a mobile App is employed to:
  - to record user's behaviour exploiting:
    - the hardware sensors of the smartphone device
    - a variety of APIs to read sensor data
  - transmit it to a central database



Dataset

- Fifty-six (56) drivers
- 8-months driving experiment
- 34,060 trips collected
- Table 1 illustrates metrics used
- Assessment in each road type separately and in total

TABLE 1 Variables recorded during the experiment

Variable name	Variable short description
ha_X	number of harsh acceleration events in X road type
ha_{urban}	number of harsh acceleration events in urban road
ha_{rural}	number of harsh acceleration events in rural road
$ha_{highway}$	number of harsh acceleration events in highway
hb_X	number of harsh braking events in X road type
hb_{urban}	number of harsh braking events in urban road
hb_{rural}	number of harsh braking events in rural road
$hb_{highway}$	number of harsh braking events in highway
$speeding_X$	total seconds of speed limit violation in X road type
$speeding_{urban}$	total seconds of speed limit violation in urban road
$speeding_{rural}$	total seconds of speed limit violation in rural road
$speeding_{highway}$	total seconds of speed limit violation in highway
$mobile_X$	total seconds of mobile phone usage in X road type
$mobile_{urban}$	total seconds of mobile phone usages in urban road
$mobile_{rural}$	total seconds of mobile phone usage in rural road
$mobile_{highway}$	total seconds of mobile phone usage in highway
$distance_X$	total distance driven in X road type
$distance_{urban}$	total distance driven in urban road
$distance_{rural}$	total distance driven in rural road
$distance_{highway}$	total distance driven in highway

Results

- Model 1: speed limits violation
- Model 2: mobile phone distraction
- Model 3: driving aggressiveness respectively
- Model 4: overall performance model
- Drivers classification:
  - percentile thresholds of 25% and 75% of Θ_β
  - non-efficient, weakly efficient and most efficient
- Results illustrated are the average values of the:
  - percentage of driving time for SP/ MU
  - events per 100 km driven for HA/ HB

TABLE 2 Driving characteristics of efficiency groups per road type and overall

Model		Efficiency classes: 1: 0 - 25 % percentile	2: 25 - 75 % percentile	3: 75 - 100 % percentile
Urban	1	20.08 % $speeding_{urban}$	11.95 % $speeding_{urban}$	6.51 % $speeding_{urban}$
	2	19.48 % $mobile_{urban}$	6.80 % $mobile_{urban}$	2.31 % $mobile_{urban}$
	3	45.97 ha_{urban} /100km 17.38 hb_{urban} /100km	27.40 ha_{urban} /100km 8.99 hb_{urban} /100km	10.71 ha_{urban} /100km 5.08 hb_{urban} /100km
	4	41.06 ha_{urban} /100km 16.75 hb_{urban} /100km 17.77 % $mobile_{urban}$ 15.79 % $speeding_{urban}$	22.85 ha_{urban} /100km 8.43 hb_{urban} /100km 6.78 % $mobile_{urban}$ 13.02 % $speeding_{urban}$	24.72 ha_{urban} /100km 6.81 hb_{urban} /100km 4.05 % $mobile_{urban}$ 8.66 % $speeding_{urban}$
Rural	1	23.79 % $speeding_{rural}$	14.21 % $speeding_{rural}$	6.33 % $speeding_{rural}$
	2	15.10 % $mobile_{rural}$	5.69 % $mobile_{rural}$	1.64 % $mobile_{rural}$
	3	23.65 ha_{rural} /100km 11.43 hb_{rural} /100km	14.28 ha_{rural} /100km 6.96 hb_{rural} /100km	6.36 ha_{rural} /100km 3.00 hb_{rural} /100km
	4	20.31 ha_{rural} /100km 8.71 hb_{rural} /100km 10.28 % $mobile_{rural}$ 20.58 % $speeding_{rural}$	12.32 ha_{rural} /100km 6.26 hb_{rural} /100km 6.51 % $mobile_{rural}$ 14.49 % $speeding_{rural}$	13.62 ha_{rural} /100km 7.13 hb_{rural} /100km 4.81 % $mobile_{rural}$ 8.97 % $speeding_{rural}$
Highway	1	32.39 % $speeding_{highway}$	13.06 % $speeding_{highway}$	3.98 % $speeding_{highway}$
	2	12.34 % $mobile_{highway}$	3.73 % $mobile_{highway}$	0.74 % $mobile_{highway}$
	3	3.40 $ha_{highway}$ /100km 1.67 $hb_{highway}$ /100km	1.74 $ha_{highway}$ /100km 1.02 $hb_{highway}$ /100km	0.98 $ha_{highway}$ /100km 0.49 $hb_{highway}$ /100km
	4	2.80 $ha_{highway}$ /100km 1.61 $hb_{highway}$ /100km 5.40 % $mobile_{highway}$ 29.31 % $speeding_{highway}$	1.91 $ha_{highway}$ /100km 1.05 $hb_{highway}$ /100km 5.61 % $mobile_{highway}$ 13.08 % $speeding_{highway}$	1.24 $ha_{highway}$ /100km 0.50 $hb_{highway}$ /100km 3.92 % $mobile_{highway}$ 7.01 % $speeding_{highway}$
Overall	1	17.12 % $speeding_{urban}$ 21.25 % $speeding_{rural}$ 24.24 % $speeding_{highway}$	12.50 % $speeding_{urban}$ 14.41 % $speeding_{rural}$ 14.26 % $speeding_{highway}$	8.37 % $speeding_{urban}$ 8.48 % $speeding_{rural}$ 9.72 % $speeding_{highway}$
	2	17.07 % $mobile_{urban}$ 13.30 % $mobile_{rural}$ 9.75 % $mobile_{highway}$	7.22 % $mobile_{urban}$ 5.99 % $mobile_{rural}$ 4.37 % $mobile_{highway}$	3.89 % $mobile_{urban}$ 2.85 % $mobile_{rural}$ 2.05 % $mobile_{highway}$
	3	36.94 ha_{urban} /100km 19.26 ha_{rural} /100km 3.12 $ha_{highway}$ /100km 12.42 hb_{urban} /100km 9.33 hb_{rural} /100km 1.44 $hb_{highway}$ /100km	30.09 ha_{urban} /100km 16.26 ha_{rural} /100km 1.76 $ha_{highway}$ /100km 10.34 hb_{urban} /100km 7.36 hb_{rural} /100km 0.95 $hb_{highway}$ /100km	17.13 ha_{urban} /100km 8.46 ha_{rural} /100km 1.32 $ha_{highway}$ /100km 7.87 hb_{urban} /100km 4.85 hb_{rural} /100km 0.87 $hb_{highway}$ /100km
	4	-	-	-

Results

- Average SP, MU, HA, HB for models 1, 2 and 3 in every road type are reducing while drivers become more efficient
- HA, HB and MU in urban roads are more than in rural and highway and those occurring in rural road are more than in highway
- Regarding SP, drivers of all classes drive over the speed limits approximately the same in urban and rural and more in highway:
  - SP for efficient drivers does not fluctuate and is limited to less than 6.5% in all road types
  - SP for non-efficient drivers ranges between 20% - 32% and
  - 12% - 14% for weakly efficient drivers
- MU for:
  - non-efficient drivers is more than the other two classes averaging at 16%
  - most efficient drivers use it less than 1.5% in average
  - weakly efficient drivers make mobile usage of less than 7%
- Model 3 implies that drivers of all classes have a 2-3 times larger number of HA than HB per 100km of driving
- After the efficiency index and coefficients are estimated for each DMU (driver), the efficient level of inputs and outputs for each DMU can be calculated
- Regarding overall model 4, thirty-eight(38) unit efficient drivers were found and therefore results are not considered significant enough to be presented

Conclusions –Discussion

- Most efficient drivers lie on the efficiency frontier and act as peers for the rest
- Classification of the driving sample based on drivers' comparative efficiency
- Methodology to estimate the optimal level of inputs and outputs for each driver to become efficient
- Most common inefficient driving practices are identified (aggressive, risky driving etc.)
- Results could be exploited:
  - by a smartphone app to provide feedback on the driving characteristics of each driver
  - for insurance pricing based on driving usage and characteristics
- Future research should:
  - center around larger driving samples
  - overcome DEA's sensitivity to outliers and drivers with zero input attributes
  - compare results of per trip and per driver analysis of each driver

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