

# DETERMINANTS OF SAFE AND PRODUCTIVE DRIVING

## EMPIRICAL EVIDENCE FROM LONG-HAUL CARGO TRANSPORT



**Jelle de Vries**

Rene de Koster, Serge Rijsdijk

Debjit Roy

VU University Amsterdam, The Netherlands

Erasmus University Rotterdam, The Netherlands

Indian Institute of Management, Ahmedabad, India

# 1. INTRODUCTION TO TOPIC

Professional drivers face continuous pressure to combine safe driving with productive driving, in a risky environment:

- U.S: approximately 330,000 large truck crashes, 4000 fatalities 104,000 injuries (NHTSA, 2012)
- India: 231.000 traffic fatalities annually (WHO, 2013), 35% of accidents involve heavy motor vehicles (Kanchan et al., 2012)
- Relatively severe consequences

# 1. INTRODUCTION: DETERMINANTS OF ACCIDENTS

- Technology
- Cultural factors
- Infrastructure
- Company characteristics (e.g. incentive system)
- Driver characteristics

# 1. INTRODUCTION: WHY DRIVERS?

- One of the few factors companies can influence
- Shortage of qualified drivers, worthwhile to invest in HR practices
- Bottom-up approach: autonomous safer drivers reduces need for more top down safety regulations.
- Are certain drivers more prone to safe/productive driving behaviour?

## 2. RESEARCH AIMS

Investigating to what extent driving safety and driving productivity are influenced by individual characteristics of the truck drivers:



**Aiding trucking companies in their efforts to increase productivity and safety by taking driver characteristics into account.**

## 2. BIG FIVE INVENTORY AND SAFETY CONSCIOUSNESS

### **Big Five Personality traits**

*Conscientiousness*: persevering, achievement-oriented

*Neuroticism*: insecure, worried, emotional

*Agreeableness*: flexible, tolerant, cooperative

*Extraversion*: assertive, talkative, active

*Openness*: curious, broad-minded, imaginative

### **Safety consciousness**

To what extent are the drivers conscious about avoiding and handling dangers in their truck and on the road?

## 2. RESEARCH ON DRIVER INFLUENCE ON PERFORMANCE

### Safety

- Highly conscientious drivers are involved in fewer accidents because of thorough approach (Arthur and Graziano, 1996)
- Highly extravert individuals are more impulsive (Depue and Collins, 1999)
- More agreeable drivers have lower accident risk and fines due to lower aggression (Cellar et al., 2000)
- Individuals scoring high on openness engage in more sensation seeking (Aluja et al., 2003)
- More neurotic drivers have higher accident risk through stress and aggressive driving (Clarke and Robertson, 2005)

## 2. RESEARCH ON DRIVER INFLUENCE ON PERFORMANCE

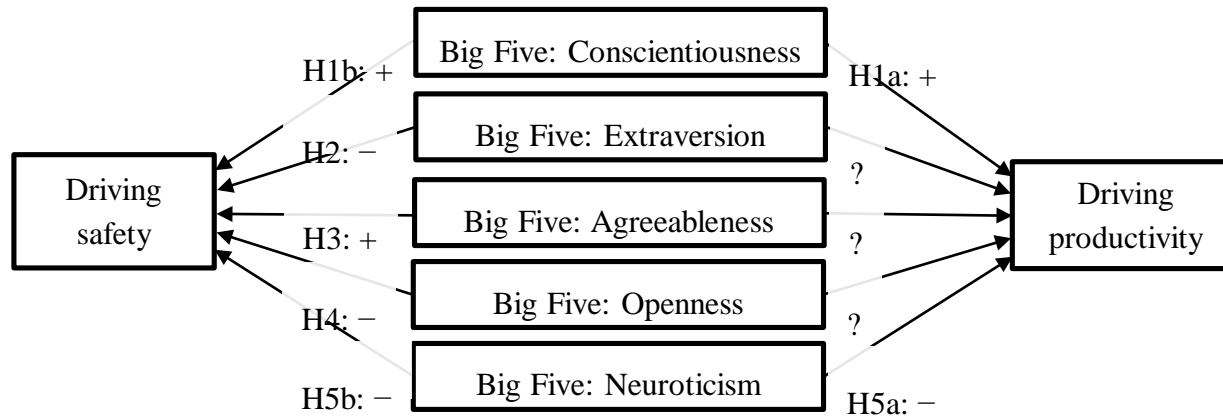
### **Productivity**

- Conscientiousness consistently positively relates to job performance (Barrick et al., 2001).
- Neuroticism consistently negatively relates to job performance (Barrick et al., 2001).

**Methods of existing research?** *Large databases or single-source data*



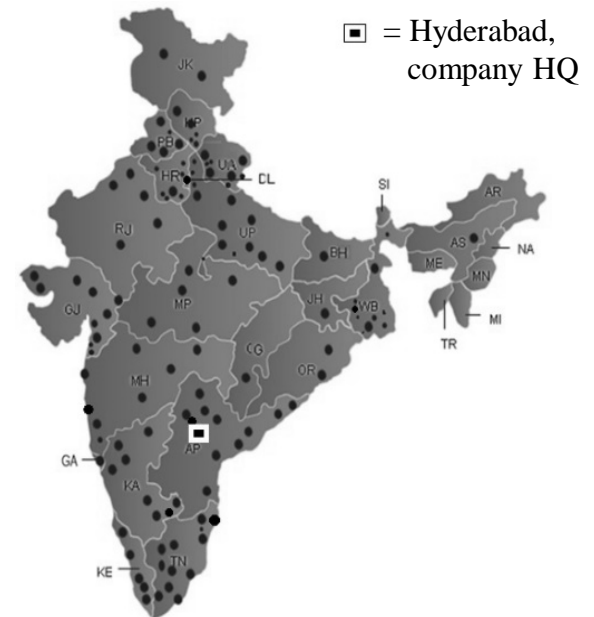
## 2. CONCEPTUAL MODEL



## 3. METHODS

### Combination of data sources:

- GPS data gathered during 370 long-haul trips on 124 routes
  - Every 4 km speed and position recorded
- Survey data of 49 truck drivers
- Data obtained through the enterprise resource planning system.



## 3. METHODS

Outcome measures:

### **Productivity**

- Driving time (no stops included, only truck movement)  
Drivers are incentivized to arrive as early as possible

### **Safety**

- Number of times a driver exceeded 70 km/h (a speed violation for trucks everywhere in India)
- Cumulative duration of exceeding 70 km/h

## 3. METHODS

### Individual characteristics

Safety consciousness (Barling, 2002)

- 7 items on a 5-point Likert scale

Big Five personality traits (Digman, 1990)

- 44 items on a 5-point Likert scale

### 3. METHODS: CONTROL VARIABLES

- Work experience of driver
- Percentage of trip during nighttime
- Origin and destination region of trip
- Average speed estimated by Google Maps (for speed violations)

### 3. METHODS: MULTILEVEL MODEL

Linear mixed effects models with random intercept used to analyze the data to account for multiple observations per driver and hierarchical nature of dataset:

**Driver level:** Individual characteristics of 50 drivers

**Trip level:** On average data measured during 8 trips per driver

$$Y_{ij} = \beta_0 + \beta_1 x_1 + \dots + \beta_k x_k + u_j + e_{ij}$$

Where  $Y_{ij}$  is the inverse of the drive time relative to the Google Maps time,  $j = 1, \dots, N$  are individuals,  $i = 1, \dots, n_j$  are trips,  $k$  is the total number of predictors,  $u_j$  is the random-error per individual, and  $e_{ij}$  is the independent error across all observations.

## 4. RESULTS: DESCRIPTIVES TRIPS

Trip distance: Average = 1,474 km, SD = 7,85 km

Driving time: Average = 2,419 min, SD = 1,250 min

Speed Average = 37 km/h

Total time: Average = 5,816 min, SD = 3,449 min

Speed violations (>70 km/h) per trip: Average = 14.4, SD = 29.41



# 4. RESULTS

## Linear mixed-effects model

### Productivity

- Safety conscious drivers take less time to complete route
- Extravert drivers take more time
- Experienced drivers take more time

Independent variable	Inverse of drive time (relative to Google Maps estimate)		
	Estimate	Std. error	t-value
BFI: Conscientiousness	0.014	0.030	0.48
BFI: Extraversion	<b>-0.067</b>	<b>0.029</b>	<b>-2.31</b>
BFI: Agreeableness	-0.014	0.028	-0.51
BFI: Openness	0.030	0.031	0.95
Work experience as driver	<b>-0.066</b>	<b>0.028</b>	<b>-2.40</b>
Safety consciousness	<b>0.073</b>	<b>0.030</b>	<b>2.43</b>
% distance covered during night	0.023	0.013	1.79
Route Index Central-North	0.094	0.194	0.49
Route Index Central-South	0.085	0.066	1.30
Route Index Central-West	-0.059	0.192	-0.31
Route Index East-East	-0.141	0.120	-1.17
Route Index East-North	-0.201	0.203	-0.99
Route Index East-South	-0.013	0.093	-0.14
Route Index North-Central	0.184	0.197	0.93
Route Index North-North	0.020	0.150	0.14
Route Index North-South	-0.165	0.094	-1.76
Route Index South-Central	<b>0.189</b>	<b>0.066</b>	<b>2.85</b>
Route Index South-East	-0.019	0.095	-0.20
Route Index South-North	-0.003	0.088	-0.03
Route Index South-South	0.022	0.079	0.28
Route Index South-West	<b>0.238</b>	<b>0.092</b>	<b>2.59</b>
Route Index West-South	<b>0.187</b>	<b>0.091</b>	<b>2.05</b>
Length of route (km)	0.011	0.027	0.41
Constant	<b>-0.880</b>	<b>0.075</b>	<b>-11.73</b>
Joint significance fixed effects (Likelihood ratio)		<b>86.9</b>	
Number of drivers		49	
Number of trips		370	

**Bold type = significant at p < .05**



# 4. RESULTS

## Zero-inflated negative binomial mixed-effects model

### Safety

- Conscientious drivers make more speed violations
- Experienced drivers make fewer speed violations

Independent variable	Dependent variable: Number of speed violations (>70 km/h)			Dependent variable: Cumulative duration of speed violations (>70 km/h)		
	Estimate	Std. error	Z-value	Estimate	Std. error	Z-value
BFI: Conscientiousness	<b>0.456</b>	<b>0.178</b>	<b>2.57</b>	<b>0.30</b>	<b>0.151</b>	<b>1.98</b>
BFI: Extraversion	0.058	0.170	0.34	0.00	0.129	-0.04
BFI: Agreeableness	0.014	0.172	0.08	-0.13	0.132	-1.00
BFI: Openness	-0.047	0.188	-0.25	0.02	0.135	0.16
Work experience as driver	<b>-0.421</b>	<b>0.166</b>	<b>-2.53</b>	-0.19	0.139	-1.33
Safety consciousness	0.093	0.179	0.52	0.13	0.139	0.90
% distance covered during night	0.025	0.074	0.33	-0.09	0.129	-0.73
Route Index Central-North	-0.225	1.340	-0.17	-0.05	2.110	-0.02
Route Index Central-South	<b>2.380</b>	<b>0.517</b>	<b>4.61</b>	<b>1.99</b>	<b>0.719</b>	<b>2.76</b>
Route Index Central-West	-22.900	93800	0.00	-19.70	2630	-0.01
Route Index East-East	-24.200	328000	0.00	-22.00	3750	-0.01
Route Index East-North	-22.600	225000	0.00	-28.00	119000	0.00
Route Index East-South	0.993	0.647	1.53	0.32	0.881	0.37
Route Index North-Central	-22.200	181000	0.00	-20.10	3270	-0.01
Route Index North-North	-22.000	59600	0.00	-20.90	3030	-0.01
Route Index North-South	<b>2.560</b>	<b>0.635</b>	<b>4.03</b>	<b>2.48</b>	<b>0.934</b>	<b>2.66</b>
Route Index South-Central	<b>2.130</b>	<b>0.527</b>	<b>4.04</b>	<b>2.14</b>	<b>0.743</b>	<b>2.87</b>
Route Index South-East	0.788	0.712	1.11	0.45	0.826	0.55
Route Index South-North	<b>2.870</b>	<b>0.615</b>	<b>4.67</b>	<b>3.03</b>	<b>0.894</b>	<b>3.39</b>
Route Index South-South	<b>2.160</b>	<b>0.635</b>	<b>3.41</b>	<b>2.43</b>	<b>0.807</b>	<b>3.01</b>
Route Index South-West	<b>2.960</b>	<b>0.667</b>	<b>4.44</b>	<b>3.46</b>	<b>0.815</b>	<b>4.24</b>
Route Index West-South	<b>2.840</b>	<b>0.665</b>	<b>4.27</b>	<b>3.52</b>	<b>0.807</b>	<b>4.37</b>
Length of route (km)	0.194	0.135	1.43	0.26	0.282	0.92
Expected avg. speed Google maps (km/h)	0.689	0.869	0.79	1.56	1.930	0.81
Constant	-1.410	1.130	-1.25	<b>2.66</b>	<b>2.380</b>	<b>1.12</b>
Joint significance fixed effects (Wald $\chi^2$ )		<b>52.3</b>			<b>1533.3</b>	
Number of drivers		49			49	
Number of trips		370			370	

**Bold type = significant at  $p < .05$**

## 4. RESULTS: IMPACT OF SC ON PRODUCTIVITY

	Top 15 safety conscious drivers		Bottom 15 safety conscious drivers		Pairwise comparison	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>F</i>	<i>p</i>
Safety consciousness	4.45	0.05	3.62	0.05	169	<.01
Average driving speed	37.84	0.72	35.2	0.82	5.94	0.02

Comparing top 15 with bottom 15 while controlling for working experience as a driver and percentage of trip distance covered during night time.

drivers scoring high on safety consciousness on average 2.64 km/h (7.5%) faster across all their trips than drivers scoring low on safety consciousness → 181 min faster on average trip

## 4. RESULTS: IMPACT OF CONSCIENTIOUSNESS ON SAFETY

	Top 15 conscientious drivers		Bottom 15 conscientious drivers		Pairwise comparison	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	F	<i>p</i>
Conscientiousness	4.05	0.1	4.63	0.08	15.76	<.01
Speed violations per 100 km driven	1.61	0.23	0.47	0.23	11.26	<.01

Comparing top 15 with bottom 15 while controlling for working experience as a driver and percentage of trip distance covered during night time.

Drivers scoring high on conscientiousness make on average more than 3x as many speed violations (1.61 per 100 km) than drivers scoring low on conscientiousness

## 5. DISCUSSION AND CONCLUSIONS

Higher driver safety consciousness relates to higher productivity

- Avoiding danger required to be productive?
- Drivers better prepared?

Higher driver extraversion relates to lower productivity

- Extravert people thrive best in social environments
- Satisfying the need for interactions through distracting activities (e.g. cell phone use?)

## 5. DISCUSSION AND CONCLUSIONS

Higher conscientiousness among drivers relates to lower safety (more speed violations)

- Pleasing the boss (by arriving early) is more important than sticking to the law?
- Intrinsically pressured to arrive early

## 5. DISCUSSION: LIMITATIONS

- Not controlled for all differences between routes
- Speed violations = unsafe driving behavior?
- Generalizability to other (Western) contexts?
- Generalizability to shorter trips?
- Impact of company structure (management/incentives)

Thank you!