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APPLICATION OF GPS AND QUESTIONNAIRES DATA FOR THE STUDY OF DRIVER BEHAVIOUR ON TWO-LANE RURAL ROADS

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ABSTRACT:

Methodologies based on naturalistic observation provide the most accurate data for studying drivers' behaviour. This paper presents a new methodology to obtain naturalistic data related to drivers' behaviour in a road segment. It is based on the combination of using global positioning system data and drivers' questionnaires. The continuous speed profiles along a road segment and the characteristics of drivers, of their trips and the type of their vehicles can be obtained for a great amount of drivers. It has already been successfully used for several studies, such as the development of models to estimate operating speed profile in two-lane rural road segments; or the characterization of driving styles. These operating speed models have been the key for the development of a new geometric design consistency model, allowing an easier road safety evaluation. Besides, knowledge on the human factors that influence speed choice may be useful for road safety media campaigns and education programs designers, and also for the improvement of intelligent driver assistance systems.

1 INTRODUCTION

Multiple factors typically combine to produce circumstances that lead a vehicle to crash. The main concurrent factors are human factors, roadway environment factors, and vehicle factors. According to the research by Treat et al. [1], human factors are the most prevalent contributing factor of crashes, being present on the 93 % of crashes; followed by roadway (34 %) and vehicle factors (13 %). However, due to its characteristics, it is also the most complicated factor to study. The best results in this area have been achieved by using data collection methodologies based on naturalistic observation. This kind of methodologies is based on subjects driving the way they usually do, in their own vehicles and without any specific instructions or interventions. Projects such as *100-Cars Naturalistic Driving Study [2]*, *SHRP2 Naturalistic Driving Study* [3] and *2 Be Safe* [4] use this data collection methodology.

The first one tracked the behaviour of the drivers of 100 vehicles equipped with video and sensor devices over an 18-month period of time. Its main objective was to provide a high level of detail concerning driver performance, behaviour, environment, driving context and other factors that were associated with critical incidents, near crashes and crashes.

Whereas *100-Cars Naturalistic Driving Study* was focused on drivers' behaviour at crash situations, the central goal of *SHRP2 Naturalistic Driving Study* is the study of how the driver interacts with and adapts to the vehicle, traffic environment, roadway characteristics, traffic control devices, and the environment. It also includes assessing the changes in collision risk associated with each of these factors and interactions.

This research is involving more than 3000 volunteer drivers, who are monitored for a three year period, beginning in 2010.

Both previous research mainly study passenger car drivers' behaviour. *2 Be Safe* aims to understand and characterize powered two wheeler (PTW) rider behaviour. This is the world's first naturalistic riding study involving instrumented PTWs.

In most of that kind of studies, drivers are volunteers who know the scope of the research project, so their behaviour may be biased. Besides, they mainly focus on drivers' behaviour at crash situations, which are rare events.

In traffic psychology, some measures, called 'intermediate measures', are used in order to study drivers' behaviour and understand drivers' perceptions of risk [5]. Those measures characterize changes in behaviour that correlate with objective changes in the driving context. Some examples of those measures are: vehicle speed, headway, overtaking frequency, hand-held cell phone use, and lane-changing frequency.

For characterizing drivers' behaviour, the most studied variable is the speed at which they drive at different road alignment elements (curves, tangents and spiral transitions) and its variations. In order to deal with this issue, it is necessary to collect data from a huge sample of people driving along a sample of elements. Speed data can be obtained by using either spot or continuous collection methodologies.

In most cases, data collection device is a manually operated radar gun or similar [6]. The use of radar gun has three important problems: human error, cosine error and drivers' behaviour affection. Pavement sensors are also used for collecting speed data [7]. Although they address those problems, they only collect data in one location, as well. However, they require the researcher to carry more equipment, require more time to install and remove and may also affect driver behaviour.

Since those methodologies allow only spot speed data collection, the study of deceleration and acceleration phenomenon is not possible. Therefore, several research projects [7] complemented data collection by using lidar guns. This way, speed data is collected in several spots within a road segment. However, even with the use of lidar guns, starting and ending points of deceleration/acceleration cannot be accurately determined.

These deficiencies in data collection may be avoided with other methods based on continuous speed tracking, such as instrumented test vehicles, driving simulators or different methods based on digital video recording and processing. Last one is only suitable for local studies at short road segments.

Some researchers [8, 9] studied the influence of the road geometric characteristics on drivers' behaviour from speed data collected using instrumented vehicles. However, the results may be conditioned by the equipment of the vehicle and the number of observations. Moreover, the sample may be biased, not enough representative of the actual driver's behaviour because volunteers knew the research objectives and they were not used to drive the instrumented vehicle.

Drivers' behaviour may also be biased at driving simulators studies. In fact, the higher speeds in simulator may be due to a lower perception of risk in the simulated road than in the actual road. However, the lower risk in simulator does not restrain the tendency to adopt higher speed on simple road alignments than on complex ones. In order to use a driving simulator as a tool for drivers' behavioural studies, it must be correctly validated [10], though.

The results of those studies may be the key for improving Intelligent Speed Adaptation (ISA) and speed limit credibility. Both of them significantly improve speed behaviour, i.e. they are effective measures to reduce speeding [11, 12].

ISA is an advanced driver assistance system that addresses driving speeding, and it leaves higher-order task control, manoeuvring and navigation to the driver. ISA can be informative, interactive or intervening. Informative ISA only displays the current speed limit continuously and prompts the driver if the speed limit is exceeded. When designing these new devices, the goal is to make them as effective as possible in reducing speed, while at the same time accepted by drivers. To achieve this, it is of great importance that the focus is on the drivers and why they make the decision to speed during their everyday driving [13].

On the other hand, speed limits should provide information to the driver about the speed he/she can drive safely in average conditions [14]. However, setting a limit does not automatically result in the required speed behaviour. One of the reasons for drivers to exceed a speed limit is considered to relate to the credibility of the speed limit. Credibility means that drivers consider a speed limit as logical or appropriate in the light of the characteristics of the road and its immediate surroundings. This is why it is important the study of the relationship between road characteristics and speed choice and the credibility of a speed limit.

This measure especially affects non-ISA users who appear to be more sensitive for the credibility of speed limits than ISA users [12].

2 OBJECTIVES

Considering the shown deficiencies on speed data collection for drivers' behaviour studies, a new data collection methodology has been developed, as an adaptation of usual naturalistic methodologies.

The main objective is getting naturalistic data in order to study drivers' behaviour in a road segment.

The researchers should be able to get enough sample size of drivers along road segments.

Collected data should be both drivers' individual continuous speed profile along a road segment and data related to their social conditions, trip characteristics and vehicle type.

Besides, data collection should not be the cause of drivers' behavioural change, so that it may be considered as naturalistic data collection methodology.

3 METHODOLOGY

This section describes the application of developed data collection methodology on ten two-lane rural road segments located in the region of Valencia (Spain). Data about the path and the continuous speed profile of actual drivers, their social characteristics, their trip characteristics and the type of their vehicles were obtained.

3.1 Data collection

For data collection, two checkpoints were located at the beginning and at the end of each road segment, controlling both directions. Two or three people controlled each checkpoint. At each one, two members were at the starting point, while the other one was at the final point. The general diagram of the data collection system is presented in figure 1.

When there was an incoming vehicle, one member of the checkpoint team stopped it and asked the driver about collaboration in the research project, emphasizing that he/she was part of the University. In order to avoid data biasing, the scope of the research was not explained at the beginning. After driver's agreement, he/she was asked about some general questions about his/her driving experience, previous knowledge of the road segment and the purpose and length of the trip. Another member of the group placed a 1 Hz GPS device on the vehicle and wrote down some data, such as the number of passengers or the type of vehicle. Driver was also encouraged to not change his/her usual driving behaviour.

This process took around 1-2 minutes. After this time period, driver was allowed to continue along the road segment.

When the vehicle arrived to the final checkpoint, a member of the team took the GPS device out of the vehicle and asked the driver some questions about his/her perception of the road segment. At this point, the driver was informed about the research project, by means of a leaflet, in order to be as fast as possible and not slow the traffic down.

This data collection methodology was implemented on ten two-lane rural road segments with no main intersections and with high lateral clearance. The general road segment characteristics are summarized in Table 1.

All the selected roads are characterized by traffic volumes low enough to reduce the potential for restricted vehicle flow but sufficient to ensure a significant sample size. On average, 180 drivers were considered for each road segment. The total data sample of the research project was 11877 vehicles·km.

The data collection was carried out during working days, between approximately 8:30 a.m. and 2:00 p.m. under dry weather conditions. The duration of each data collection depended on the AADT of the corresponding road segment and the amount of data needed. It was also needed to consider at least one hour before and after the test in order to set and pick up all the equipment placed on the road.

A provision of GPS devices was always needed at both checkpoints. Depending on the traffic flow balance by direction, at some moments it was needed to transport devices between checkpoints, in case of lack of devices at one checkpoint.

Some additional equipment was needed in order to perform the test, besides of GPS devices. Some traffic sign and guidance elements had to be used for warning drivers about the presence of the checkpoints. A safe area was created at each checkpoint for allowing their members to work safely. They also wore safety vests.

3.2 Naturalistic data test

GPS devices contain the information about position and speed of all drivers along the road segment under study. The main goal of this field data collection is to obtain accurate, naturalistic and disaggregated data from actual drivers. Thus, it is important to ensure that drivers perform their driving task without being influenced by the presence of GPS devices, by means of a naturalistic data test.

The test was carried out during the first two field data collections, comparing data obtained from drivers who were driving the day of the experiment and drivers who were driving the day before the experiment. Speed data from both types of drivers was obtained at the same spots. Those locations were a sharp curve and a long tangent at each road segment. A sharp curve is a control element where road geometric characteristics have great influence over driver speed choice; whereas a long tangent is an element where driver may reach his/her desired speed. So, speed at those locations may be assumed as speed boundaries.

Some video cameras were set closed to the roadside, hidden from driver's vision. They were recording the traffic flow in order to calculate the speed of individual drivers. In order to perform speed calculation, two pairs of references were located at each control element (Figure 2). Those references were spaced a known distance. Thus, knowing the distance between references and the time the vehicle spent on going from one to the other, it was possible to calculate vehicles' individual speeds.

Individual operating speeds of drivers involved and not involved in the field data collection was compared, for checking if they were influenced by the presence of GPS devices. The analysis was performed by means of least significant difference (LSD) intervals. As the intervals overlap, the population means are not significantly different from each other at the 95 % confidence level. Consequently, no statistical difference was found between people driving the data collection day (with GPS) and other day (without GPS) [15].

Recorded traffic was also used for determining the operating speed at those spots. By comparing speeds obtained from video cameras and GPS devices at the same moment, data obtained from last ones was validated.

3.3 Free-flow conditions test

In order to analyse the influence of the infrastructure over drivers' behaviour and to characterize driver groups from their speed choice, involved vehicles are supposed to drive at free-flow conditions. This study defines free-flow conditions as those of isolated vehicles with a minimum headway of at least 5 seconds. It is assumed that vehicles with shorter headways might be constrained by a lead vehicle.

During data collection, vehicles were released from the initial point of the road segment at free flow conditions, but they might be disturbed by other vehicles along the road segment. In this case, there was not a simple way for determining if the registered data was under free or non-free flow conditions. Thus, a methodology was developed in order to determine the road segment where a driver drove under non-free flow conditions.

From GPS data treatment different continuous speed profiles are available: individual speed profile for each single driver and every continuous profile corresponded to every percentile of speed distribution. The free-flow conditions test consists on those profiles comparison.

It is supposed that each single driver behaves in a particular way, approaching his/her individual speed profile to certain operating speed percentiles. This behaviour was observed under free-flow conditions, but the difference between profiles increased when the driver was disturbed due to traffic flow. Therefore, for each individual speed profile, a non-free flow road section may be identified by means of comparing different aggregated speed percentiles profiles and individual speed profiles.

Figure 3 shows an example of a vehicle constrained by a lead one. It is clear that around the point station 4000 m the vehicle suddenly changed its behaviour, driving at an unusual speed. This road segment of the individual speed profile was therefore not considered in the study.

4 APPLICATIONS

Described data collection methodology allows us to obtain data on several road segments of vehicle paths, individual continuous speed profiles, social characteristics of drivers, of their trips and the type of their vehicles. These data are the base for performing new and more accurate research.

4.1 Operating speed profile models for geometric design consistency evaluation

Geometric design consistency has an important influence over road safety because it refers to the conformance of highway geometry to driver expectancies. The main technique for design consistency evaluation is the examination of the operating speed, defined as the 85^{th} percentile of speed distribution, and its variations. A continuous operating speed profile is needed. However, during road design phase operating speed can only be estimated as a function of the roadway geometric characteristics.

Several models have been developed to predict operating speed at curve and tangent sections, and some research has been carried out to study deceleration and acceleration phenomena. Most of them were based on spot speed data collection [16, 17, 18, 19]. Therefore, some hypotheses had to be made in order to develop operating speed profiles construction rules, such as considering constant speed at curves. Besides, spot speed data collection is only able to determine the speed at two previously located spots. Thus, for determining deceleration and acceleration rates, the length of the transition zone is unknown and it had to be assumed constant for all drivers.

This new methodology addresses these problems. The continuous operating speed profiles help the researchers to check the behaviour of all drivers at different alignment elements, so the previous hypotheses can be considered or rejected based on naturalistic data consideration. Also, deceleration and acceleration lengths are known for all individual drivers, so more accurate analysis can be done.

Taking into account these considerations, it can be concluded that operating speed and deceleration/acceleration rates models calibrated from continuous naturalistic speed data fit better drivers' behaviour than those based on spot data do.

According to this assumption, operating speed models for tangent and curve sections have been developed based on operating speed profiles. Besides, other models have been calibrated for estimating the 85^{th} percentile of deceleration/acceleration rates, instead of the deceleration/acceleration rate from 85^{th} percentile speed profile [5].

Those models have been the key for the development of a new geometric design consistency model [20]. It allows the estimation of the crash rate of a road segment. Thus, this data collection methodology has turn into a tool for road safety evaluation on both road design phase and operation phase.

4.2 Human factors analysis

As a result of data collection and treatment, individual continuous speed profile is available for each single vehicle and for each road segment. Besides, the different questions asked to drivers before and after the test allow the characterization of some variables, such as: driver's characteristics (age, gender, driving experience); characteristics of the trip (distance, regular or not, number and type of passengers); and vehicle type.

Therefore, it is possible to study the relationship between both types of variables, instead of performing an aggregated analysis. The obtained results may be used for studying: drivers' speed perception; driving styles characterization; and consistency of drivers' behaviour among elements, among road segments and along the time. It may also be the base for the validation of driving simulators that have the purpose of drivers' behaviour study.

The analysis about the influence of those variables over the developed speed on tangent sections has already performed, based on a sample of 78 tangents and 6133 driver·tangents, since one driver might drive along several tangents. This analysis consisted on a multifactor ANOVA, e.g. a multifactor analysis of variance, for the variable *Speed*, considering:

- *Driver Age*: this variable was divided into 5 years intervals.
- *Driver Sex*: it was divided into man and women.
- *Driver Experience*: it measured the amount of kilometres driven by each driver in the last year.
- *Passenger*: this variable considered the presence of passenger inside the vehicle, taking into account if they were children, adult or elderly people.
- *Trip Frequency*: it identified whether the trip was regular or not.
- *Trip Length*: the trip length was classified into short, medium and long distance trip. It was also included if the trip was a professional route.
- *Trip Purpose: it identified whether the purpose of the trip was work or not.*
- *Vehicle Type*: the considered vehicle types were light truck, van, minivan, all-terrain and passenger car.

The ANOVA analysis decomposed the variability of the variable *Speed* into the contributions due to the different factors. It measured the contribution of each factor having removed the effects of all other factors. The ANOVA results showed that all factors, apart from *Trip Purpose*, presented p-values less than 0.05, so those factors had a statistically significant effect on *Speed* at the 95 % confidence level.

In order to characterize the effect of each factor on the developed speed on tangents, several LSD intervals were performed. They allowed significant differences identification among variables at the 95 % confidence level, and forming groups of means within which there were no statistically significant differences.

Figure 4 shows the plotted LSD intervals for the study of the effect of the driver related factors on the developed speed on tangents.

Considering the age of the drivers, 5 groups can be identified: 18-21, 21-25, 26-55, 56-75, >76. Drivers tend to increase their speed after getting the driving licence and they tend to gradually decrease it after being 26 years old.

On the other hand, men tend to drive faster than women, and also do it drivers with higher driving experience.

Figure 5 shows the plotted LSD intervals for the study of the effect of the trip related factors on the developed speed on tangents. Drivers tend to drive faster when their trips are regular. It is probably due to the fact that they know the road characteristics. Higher speeds have also been found out when the driven distance was long.

The factor related to the amount of passengers inside the vehicle has also been identified as significant. Drivers develop higher speeds when they drive alone than when they are accompanied, especially by elderly people (Figure 6).

The *Vehicle Type* factor, as well as *Driver Age*, presented different groups (Figure 7). Three groups can be detected: light truck, van and the group consisted of minivan, passenger car and all-terrain. The recorded speed was higher for the last group.

In summary, men drive faster than women, and the older the driver is the slower he/she drives. Driver's experience is also a significant variable, so people with less driving experience drive slower. Besides, people drive faster in a regular trip and/or when they are alone in the car. These conclusions are similar to those obtained by previous studies [21, 22, 23].

This is an initial approach to drivers' behaviour on tangents. An additional multivariate analysis is necessary because of correlations among the independent variables which may give rise to confounding of effects.

Other developed research focused the study of drivers' behaviour on the variations of deceleration and acceleration [24, 25]. With data obtained from the proposed data collection methodology it has also been performed the analysis about the influence of the variables non related to the infraestructure over the deceleration and acceleration. In that case, almost none variable was significant, so, according to the results, deceleration and acceleration may not be considered as a variable for drivers' behaviour characterization.

The knowledge of the influence of those data about drivers' behaviour may be useful for road safety media campaigns and education programs designers, but also for the improvement of intelligent driver assistance systems.

5 CONCLUSIONS

An adaptation of previous naturalistic data collection methodology has been developed for studying drivers' behaviour on two-lane rural roads. This methodology consists on getting continuous speed profiles of actual drivers by placing on their vehicles GPS devices. Besides, data related to the social characteristics of the driver, the purpose of his/her trip and the type of his/her vehicles are obtained from questionnaires taken during the test.

This data collection methodology was implemented on ten two-lane rural road segments, involving an average of 180 volunteers per test, considering both road directions. The total data sample of the research project was 11877 vehicles·km.

In order to test if this data collection can be considered as naturalistic, a comparison analysis was carried out between spot speed data registered a day before data collection and spot speed data recorded during data collection. Results showed that there are no significant differences between both data.

With data obtained from the new data collection methodology, aggregated (speed percentiles) and disaggregated (driver individual data) analysis may be performed. In fact, it was successfully used in order to calibrate the models and construction rules for getting continuous operating speed profile of a two-lane rural road segment. Those models, based on aggregated data, allow road design consistency evaluation and road safety improvement.

For this kind of analysis it is necessary to ensure free flow conditions. Therefore, a procedure was developed in order to remove from the collected data all individual speed-constrained sections. This procedure is based on the comparison of individual speed profiles and percentiles speed profiles.

On the other hand, disaggregated data were used for studying the influence of driver's characteristics and the characteristics of trip and the vehicle on chosen speed and deceleration/acceleration rates.

Therefore, this data collection methodology turns into a new tool for drivers' behaviour and road design evaluation.

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7 REFERENCES

1. Treat, J. R., Tumbas, N. S., McDonald, S. T., Dhinar, D., Hume, R. D., Mayer, R. E., Stansifer, R. L., and Castellan, N. J.: ‘Tri-level Study of the Causes of Traffic Crashes: Final report—Executive Summary’, Report No. DOT-HS-034-3-535-79-TAC(S). Institute for Research in Public Safety, Bloomington, IN, 1979.
2. Dingus, T. A., Klauer, S.G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knipling, R.R.: ’The 100-car naturalistic driving study; Phase II- Results of the 100-car field experiment’, Report No. DOT HS 810 593. Virginia Tech Transportation Institute, Blacksburg, VA, 2004.
3. http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Public/Pages/The_SHRP_2_Naturalistic_Driving%20Study_472.aspx, accessed September 2012.
4. http://www.2besafe.eu/, accessed September 2012.
5. Fourie, M., Walton, D., and Thomas, J.A.: ‘Naturalistic observation of drivers’ hands, speed and headway’, Transportation Research Part F: Traffic Psycology and Behaviour, vol. 14, 2011, pp. 413-421.
6. Gibreel, G. M, Easa, S. M., and El-Dimeery, I.A.: ‘Prediction of operating speed on three-dimensional highway alignments’, Journal of Transportation Engineering, 2001, pp. 21-30.
7. Fitzpatrick, K., and Collins, J.: ‘Speed-profile model for two-lane rural highways’, Transportation Research Record, vol. 1737, 2000, pp. 42-49.
8. Yang, L., and Hassan, Y.: ‘Driver speed and acceleration behavior on Canadian roads’, 87th Annual Meeting of the Transportation Research Board, Washington, D.C., USA, 2008.
9. Hu, W., and Donnel, E.T.: ‘Models of acceleration and deceleration rates on a complex two-lane rural highway: results from a nighttime driving experiment’, 87th Annual Meeting of the

Transportation Research Board, Washington, D.C., USA, 2008.

10. Bella, F.: 'Driving simulator for speed research on two-lane rural roads', Accident Analysis and Prevention, vol. 40, 2008, pp. 1078-1087.

11. Van Nes, N., Houtenbos, M., and Van Schagen, I.: 'Improving speed behaviour: the potential of in-car speed assistance and speed limit credibility', IET Intelligent Transport Systems, Special Issue – selected papers from HCD 2008.

12. Van Nes, N., and Van Schagen, I.: 'Opportunities to improve speed behavior: Credibility of speed limits and the use of ISA', Advances in Transportation Studies, vol. 20, 2010, pp. 39-46.

13. Warner, H.W., and Aberg, L.: 'Drivers' decision to speed: A study inspired by the theory of planned behavior', Transportation Research Part F: Traffic Psycology and Behaviour, vol. 9, 2006, pp. 427-433.

14. Goldenbeld, C., and Van Schagen, I.: 'the credibility of speed limits on 80 km/h rural roads: The effects of road and person(ality) characteristics', Accident Analisys and Prevention, vol. 39, 2007, pp. 1121-1130.

15. Pérez-Zuriaga, A.M, García García, A., Camacho-Torregrosa, F.J. and D'Attoma, P. "Modelling operating speed and deceleration on two-lane rural roads with global positioning system data". Transportation Research Record, vol. 2171, 2010, pp. 11-20.

16. Lamm, R., Psarianos, B., and Mailaender, T.: 'Highway design and traffic safety engineering handbook'. McGraw-Hill, New York, 1999.

17. Ottesen, J.L., and Krammes, R.A.: 'Speed profile model for a design consistency evaluation procedure in the United States', Transportation Research Record: Journal of the Transportation Research Board, vol. 1701, 2000, pp. 76-85.

18. Fitzpatrick, K., and Collins, J.M.: 'Speed-profile model for two-lane rural highways', Transportation Research Record: Journal of the Transportation Research Board, vol. 1737, 2000, pp. 42-49.

19. Park, P.Y., Miranda-Moreno, L.F., and Saccomanno, F.F.: 'Estimation of speed differentials on rural highways using hierarchical linear regression models', Canadian Journal of Civil Engineering, vol. 37 (4), 2010, pp. 624-637.

20. Camacho-Torregrosa, F.J., Pérez-Zuriaga, A.M, and García García, A. "New geometric design consistency model based on operating speed profiles for road safety evaluation". 3rd Road

Safety and Simulation Conference, Indianapolis, USA, 2011.

21. Wasielewski, P.: ‘Speed as a measure of driver risk: observed speeds versus driver and vehicle characteristics’, Accidents Analysis and Prevention, vol. 16 (2), 1984, pp. 89-103.
22. Jorgensen, F., and Polak, J.: ‘The effect of personal characteristics on drivers’ speed selection. An economic approach’, Journal of Transport Economics and Policy, 1993, pp. 237-252.
23. Williams, A.F., Kyrychencko, S.Y, and Retting, R.A.: ‘Characteristics of speeders’, Journal of Safety Research, Vol. 37, 2006, pp. 227-232.
24. Lajunen, T., Karola, J., and Summala, H.: ‘Speed and acceleration as measures of driving style in young male drivers’, Perceptual and Motor Skills, vol. 85, 1997, pp. 3-16.
25. Wahlberg, A.E.: ‘Speed choice versus celeration behavior as traffic accident predictor’, Journal of Safety Research, vol. 37, 2006, pp. 43-51.

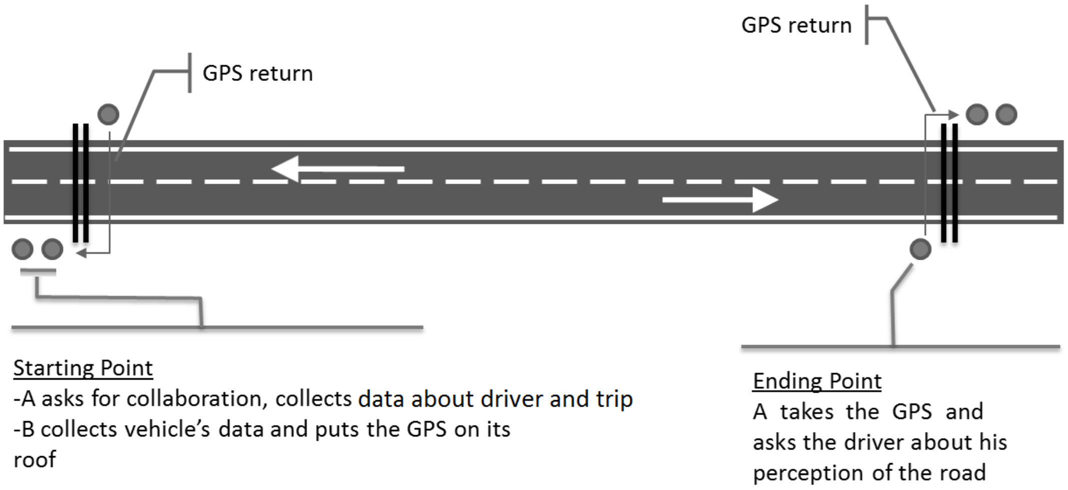


Figure 1. Data collection diagram

Figure 2. References for naturalistic data test

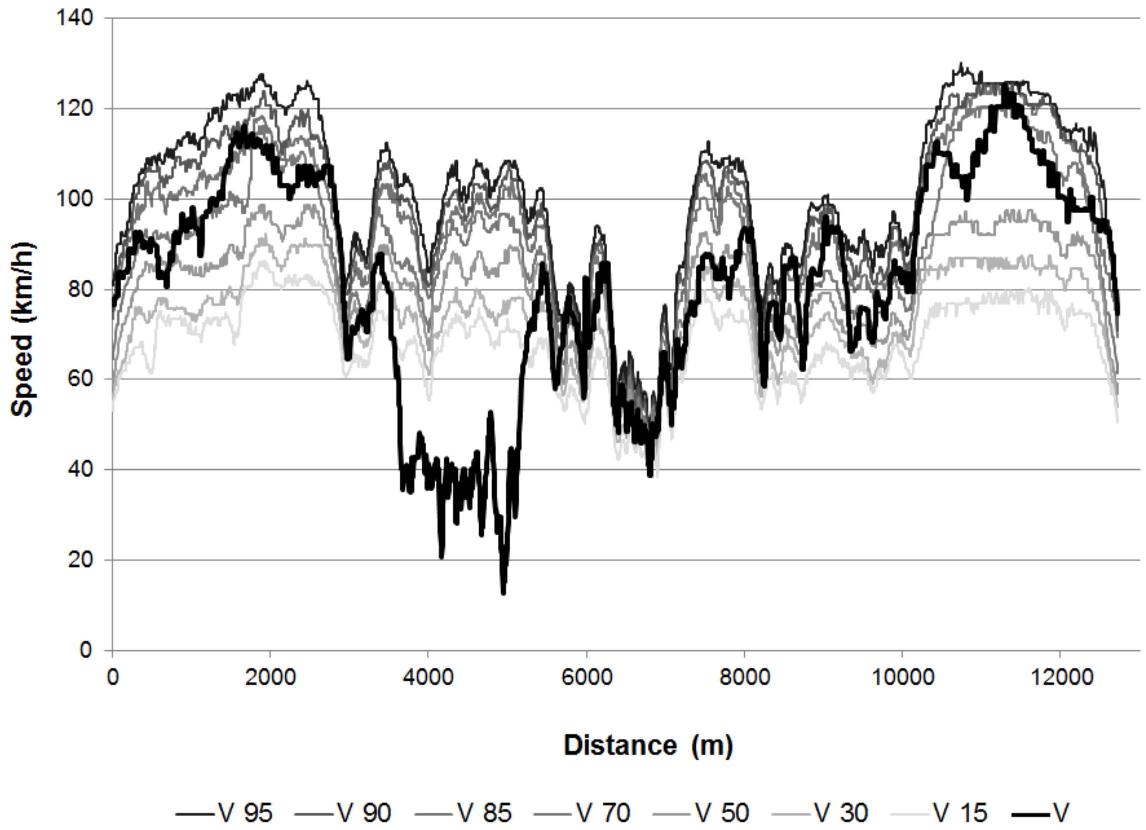


Figure 3. Free-flow conditions test

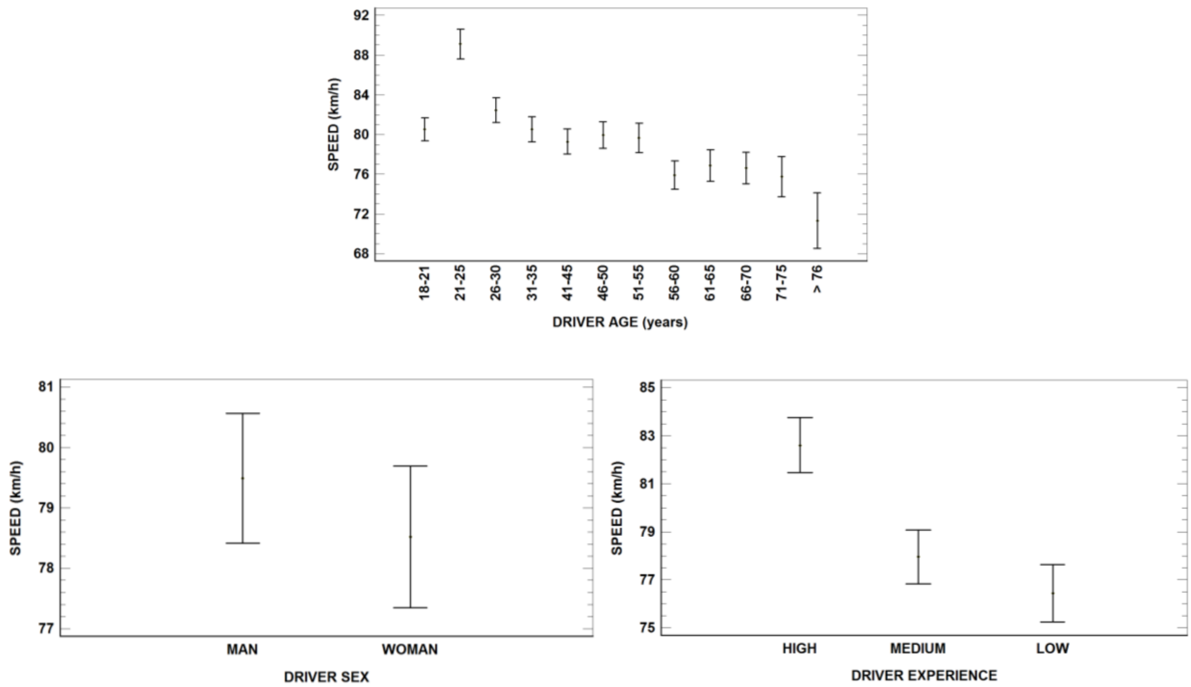
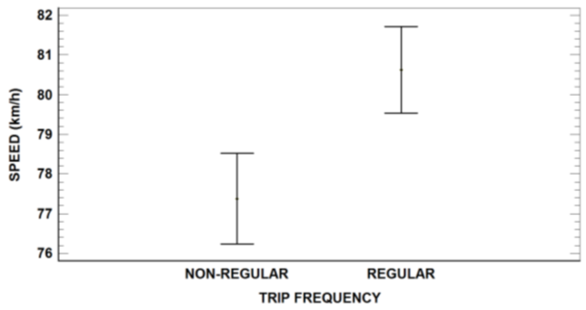


Figure 4. Means and 95 % LSD intervals. *Driver Age, Driver Sex* and *Driver Experience*



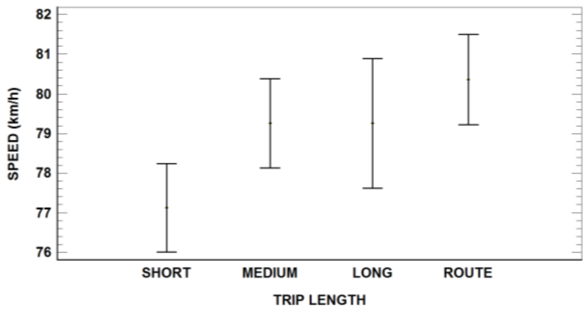


Figure 5. Means and 95 % LSD intervals. *Trip Frequency* and *Trip Length*

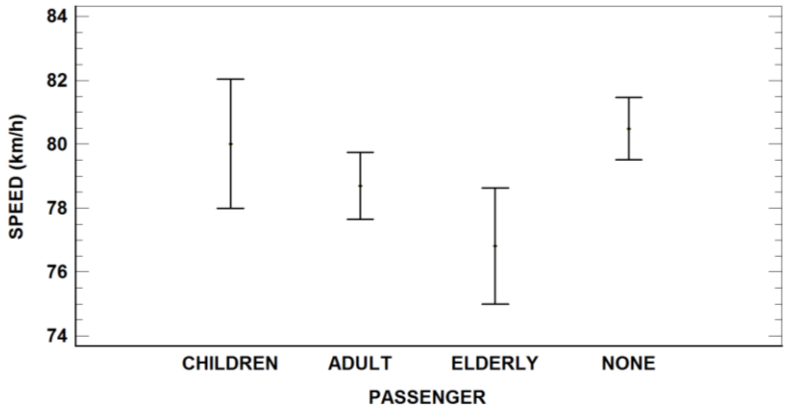


Figure 6. Means and 95 % LSD intervals. *Passenger*

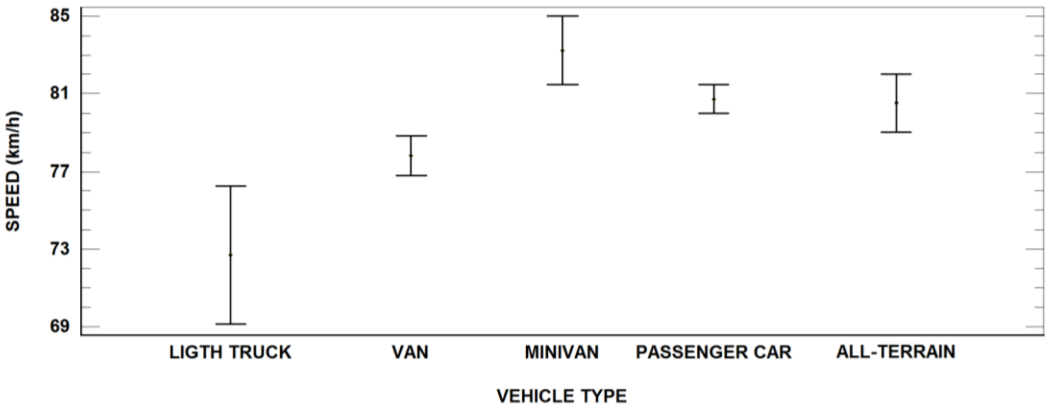


Figure 7. Means and 95 % LSD intervals. *Vehicle Type*

ID	Road segment	Road segment length (km)	Estimated AADT (vpd)	Forward direction observations	Backward direction observations
1	CV-35	13.40	860	70	90
2	CV-35	8.20	2257	121	120
3	CV-333	5.10	2419	101	89
4	CV-50	5.70	4852	116	96
5	CV-372	4.50	4149	77	117
6	CV-305	4.40	6086	112	105
7	CV-370	8.30	2523	61	79
8	CV-401	6.00	5292	102	91
9	CV-376	6.70	2656	58	53
10	CV-310	4.70	6809	74	58

Table 1. Summary of road segment characteristics