Drivers Behavior In Interchange Ramps Depending On Their Age, Vehicle Type And Vehicle Age

Trakakis E. Antonios[1], Apostoleris Konstantinos, Psarianos Basil

National Technical University of Athens (NTUA), School of Rural and Surveying Engineer
9 Iroon Polytechniou Str., GR-15780, Athens, Greece,
Email Author 1: atrakakis@mail.ntua.gr
Email Author 2: kapostol@central.ntua.gr
Email Author 3: bpsarian@mail.ntua.gr

Abstract

During 21st century road safety studies have intensified more than ever, because of vehicles evolution mainly. Nowadays every newer vehicle can reach higher velocity and offer a greater sense of safety to its driver, due to technological development of the automotive industry. Therefore, high velocity values are simply applied by almost all drivers, as the sense of safety offered by vehicle can lead to the illusion of moving at a lower velocity, compared to the actual one.

Most studies concern road networks and a lower percentage concerns interchanges or intersections. In the present study, velocity within an interchange curve is recorded and related with drivers age group and vehicle type and age for 4 interchanges and specifically for 6 horizontal curves in total. Furthermore, the investigated ramps include trumpets, and clover and diamond sections.

This research aims to clarify the effect of vehicle type, vehicle age and driver age on driving behavior, with direct application to the Greek reality. The difference as compared to previous Greek studies is the fact that the present research is conducted in interchanges, where the level of driving difficulty increases and the aggressive behavior is easier to be detected and investigated, based on the aforementioned factors.

Hence a main aim is the clarification of the range of velocities that can be applied in interchange ramps of different radii, by drivers of different age, by different vehicle types and by different vehicle ages and at the same time it is desirable to be investigated the criticality of the above factors in driving behavior. There is not much research in the literature (and specifically for interchanges) that examines the speed profiles of drivers of different ages and vehicles of different types and ages.

Additionally, by investigating the velocities based on the age of driver, is desirable to be examined whether younger drivers (age group that appears a significant number of deaths) apply higher velocities in interchanges compared to the velocities applied by the other age groups in question. Causality is therefore sought and speed profiles can be a first step towards new conclusions. Comparatively with the researches for interchanges worldwide, this research can determine -with considerably accuracy- the velocity within the ramp, as the velocity data collected every 0.01 second.

Observing the results, into most of the examined ramps, younger drivers move much faster than the older ones and feel more safe during their transition from the tangent to the curve of ramp, drivers of larger vehicles apply higher velocity than the drivers of other vehicle types and drivers of newer vehicles move faster than the corresponding ones of older vehicles.

Keywords: Road Safety, Interchanges, Driver Age, Vehicle Type, Vehicle Age, Speed Profiles

1. Introduction

Taking into account that more than 1.4 billion vehicles are travelling in the world, road network highlights the importance of road safety worldwide, especially in the last three decades. The ultimate targets of road safety include safe circulation of vehicles and pedestrians mainly.

It would be ideal to achieve the above targets in full, but in reality, accidents are inevitable either due to roads design or mainly due to inherent driving behavior, which has proven to be the main cause of accidents. As a result, there are more realistic global targets for reducing road accidents, with emphasis on reducing the number of deaths and injuries.

[1] * Corresponding author. Tel.: +30 210 772 2628
E-mail address: atrakakis@mail.ntua.gr

In Europe, about 26,000 people die each year and 1.1 million are injured due to a road accident. Also, more than 5.5 thousand pedestrians lose their lives due to a road accident inside and outside urban road network (mainly around the cities). Most of those who were killed in road accidents were over 25 years old, and 37% of them belong to 25-49 years old age group. Of the deaths due to a car accident 8% involves road accidents, 37% on urban roads and 55% on rural roads. (European Road Safety Observatory, 2018).

Nevertheless, over the years the fatality rate due to an accident has decreased significantly (NCHS, 2018). Certainly, the development of automotive industry and its innovative safety systems are key factors. The chances of being killed in a road accident are clearly higher in cases of older vehicles compared to newer ones (NHTSA, 2005). Another determining factor is the age of the driver. NHTSA's research (2005) has shown and clarified that every younger age group is increasingly involved in a fatal vehicle accident. In particular, drivers between 16 and 24 years old seem to be the most hazardous based on this research.

In addition to the above, the same investigations quote a set of data, which show that the death toll is overwhelmingly lower in SUV types compared to smaller vehicle types. Also, the number of deaths in road accidents, where the vehicles rolled over, is significantly lower in SUV types.

2. Past Studies

Fatality rate based on speed

Fatal accidents are a common global phenomenon. Fatal accidents can be attributed to many causes, such as speeding, negligence, lack of attention, etc. Between 2001 and 2019 is observed, through Figure 1, that driving speed was a major fatal accident factor, as there were years when the death toll exceeded 12,000-13,000 and the fatality rate exceeded 30%.

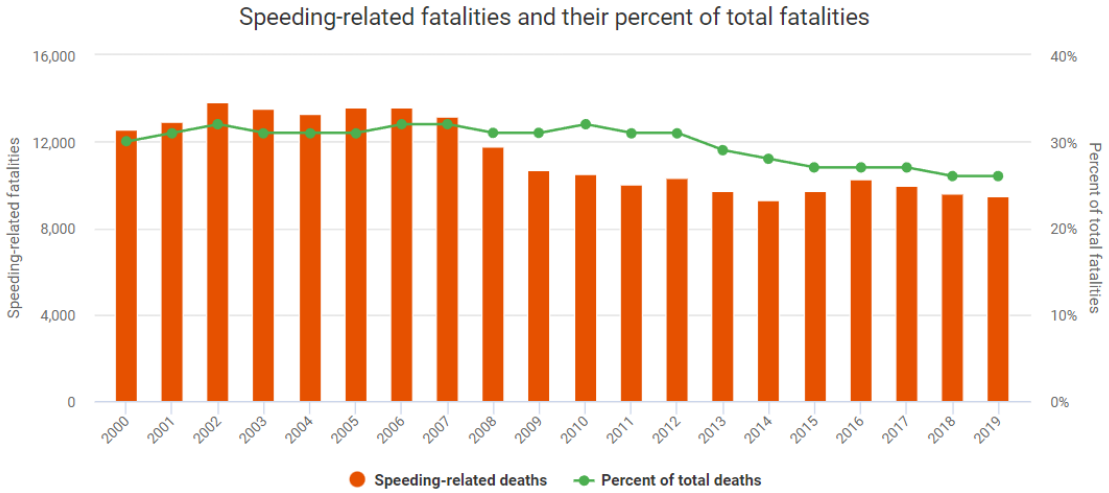

Figure 1: Speeding-related fatalities and their percent of total fatalities (National Safety Council, 2020)

Velocity elements for age groups and relative driver factors

In Horberry et al. (2006) research, in respect to the minimum speeds applied by drivers of different age groups in hazardous conditions, the elements presented in Table 1 were exported. From the table it can be observed that in hazardous conditions the age group of drivers under 25 years, applied almost twice higher minimum speed compared to drivers between 30 and 45 years old and almost three times higher minimum speed compared to drivers over 60 years old. It is noted, that the table below was derived taking into account investigations in urban and semi-urban environments, however it can capture the influence of the age group on the applied speed.

Table 1: Mean minimum speed (km/h) reached during hazard (Horberry et al., 2006)

Age Group	Minimum Speed
Under 25 years	32.46
30-45 years	17.23
Over 60 years	11.76

Gu et al. (2020), between other analyzes, used RAIRs (Relative Accident Involvement Ratios) to examine the influence of driver age on involvement in fatal accidents in interchanges.

Evaluating the data presented in Figure 2, is obtained that the teenage drivers (15 to 19 years old) mainly and secondarily the young (20 to 24 years old) drivers and the older-elderly (75+ years old) drivers, are more often involved in a road fatal accident. This observation, regarding the two younger age groups, is justified by the conclusion of Scott-Parker and Oviedo-Trespalacios (2017). They concluded that younger drivers have a higher tendency to take risks and be aggressive when driving. It is estimated that the high value of RAIRs of older-elderly (75+) drivers is based, probably, on the negligence and the lack of attention characterize this age group. On the other hand, is less likely for drivers aged between 25 and 64 years old to be involved in a fatal accident. Among the aforementioned three younger age groups (15-19, 20-24 and 25-64) and adding data for 65-74 years old drivers, is observed a decreasing tendency in RAIRs, as age increases.

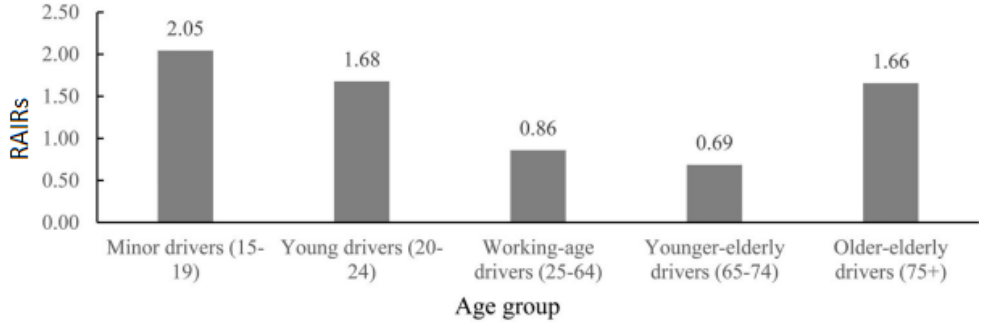

Figure 2: Relative accident involvement ratios (RAIRs) by driver age (Gu et al., 2020)

Fatalities per age group and vehicle type and age

Younger drivers' fatalities occur because of high applied velocity and aggressive driving behavior mainly. Contrarily, older drivers are involved in fatal accidents usually due to driving error (mainly due to negligence, lack of attention or slow reflexes). According to National Highway Traffic Safety Administration (NHTSA) (2001), in 2001, in United States the most fatal age group was constituted by drivers between 16 and 20 years old, followed by drivers between 21 and 24 years old and drivers over than 69 years old. Results are presented in Figure 3 below.

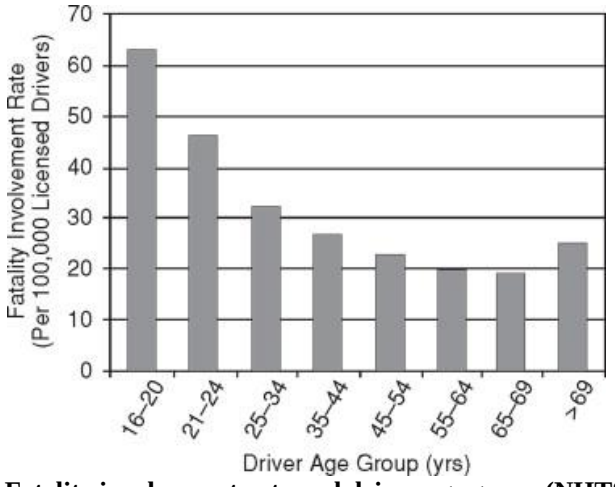

Figure 3: Fatality involvement rate and driver age group (NHTSA, 2001)

Fatalities per vehicle age group

According to NHTSA (2013) and the results presented in Figure 4, it is proved that every newer technology vehicle is safer than every older one. This conclusion came up based on the percent killed depending on the vehicle age by model year. Additionally, observing Figure 5 regarding the drivers of every newer vehicle, the probabilities being fatally injured are lower. Hence, the following figures emphasize the significance of vehicle age in road safety analyzes.

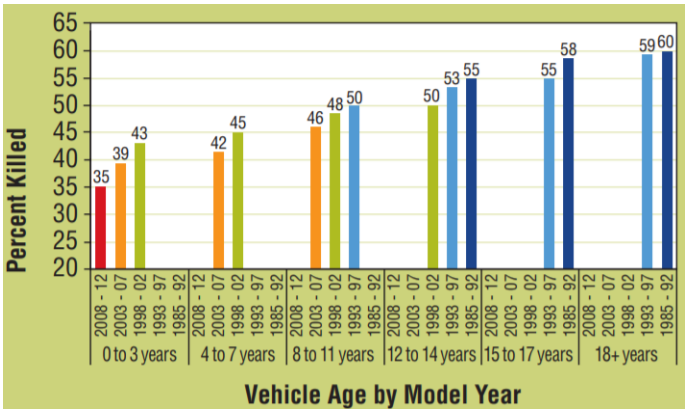

Figure 4: Percentage killed by vehicle age and model year. FARS 2005–2011 (NHTSA, 2013)

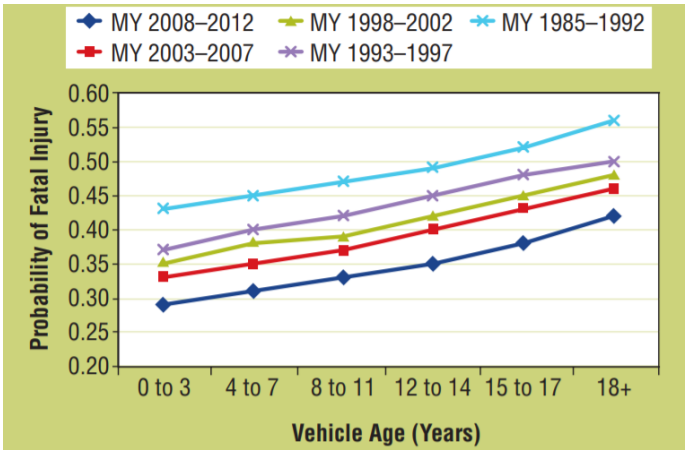

Figure 5: Probabilities of passenger vehicle driver being fatally injured, by vehicle age and vehicle model year. Reference categories coded for all other regression variables. (NHTSA, 2013)

Fatalities per vehicle type

Furthermore, vehicle type is one of the most significant factors affect driving behavior. Every vehicle offers to its driver a specific applied speed potential. According to Jayaratne & Kumarage (2005), in 2001 and 2002, small or medium vehicles were involved in 267 recorded fatal accidents, while SUV were involved in 111 additional fatal accidents.

Specifically, according to NHTSA (2006), for the years between 1997 and 2004, fatalities in all crashes mainly and fatalities in rolled over vehicle secondarily were much more in passenger vehicles (of any size) than in SUV.

Table 2: Fatalities in all crashes by vehicle type and size (NHTSA,2006)

	Fatalities in all crashes		Fatalities in rolled over vehicle	
Year	Passenger Vehicles	SUV	Passenger Vehicles	SUV
1997	32,448	2,380	9,527	1,489
1998	31,899	2,713	9,773	1,705
1999	32,127	3,026	10,140	1,902
2000	32,225	3,358	9,959	2,064
2001	32,043	3,530	10,157	2,149
2002	32,843	4,031	10,729	2,471
2003	32,271	4,483	10,442	2,661
2004	31,693	4,735	10,553	2,920
Total	**257,549**	**28,256**	**81,280**	**17,361**

3. Data Collection

Methodology

The data collection took place using followed observer method, i.e. the equipped (researcher's) vehicle was following the leading one with the same velocity (always trying to maintain a stable distance), the same braking (regarding the intensity and the position of the braking), etc., desiring each reaction to reflects -as much as possible- the motion of the leading vehicle. For each leading vehicle, researcher tried to note driver age and vehicle type and age. It should be mentioned that driver and vehicle age constitute researcher's estimate based on visual contact, as this experimental procedure was not made known to the driver of the leading vehicle until the measurement was completed.

The measurements used in the research, are those which the examined drivers consented to their use. Nevertheless, after the recording procedure, the examined vehicle age group was accurately determined, identifying the characteristics of the model with the standards of the automotive industry from which it was designed. Regarding the drivers age, it constitutes a clearly estimation of the researcher.

The measurement procedure took place during morning hours of each weekend between 4th January and 1st March 2020. The prevalence of good weather conditions was essential for the success of the procedure, because the road was completely dry and the recorded velocities and the inherent driving behavior could not be affected by the weather conditions.

For each driver, according to the recording data, a characteristic velocity value was obtained corresponding to the passage through the curve of the ramp. This value was selected at the location where the driver, having reduced the velocity for the transition from the tangent to the curve, maintained a stable velocity within the curve. This velocity can be characterized as passing velocity and corresponds to the limit value applied by driver in order to feel safe.

The velocity recording of the leading vehicle started many meters before the ramp (within the previous tangent) and was completed many meters after the ramp, in order to create a complete speed profile for each driver. Having -through VERICOM 4000RG's GPS- the advantage of velocity data collection per 0.01second, the estimation of velocity within the curve was performed with considerable accuracy. Regarding the correlation between velocity and location, VERICOM 4000RG's GPS is recording X, Y and Z coordinates with a time-lapse of 0.01second, so that the curve could be located precisely and the velocity of vehicle could be found in every part of curve.

From the literature reviewed above, it was observed that younger age groups are more involved in road fatal accidents, while drivers of older vehicles is more likely to be fatally injured. The number of the recorded deaths of passenger vehicles passengers (including drivers) is much higher than the corresponding one for SUV. Therefore, an additional aim of this research is to measure the transit velocities and based on the results to try to explain the conclusions drawn from the literature sources based on the velocity factor.

Measurements equipment

VERICOM 4000RG is a 3D accelerometer that has a built-in coordinate recorder and offers the ability to export the elements of road horizontal and vertical alignment. Utilizing the built-in GPS, the recordings of position coordinates and velocity per 0.01 second were made. During measurements period in most cases the vehicle was able to follow the leading vehicles and to respond satisfactorily to the recording of their motion (braking, acceleration, etc.). In some cases there were difficulties during the measurements and as a result the specific measurements were excluded from the analyzes. Specifically, measurements were rejected when:

- the motion of the leading vehicle was hindered by another vehicle
- the driver of leading vehicle decelerated unnecessarily
- the drivers of leading vehicles did not approve the inclusion of their driving behavior in the experiment.

Image 1: VERICOM400RG (placed on researcher's vehicle)

Selected interchange ramps

The selection of the examined interchange ramps was based on the following prerequisites:

- at least one ramp with a radius of less than 40 meters
- at least one ramp with a radius between 40 and 100 meters
- at least one ramp with a radius of more than 100 meters
- ramps of similar radii for comparison of results
- different ramps types

In images 2-5, the red line reflects the corridor, where the VERICOM 4000RG were in use.

Image 2: Kifisias Interchange, 28 meters radius horizontal curve (clover section)

Image 3: Kimis Interchange, 34 and 50 meters radii horizontal curves (trumpet)

Image 4: Kapodistriou Interchange, 33 meters radius horizontal curve (diamond section)

Image 5: Alimou Interchange, 175 and 39 meters radii horizontal curves (trumpet)

4. Results

Velocity within the curve and driver age group

Table 3 contains the values of maximum, mean and minimum velocity corresponding to each examined driver age group, while Figure 6 presents the data for all velocity recordings in the 6 studied horizontal curves. Every point of the figure may reflect for more than one recorded velocity value. It is observed, according to Table 3 and Figure 6, that the youngest age group (drivers 20 to 30 years old) is the fastest one and the drivers 30 to 40 and 40 to 50 years old are following. The mean and the minimum velocity of these two last mentioned age groups are equal. However, the deviation of velocity values between drivers 20 to 30 years old and 40 to 50 years old is not significant, regarding the mean and the minimum velocity, as opposed to maximum velocity. Also, drivers 20 to 40 years old seem to feel more comfortably applying higher velocity values compared to the older ones.

Table 3: Maximum, mean and minimum velocity for each age group in interchange ramps branches

Age Group (Years)	Max. Velocity (km/h)	Mean Velocity (km/h)	Min. Velocity (km/h)	Sample Size
20 to 30	93	48	28	69
30 to 40	86	46	30	58
40 to 50	72	46	30	38
50 to 60	65	41	27	43
Over 65	61	38	27	13

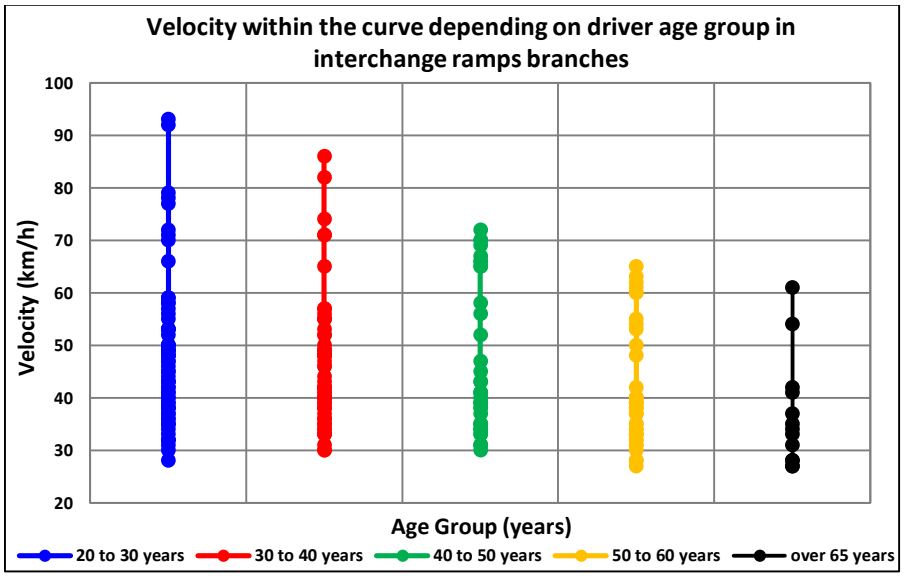

Figure 6: Velocity within the curve depending on driver age group in interchange ramps branches

Velocity within the curve and vehicle type

Table 4 contains the values of maximum, mean and minimum velocity corresponding to each vehicle type examined. Also, Figure 7 contains all the recorded velocities per vehicle type for the both 6 studied horizontal curves. Each point represents one or more measurements, as in the previous analysis. It is observed, according to Table 4 and Figure 7, that drivers of larger vehicles apply higher velocity than the drivers of smaller ones.

Specifically, drivers of SUV seem to feel more comfortably applying high velocity values, compared to the drivers of other vehicle types. This can be confirmed by all velocity values (maximum, mean, minimum) and specifically by checking, mainly, the significant deviation in maximum and mean velocity values. From the measurements it is observed that larger vehicles seem to offer higher sense of safety for the driver. This sense has a direct influence on driving behavior and specifically on the applied velocity values. Taking into account that larger vehicles can usually reach higher velocity values, they lead their drivers to apply high velocities.

Table 4: Maximum, mean and minimum velocity for each vehicle type in interchange ramps branches

Vehicle Type	Max. Velocity (km/h)	Mean Velocity (km/h)	Min. Velocity (km/h)	Sample Size
Hatchback	71	40	27	102
Sedan	82	46	28	81
SUV	93	52	32	40

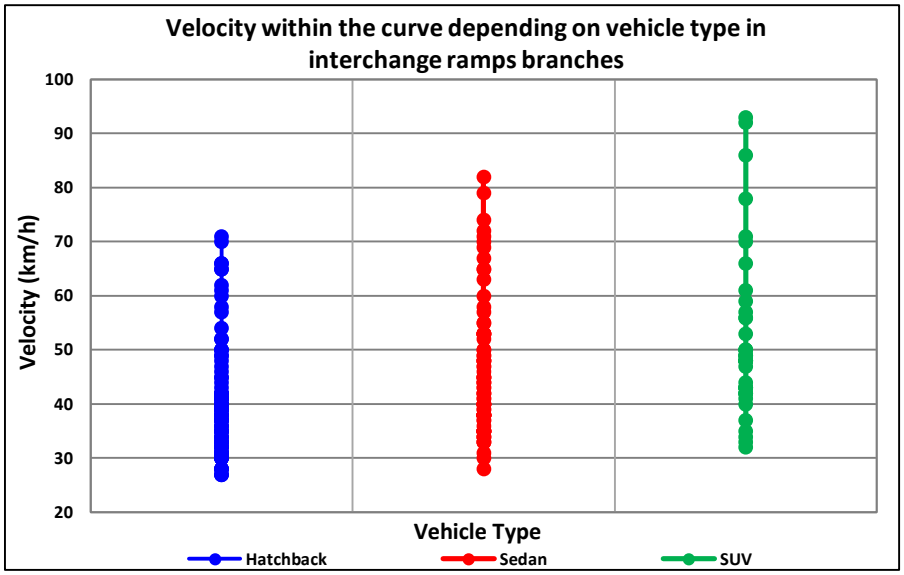

Figure 7: Velocity within the curve depending on vehicle type in interchange ramps branches

Velocity within the curve and vehicle age group

Table 5 shows the values of maximum, mean and minimum velocity in all the examined curves, while Figure 8 contains the velocity data for all the vehicles participated in this research depending on their age. For the points of the figure, applies everything mentioned previously. It is observed, that the newer vehicles enable drivers to apply higher velocity values and to feel safer in this application. For newer vehicles, in addition to the significant deviation between the mean velocity values, there is an even greater deviation in the maximum velocity values. This could be explained by the fact that every next decade the equipment of vehicles is enriched with more innovative systems, which offer more comfort and safety and a greater sense of the above. As vehicles manufacturing technology is evolved, drivers feel more comfortably applying higher velocity values.

The sample size of 1990s' vehicles is the smallest one, because these vehicles are no longer frequently circulated. However, the 13% of the sample belongs to old vehicles, something which reduces the provided road safety level.

Table 5: Maximum, mean and minimum velocity for each vehicle age group in interchange ramps branches

Vehicle Age Group (Decade)	Max. Velocity (km/h)	Mean Velocity (km/h)	Min. Velocity (km/h)	Sample Size
1990	65	40	30	30
2000	78	44	28	100
2010	93	47	32	93

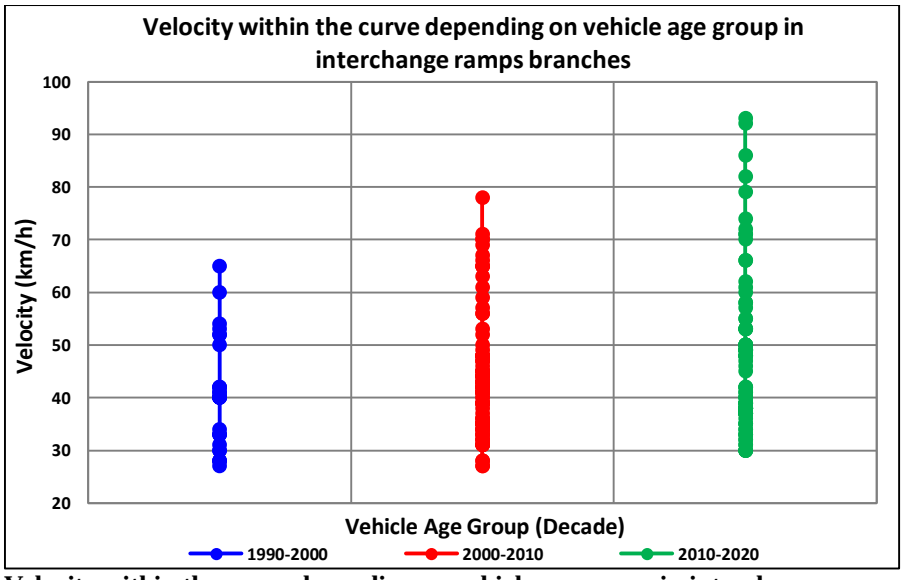

Figure 8: Velocity within the curve depending on vehicle age group in interchange ramps branches

Vtangent - Vramp and driver age group

Another way to examine the effect of age group on driving behavior is to examine the velocity reduction during the transition from the tangent to the curve of ramp. The fulfilled measurements include a large set of recorded velocities of vehicles during their motion in the tangent precedes the ramp. Therefore, subtracting the velocity within the curve of ramp from the velocity in the tangent, Figure 9 can be formed for the age groups under consideration. It is clear, that the deviation between the velocity in the tangent and the corresponding one within the curve of ramp increases as drivers age increases, too. According to Table 6, this increase seems to be smooth, regarding the maximum and minimum differences in each age group, while the same trend is followed by the mean values. This finding is explained by driver's sense of safety and the inherent driving behavior.

Previously, the research has concluded that the older drivers are more conservative than the younger ones. This conclusion also explains the following elements. In particular, older drivers feel less comfortably during their transition from the tangent to the curve of ramp, reducing -with a faster rate- the applied velocity between these road sections. On the contrary, younger drivers feel safer while transitioning from the tangent to the curve of ramp, as evidenced by the data for drivers between 20 and 40 years old.

The difference between Vtangent and Vramp (Vtangent - Vramp) seems to be a representative element of driving behavior, given that in previous analyzes it was found that the applied velocity of younger drivers is much higher than the corresponding one of older drivers.

Table 6: Maximum, mean and minimum Vtangent - Vramp for each age group in interchange ramps branches

Age Group (Years)	Maximum (km/h)	Mean (km/h)	Minimum (km/h)	Sample Size
20 to 30	26	17	1	33
30 to 40	32	18	6	40
40 to 50	36	23	7	29
50 to 60	40	27	8	47
Over 65	45	29	12	15

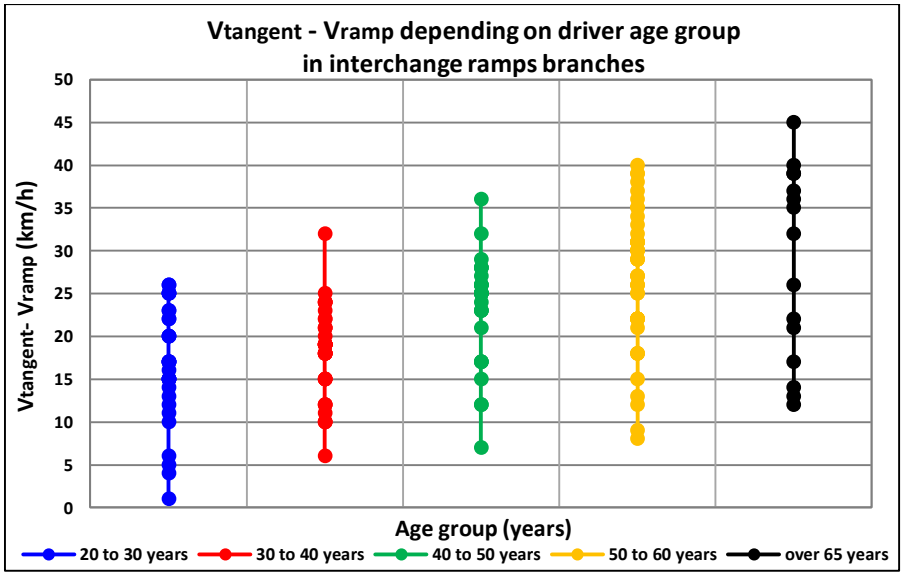

Figure 9: Vtangent - Vramp depending on driver age group in interchange ramps branches

It is observed that the total sample size is smaller than the corresponding one of the above analyzes. This observation resulted because there were not data collection for all the examined vehicles regarding their motion in the tangent precedes the curve of ramp.

5. Conclusions

From the analysis presented, very important conclusions derive, which are:

- Younger drivers apply higher velocity values than the older ones.
- Drivers between 20 and 40 years old feel more comfortably applying higher velocity values than the older drivers.

- Interchange ramps branches are treated more conservatively by older drivers as opposed to younger ones.
- Drivers between 40 and 50 years old keep stable velocity without applying higher or lower velocity values, probably because of their driving experience.
- Drivers of larger vehicles apply higher velocity values compared to drivers of smaller vehicles.
- Specifically, drivers of SUV feel more comfortable and safe applying high velocity values.
- The above conclusions confirm that vehicle type affects driving behavior.
- Drivers of newer vehicles apply higher velocity values than drivers of older vehicles.
- The vehicles of every next decade can reach higher velocity values (and at a faster rate) than vehicles created the decade before. This capability seems to significantly influence the driving behavior.
- It seems that vehicle type and age influence driving behavior more crucially than drivers age, because of the higher deviation values between the different categories in vehicle analysis in contrast to age analysis.
- That high percentage of 1990's vehicles still in circulation, has to be worrying.
- It is obvious that interchanges do not affect the driving behavior (based on human factor) more than other main road sections (tangents, curves, etc.).
- It is observed that younger drivers (20 to 40 years old) do not significantly reduce their velocity, while transitioning from the tangent to the curve of ramp, although they choose to apply significantly higher velocities. The above observation reinforces the conclusion that the drivers of this age group feel more comfort and safety applying high velocity values.
- Higher velocity values applied by younger drivers may be a causal factor regarding the high fatal rate of these age groups.

References

1. Dissanayake S. (2004). COMPARISON OF SEVERITY AFFECTING FACTORS BETWEEN YOUNG AND OLDER DRIVERS INVOLVED IN SINGLE VEHICLE CRASHES.
2. European Commission. Road Safety web-portal.
3. European Road Safety Observatory (2018). Annual Accident Report.
4. Horberry T., Anderson J.,Regan M.A., Triggs T.J. & Brown J. (2006). *Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance*. Accident Analysis & Prevention Volume 38, Issue 1.
5. Jayaratne M.D.R.P., Kumarage Amal S. COMPARISON OF ACCIDENT RATES BETWEEN VEHICLE TYPES IN SRI LANKA. Proceedings of the Engineering Research Unit Symposium University of Moratuwa, 2005.
6. National Center of Health Statistics (2018).
7. National Safety Council (2020).
8. NHTSA Fatality Analysis Reporting System (FARS).
9. NHTSA, National Center for Statistics and Analysis, "2004 Annual Assessment of Fatal Motor Vehicle Traffic Crashes," Washington, DC, 2005.
10. Scott-Parker, B., & Oviedo-Trespalacios, O. (2017). Young driver risky behaviour and predictors of crash risk in Australia, New Zealand and Colombia: Same but different? Accident Analysis and Prevention, 99(Pt A), 30–38.
11. Traffic Safety Facts: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. DOT HS 809484.National Center for Statistics and Analysis, National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, D.C. 2002.
12. Traffic Safety Facts (2013): How Vehicle Age and Model Year Relate to Driver Injury Severity in Fatal Crashes. DOT HS 811 825. National Center for Statistics and Analysis, National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, D.C.
13. www.nrso.ntua.gr Accessed Octrober 28, 2021.
14. Xin Gu, Mohamed Abdel-Aty, Jaeyoung Lee, Qiaojun Xiang & Yongfeng Ma (2020): Identification of contributing factors for interchange crashes based on a quasi-induced exposure method, Journal of Transportation Safety & Security, DOI: 10.1080/19439962.2020.181278.