TOMAŽ TOLLAZZI, Ph.D.
E-mail: tomaz.tollazzi@uni-mb.si
MARKO RENČELJ, Ph.D.
E-mail: marko.rencelj@uni-mb.si
VLASTA RODOŠEK, M.Sc.
E-mail: vlasta.rodosek@uni-mb.si
BORUT ZALAR, Ph.D.
E-mail: borut.zalar@uni-mb.si
University of Maribor, Faculty of Civil Engineering
Department of Traffic Management
Smetanova 17, SI-2000 Maribor,
Republic of Slovenia

Safety and Security in Traffic
Preliminary communication
May 12, 2009
May 17, 2010

TRAFFIC SAFETY OF OLDER DRIVERS IN VARIOUS TYPES OF ROAD INTERSECTIONS

ABSTRACT

In industrialized countries people over 50 years of age represent a rapidly growing part of population. Their lifestyle is also becoming more active, which means that the percentage of older drivers in the population of all drivers is also increasing. Many different studies have shown that elderly drivers are more frequently involved in specific types of accidents, especially at intersections.

In the past 15 years there was a trend of increasing popularity of roundabouts in Slovenia. Their introduction was generally supported by the arguments of increased traffic-flow capacity and traffic safety as well. The studies on which these arguments are based were performed with an "ideal" type of driver in mind; the one that fully understands new rules and reacts correctly in all situations that may occur at such intersections, where there are no light signals to guide them. An elderly person does not necessarily conform to that ideal and if the percentage of elderly drivers became significant, the premises of the above mentioned studies may not be correct anymore which in turn implies that their results could also be questioned.

The present study concentrated on the evaluation of traffic safety of elderly drivers, at various types of intersection, from their own perspective. Various statistical analyses of obtained data were performed. The most important finding was that we may claim, with high degree of probability, that the average person of the age of over 60 feels more unsafe at double-lane roundabouts than they would feel had the same intersection been equipped with traffic lights.

Elderly traffic participants will always cause more accidents or participate in them due to hazardous factors. Challenge, arising from many different studies and researches, is in studying what measures and solutions can reduce the risk for elderly participants.

KEYWORDS

traffic safety, road intersections, roundabouts, elderly people, older drivers

1. INTRODUCTION

Many different studies show that the average age of the population in developed countries in general, and also in Slovenia in particular, is increasing. There are many reasons for this phenomenon, the most important being the development of medical science, higher living standard in general and also improvement in the quality of micro-environment at work and at home. Statistical analysis shows that today in the USA people over 70 represent 9% of population [1]. In the European Union already 17.1% of citizens are older than 65 years [2]. In Slovenia there were 2,025,866 inhabitants at the end of the year 2007. A total of 300,248 were older than 64 years, which represents 14.82% of population. This means that almost every 7th person in Slovenia is older than 64. It is a fact that most of these persons are still active participants of road traffic, especially in city traffic. Therefore, in industrialized countries, drivers over 60 years of age represent a rapidly growing part of driving population.

As the older population is growing at a faster rate than the general population, it is anticipated that the number of injured and killed, both vehicle occupants and pedestrians, will rise [3]. In order to be safe as a participant in road traffic, a person should posses certain psychophysical qualities, which enables one to react quickly and correctly to sudden and unexpected changes of traffic situation around them. It is well-known that the quality of sight and hearing as well as the flexibility and reaction time deteriorate with the advancing age. Older drivers are more often considered responsible for crashes and they have more fatal accidents, especially because they are more vulnerable. Many different studies have shown that elderly drivers are more frequently involved in specific types of accidents (e.g. situations involving more than one vehicle, especially at intersections). Some results are concerned with the behaviour of different population groups, with respect to age, and safety of elderly road traffic participants. Older drivers have more error accidents and this tendency increases with age. An error accident is defined as the failure of the planned action to achieve a desired outcome without the intervention of some chance or unforeseeable event [4]. In general, these studies consistently find correlation between crash rates and older driver's traffic safety: accidents are more likely to occur in good weather, during daylight hours, at intersections, while marking turns: their causes are not excessive speed or alcohol. These results show that the problem of older drivers in road traffic in overall safety is not negligible even today, while its importance will rise in the future.

In general, in urban areas, there are many factors that contribute to the low level of traffic safety [5]. One of them is certainly high number of intersections where drivers change their driving directon. This creates many trouble points. Another reason is high amount of information that the drivers should pay attention to, high number of signals allowing and forbidding something, and in the end there are too many vehicles of different types concentrated in a small area, among them being also delivery vehicles and trucks [6], but the authors believe that the main reason for participation of the elderly in specific types of accidents is their lower psychophysical ability.

In Slovenia there was only one investigation pertaining to this field of research [7], which concentrated on understanding those difficulties and obstacles facing older participants in traffic flow, which are caused by the decrease of their motorised abilities. Because of this we conducted a study among elderly drivers in three different cities. The first city, in the sequel we call it L, is the capital of Slovenia. It has a large population of elderly persons among permanent inhabitants. Because of the recent trends of moving all shopping centres away from the centre, many depend on their cars in order to fulfil their daily needs so they can be assumed as being thoroughly familiar with urban traffic situations. The second city, in the sequel we call it C, is smaller but rapidly developing in the last decade. It has large rural surroundings and many older drivers are occasional migrants settling some administrative affairs or visiting the regional hospital. The third city is our university town, to be called M, which is, according to most social parameters, somewhere in the middle between L and C. Our main objective is to determine the response, among the population of drivers over 60 years of age, to the safety of new type of intersection (roundabouts, introduced in the last 15 years), while comparing it to the classical type of intersection with traffic lights.

We analyzed the collected data for significant correlations between safety assessments for three intersection types (the classical type equipped with traffic lights, one-lane roundabout, double-lane roundabout) and various variables concerning drivers: age, years of driving experience, type of town (L, C or M) where most of the driving is done and previous involvement in accidents.

Beside theoretical interest, our research should have practical consequences. In Slovenia there is still a lot of road and intersection construction going on at the moment. This trend will continue for several more years. As we already mentioned, it is current fashion not only that many of the newly constructed intersections are of roundabout type, but also that many previously built classical signal-controlled intersections have been rebuilt into roundabout ones. It was our goal to assess if this practice should commence or, concerning the increase of older population, some of the current strategies are to be amended. In the sequel we wish to offer numerical arguments to support the thesis, that because of slower adaptation to novelties and lesser motorised abilities, the older drivers feel the safest at classical road intersections.

2. SOME KNOWN STATISTICAL FACTS

2.1 Ageing of population

In the last 50 years the average lifespan increased mostly in the developing countries (for 22 years) and is currently approximately 63 years. In developed countries, where it was high already in around 1960, it increased by 11 years and is currently approximately 75 years. A boy, respectively, a girl born in Slovenia in the period 2002/2003 can expect to live, on the average, 73 and 81, respectively [8]. In Slovenia, the percentage of population over 65 years of age already exceeds the percentage of population of those below 15 years of age. It must be emphasized at this point that in Slovenia the driver's licence for category B is valid until 80 years of age. Around 1950 the average age in the country was 30, at the end of 2004 it rose already to 40.3 years. In the next 50 years, due to low birth figures, we can expect quite rapid trend of further average age rise. According to the basic variant of Eurostat projections [8], by the year 2050, the total population of Slovenia should decrease by approximately 5%. Almost one third of population (31.1% to be more exact) should at that time reach the age of over 65, while the percentage of population below 15 years of age should drop to less than 13%. If this projection is true, we can imagine that the research of the behaviour of older drivers, concerning their own safety and also safety of other road traffic participants, should be taken more seriously into account than it was the case in the past.

According to the data compiled by the United Nations in 2004 already 75.4% of population in the developed countries lived in the urban areas. Slovenia is a very small country with rather well developed road network and most cities with population below 100,000. Because of this fact, many professionals, working in cities, buy their houses in rural areas in a 20km radius around the cities. Hence, the official percentage of only 50% of population living in urban areas at the end of the year 2004 does not really correctly reflect the traffic situation, and we may more correctly assume that the 75% of population of Slovenia is involved in daily urban traffic.

2.2 Older persons' involvement in traffic accidents

It is not easy to define who an older driver is. Beside the chronological age, some consider also functional age, where various factors, such as general health problems, lower quality of sight and/or hearing, etc. are taken into account [9]. If some factors are present for a given individual, their ability to drive safely is also affected to some degree.

The increasing danger to older road traffic participants does not originate so much from the increase of time of their participation in traffic, but from the fact that the total number of traffic accidents is increasing and, as the data seem to suggest, the probability of injury during an accident increases with the participant's age. Among pedestrians and cyclists, the number of accidents and injuries increases regardless if they are responsible for the accident or not. Among drivers the number of injuries starts to grow significantly with the age. Older drivers, who get injured in an accident, appear more often as those who caused the accident.

In order to show how serious the problem of the older drivers and pedestrians safety in today's traffic within Slovenia is, we conducted an analysis of traffic accidents for the years 2005 and 2006. The findings are presented in *Table 1* (all persons involved in accidents) and *Table 2* (only persons that caused those accidents), where we concentrated on persons whose age at the moment of accident was 64 years or more.

In the period 2003–2007 there was a total of 355,914 persons involved in various road traffic accidents in Slovenia. Among this total 21,462 persons (6.03%) were in the age category of 64 years or more. What causes concern is the fact that these older persons caused 55.2% of accidents they were involved in. In the mentioned period a total of 1329 persons died on the Slovenian roads. Among them there were 242 persons (18.2%) whose age was 64 years or more.

It is also illustrative to consider the role played by the persons over 64 years of age involved in traffic accidents. The findings are shown in *Table 3* (all persons involved in accidents) and *Table 4* (only persons that caused those accidents).

Tables 3 and 4 show that among persons over 64 years of age, who were responsible for accidents, most of them were motorcar drivers. Because of this, it will be necessary in the future to pay more attention to the design of such elements of city road-network infrastructure which will enhance the feeling of safety for older drivers.

With this remark in mind, we designed an analysis whose goal was to determine how the population of older drivers assesses the impact of various types of road intersections and various traffic signs. In this article we present the results concerning road intersections.

Table 1 – Traffic accidents – all persons involved in accidents

	No. of persons involved			Dead			Serious injuries			Other injuries			Uninjured		
	All	64+	%	All	64+	%	All	64+	%	All	64+	%	All	64+	%
2005	62,155	3,783	6.0	257	44	17.1	1,295	168	12.9	13,424	678	5.0	47,179	2,893	6.1
2006	63,542	4,019	6.3	262	36	13.7	1,261	162	12.8	15,368	801	5.2	46,651	3,020	6.4

Table 2 – Traffic accidents - persons that caused accidents

	No. of persons involved			Dead			Serious injuries			Other injuries			Uninjured		
	All	64+	%	All	64+	%	All	64+	%	All	64+	%	All	64+	%
2005	30,142	2,092	6.9	139	22	15.8	645	72	11.1	4,486	209	4.6	24,872	1,789	7.1
2006	30,263	2,191	7.2	152	15	9.8	631	57	9.0	4,805	244	5.0	24,675	1,875	7.6

Table 3 - Role played by persons over 64 years - all persons involved in accidents

	2005			2006		
	All	64+	%	All	64+	%
drivers	92	10	10.87	96	9	9.38
passengers	55	8	14.55	55	5	9.09
pedestrians	37	19	51.35	36	14	38.89
tractor drivers	4	1	25.00	2	0	0.00
motorbike drivers	5	2	40.00	12	2	16.67
cyclists	18	4	22.22	14	6	42.86

Table 4 - Role played by persons over 64 years - persons that caused accidents

	2005			2006		
	All	64+	%	All	64+	%
drivers	75	9	12.00	84	8	9.52
pedestrians	13	7	53.85	12	3	25.00
tractor drivers	4	1	25.00	2	0	0.00
motorbike drivers	2	1	50.00	9	1	11.11
cyclists	12	4	33.33	8	3	37.50

3. USED METHODS

3.1 Participants

Data was collected by last year students of traffic engineering, who, in a random fashion, wandered around those three towns, picking up car, motorcycle and bicycle drivers at various parking places.

Our analysis was conducted in three Slovenian towns of different sizes. Their population is 37,000 (C), 110,000 (M) and 250,000 (L) inhabitants respectively. To each of these towns several students were sent with a total of 450 questionnaires; 252 in town L, 126 in town M and 72 in town C. They walked around those towns in a random fashion and questioned older drivers at various parking lots. Beside the active drivers, questionnaires were also distributed to two other groups of people of over 60 years of age: non-drivers (including cyclists and pedestrians) and occasional drivers (those who possess a valid driver's licence but drive very seldom; typically once a week or less). All participants remained anonymous.

3.2 Variables

In the sequel the following notation is used. Y_A and Y_D denote random variables describing the "absolute" age of a person and the "driving" age, i.e. the number of years the person has had a valid driver's licence for category B vehicles.

A_{TL}, A_{R1} and A_{R2} denote random variables which describe the safety assessment for road intersections with traffic lights, one-lane roundabouts and double-lane roundabouts, respectively. These three variables are normalized in order to take values between 0 (meaning unsafe) and 1 (meaning 100% safe).

These variables are considered in several different populations, which are divided by the size of town of residence (small, medium, large) and their driving status (regular, occasional, non-driver).

4. RESULTS

First, we considered the two basic statistical parameters, the mean and the standard variation S, for obtained samples of safety assessment for A_{TF}, A_{R1} and A_{R2} in various populations. The results, which were computed from the completed questionnaires, are given in *Table 5*. They are presented for each of the three cities separately (first three rows) and cumulatively (the fourth row). Rows 1–4 present the results for regular drivers, rows 5–8 for occasional drivers and rows 9–12 for non-drivers.

In the next step the estimations (both lower and upper) are derived for the general mean of the variables A_{TL}, A_{R1} and A_{R2} in all subpopulations with various degrees of certainty. We treated their general means and standard deviations as unknowns, so all calculations were performed using the standard Student t-test. Since we used the numerical integration, we did not replace the Student distribution with the Gauss normal distribution, despite the fact that the number of samples is greater than 30, which used to be the justification for such a replacement in the time when distribution tables were still used. Results of our com-

Table 5 – Complete results of questionnaire - the mean and the standard variation S

	$\overline{A_{TL}}$	$S(A_{TL})$	$\overline{A_{R1}}$	$S(A_{R1})$	$\overline{A_{R2}}$	$S(A_{R2})$
drivers L	0.684	0.333	0.868	0.220	0.605	0.203
drivers M	0.750	0.274	0.725	0.295	0.475	0.273
drivers C	0.678	0.240	0.642	0.229	0.214	0.247
all drivers	0.712	0.279	0.772	0.293	0.391	0.375
occ. drivers L	0.439	0.279	0.429	0.286	0.308	0.230
occ. drivers M	0.623	0.215	0.598	0.284	0.336	0.310
occ. drivers C	0.583	0.312	0.375	0.298	0.176	0.236
all occ. drivers	0.519	0.278	0.478	0.299	0.352	0.322
non-drivers L	0.433	0.335	0.400	0.327	0.267	0.264
non-drivers M	0.671	0.284	0.500	0.292	0.232	0.273
non-drivers C	0.500	0.408	0.306	0.295	0.111	0.280
all non-drivers	0.525	0.348	0.420	0.317	0.282	0.328

putation have been collected in Tables 6, 7 and 8. We briefly recall the basic theory behind that computation.

Let $X_1, X_2, \ldots, X_n$ be a sample of mutually independent measurements for the random variable X, whose mean is μ. If we denote by X and S sample mean and sample standard deviation respectively, then the variable

$$T = \sqrt{n}\frac{\overline{X}-\mu}{S} \tag{1}$$

is distributed according to the Student's law with $n-1$ degrees of freedom. The density function for this law is given by

$$p_{n\text{-}1}(u) = \frac{\Gamma(n/2)}{\Gamma((n-1)/2)\sqrt{(n-1)\pi}}\left(1+\frac{u^2}{n-1}\right)^{-n/2} \tag{2}$$

The Student's law is symmetric with respect to the variable u, so in the sequel we always compute the probabilities concerning this law on symmetric intervals. More precisely: in order to give an estimate for μ, with a given probability P, we first compute a constant c such that

$$\int_{-c}^{c} p_{n\text{-}1}(u)du = P \tag{3}$$

Next we infer that the value

$$\sqrt{n}\frac{\overline{X}-\mu}{S} \tag{4}$$

lies within the interval $[-c, c]$ with the probability P, i.e.

$$-c \leq \sqrt{n}\frac{\overline{X}-\mu}{S} \leq c \tag{5}$$

The estimates for the unknown quantity μ, with probability P, are obviously equal

$$\overline{X} - \frac{cS}{\sqrt{n}} \leq \mu \leq \overline{X} + \frac{cS}{\sqrt{n}} \tag{6}$$

Since we had different sizes of samples in each of our three cities, the values of n and c were different in our computations. Lower and upper estimates for the mean of safety assessments were computed with the probabilities 90%, 95% and 99%. The results are presented in three different tables (see *Table 6*, 7 and 8). For example, in our total sample the subgroup of occasional drivers from L consisted of $n = 98$ persons. From *Table 5* we find $A_{TL} = 0.439$, $S = 0.279$ holds for this subgroup. With some experimental work, concerning the interval of integration, we found

$$\frac{\Gamma(98/2)}{\Gamma(98/2)\sqrt{97\pi}}\int_{-1.6607}^{1.6607}\left(1+\frac{u^2}{97}\right)^{-98/2} du = 0.90000 \tag{7}$$

so we take $c = 1.6607$. From the above formula we can deduce, with 90% probability,

$$0.439 - \frac{1.6607 \cdot 0.279}{\sqrt{98}} \leq \mu \leq \\ \leq 0.439 + \frac{1.6607 \cdot 0.279}{\sqrt{98}} \tag{8}$$

$$0.3922 \leq \mu \leq 0.4858 \tag{9}$$

Other entries in Tables 6, 7 and 8 were computed in a similar way. We rounded all figures to three decimal places. The basic divisions of rows in all of these tables are the same as in *Table 5*. Each entry is given in the form l – u where l is the lower estimate and u the upper estimate.

From this data we can see that in general not much can be said for the relation between A_{TL} and A_{R1}, i.e. the feeling of safety in one-lane roundabouts and intersections equipped with traffic lights cannot be compared in a unique fashion. This is however not the case for A_{TL} and A_{R2}. By looking at *Table 6* we see that in every measured subpopulation the upper bound for the mean of A_{R2} is still smaller than the lower bound for the mean of A_{TL}. Thus, we may form the following statistical hypothesis: the mean of A_{TL} is bigger than the mean of A_{R2}. In everyday language this means that we claim that our collected data show that an average person of over 60 years of age, regardless of their driving habits, feels less safe in double-lane roundabouts than they would feel if the same intersection was equipped with traffic lights.

Table 6 - Complete results of questionnaire – derivation of the estimations; P = 90%

P = 90%	$\mu(A_{TL})$	$\mu(A_{R1})$	$\mu(A_{R2})$
drivers L	0.593 – 0.775	0.808 – 0.928	0.449 – 0.561
drivers M	0.667 – 0.832	0.646 – 0.804	0.402 – 0.548
drivers C	0.597 – 0.786	0.504 – 0.746	0.102 – 0.326
all drivers	0.663 – 0.761	0.721 – 0.823	0.326 – 0.456
occ. drivers L	0.392 – 0.486	0.381 – 0.477	0.237 – 0.347
occ. drivers M	0.577 – 0.669	0.537 – 0.659	0.269 – 0.403
occ. drivers C	0.475 – 0.690	0.272 – 0.478	0.080 – 0.248
all occ. drivers	0.485 – 0.553	0.441 – 0.515	0.312 – 0.392
non-drivers L	0.360 – 0.505	0.338 – 0.462	0.223 – 0.317
non-drivers M	0.596 – 0.756	0.423 – 0.577	0.160 – 0.304
non-drivers C	0.375 – 0.623	0.186 – 0.426	0.000 – 0.225
all non-drivers	0.472 – 0.578	0.371 – 0.469	0.232 – 0.332

Table 7 - Complete results of questionnaire – derivation of the estimations; P = 95%

P = 95%	$\mu(A_{TL})$	$\mu(A_{R1})$	$\mu(A_{R2})$
drivers L	0.574 – 0.794	0.796 – 0.940	0.438 – 0.572
drivers M	0.662 – 0.832	0.630 – 0.820	0.387 – 0.563
drivers C	0.584 – 0.808	0.519 – 0.767	0.080 – 0.348
all drivers	0.654 – 0.770	0.711 – 0.833	0.313 – 0.469
occ. drivers L	0.383 – 0.495	0.371 – 0.486	0.267 – 0.354
occ. drivers M	0.568 – 0.678	0.525 – 0.671	0.256 – 0.416
occ. drivers C	0.454 – 0.712	0.252 – 0.498	0.069 – 0.265
all occ. drivers	0.478 – 0.560	0.434 – 0.522	0.305 – 0.339
non-drivers L	0.346 – 0.520	0.326 – 0.474	0.214 – 0.327
non-drivers M	0.581 – 0.761	0.407 – 0.593	0.145 – 0.319
non-drivers C	0.350 – 0.650	0.110 – 0.447	0.000 – 0.247
all non-drivers	0.462 – 0.588	0.362 – 0.478	0.222 – 0.342

Table 8 - Complete results of questionnaire – derivation of the estimations; P = 99%

P = 99%	$\mu(A_{TL})$	$\mu(A_{R1})$	$\mu(A_{R2})$
drivers L	0.537 – 0.831	0.771 – 0.965	0.415 – 0.595
drivers M	0.632 – 0.868	0.598 – 0.852	0.358 – 0.592
drivers C	0.484 – 0.872	0.458 – 0.828	0.014 – 0.413
all drivers	0.636 – 0.789	0.692 – 0.852	0.288 – 0.494
occ. drivers L	0.365 – 0.513	0.353 – 0.505	0.254 – 0.369
occ. drivers M	0.549 – 0.697	0.500 – 0.695	0.230 – 0.442
occ. drivers C	0.390 – 0.775	0.191 – 0.559	0.022 – 0.312
all occ. drivers	0.465 – 0.573	0.420 – 0.536	0.289 – 0.415
non-drivers L	0.317 – 0.549	0.301 – 0.499	0.196 – 0.346
non-drivers M	0.550 – 0.792	0.376 – 0.624	0.116 – 0.348
non-drivers C	0.295 – 0.704	0.306 – 0.502	0.000 – 0.297
all non-drivers	0.441 – 0.609	0.344 – 0.496	0.203 – 0.361

Table 8 shows that we can no longer claim this to be true up to the significant level of 99%, so we proceed in a different way. Using numerical integration we can give even more precise estimate concerning the maximal degree of probability under which our data confirm the hypothesis $\mu(A_{TL}) > \mu(A_{R2})$.

In all cases where the sample mean of A_{TL} is smaller than the sample mean of A_{R2}, we can establish, being given the probability P, the upper bound for $\mu(A_{R2})$ and the lower bound for $\mu(A_{TL})$ with respect to P. If the upper bound for $\mu(A_{R2})$ is the smaller of both numbers, we conclude that $\mu(A_{R2})$ is smaller than $\mu(A_{TL})$ with probability P. Now we look for such, maximal possible, probability P that those bounds would actually coincide. If n is the number of independent samples, we look for such P that

$$\int_{-c}^{c} p_{n-1}(u)du = P \tag{10}$$

$$\overline{A_{R2}} + \frac{cS_{R2}}{\sqrt{n}} = \overline{A_{TL}} - \frac{cS_{TL}}{\sqrt{n}}. \tag{11}$$

For example, if we look at the population of all occasional drivers, whose sample consisted of 183 persons, we can get the following data from *Table 5*

$$\overline{A_{R2}} = 0.352,\ S_{R2} = 0.322,\ \overline{A_{TL}} = 0.519,\ S_{TL} = 0.278 \tag{12}$$

which implies

$$0.352 + \frac{0.322 \cdot c}{\sqrt{183}} = 0.519 - \frac{0.278 \cdot c}{\sqrt{183}} \tag{13}$$

The solution of this equation is $c = 3.765$ which implies that maximal probability under which we may claim our hypothesis (the average person over 60 years of age, using their car only occasionally, feels more safe at the traffic-lights intersection than at double-lane roundabout) is

$$\int_{-3.765}^{3.765} p_{182}(u)du = \frac{\Gamma(183/2)}{\Gamma(182/2)\sqrt{182\pi}} \int_{-3.765}^{3.765} \left(1 + \frac{u^2}{182}\right)^{-183/2} du \tag{14}$$

$$= 0.99978 = 99.978\% \tag{15}$$

In a similar way we can compute the probabilities for this hypothesis in other above-considered subpopulations. The results of this computation are summarized in *Table 9*.

With this sample assurance of correctness of our hypothesis, it is natural to ask how the answers depend upon age and driving experience. In other words, we look for correlations k between $\{A_{TL}, A_{R2}\}$ and $\{Y_A, Y_D\}$.

From our samples we computed the following figures (*Table 10*).

For drivers even these sample correlations are rather low, so we did not compute any further estimates. It seems that the age itself is not very significantly correlated with the safety assessment for various types of road intersections. On the other hand Tables 6, 7 and 8 suggest that the living environment (rural, urban, and metropolitan) is much more significant.

Table 9 - Probabilities of the hypothesis

subpopulation	probability of claimed hypothesis
drivers L	95.356%
drivers M	99.715%
drivers C	99.689%
all drivers	99.999%
occ. drivers L	98.761%
occ. drivers M	99.993%
occ. drivers C	99.907%
all occ. drivers	99.978%
non-drivers L	96.412%
non-drivers M	99.999%
non-drivers C	97.251%
all non-drivers	95.356%

Table 10 – Answers dependent upon age and driving experience

	$k(A_{TL}, Y_A)$	$k(A_{TL}, Y_D)$	$k(A_{R2}, Y_A)$	$k(A_{R2}, Y_D)$
active drivers	0.007	0.099	0.134	0.074
occasional drivers	0.015	0.009	0.018	0.052
non-drivers	0.121	–	0.262	–

5. ADDITIONAL DISCUSSIONS

5.1 Comments according to the types of road intersection

First, the results concerning the classical type of road intersection equipped with traffic lights are discussed. Among the persons who frequently participate in road traffic there are no statistically significant differences regarding the size of town in their safety assessments for this type of intersection. This is not the case with occasional drivers, cyclists and pedestrians. Those living in the big city L give significantly lower estimates than those living in M or C. This may be connected with changing driving habits (towards more aggressive one) of the younger active urban population. In all three cities regular drivers give higher estimates than occasional drivers (which is obviously an expected result), but the figures given by occasional drivers and non-drivers show no significant differences.

Results for one-lane roundabouts show the same expected pattern; regular drivers, namely, in all three cities give higher marks than occasional drivers and non-drivers from the same city, while the results for the latter two categories show no significant difference. There is, however, one difference from the previous type of intersection. Regular drivers from the biggest city L assessed one-lane roundabouts significantly better than those from smaller cities.

Results for double-lane roundabouts show the marks given by the driving population in the smallest city C to be significantly lower than those given in L and M. The figures they give are very low indeed, which might suggest that older population of small cities rejects the very idea of a double-lane roundabout. This could be explained, since the population in C is much less exposed to such type of intersection (there are at present only few of them in the entire C), that older persons need a lot of time to adjust to the rules concerning changing lanes inside such a roundabout. The same phenomenon of C giving the lowest marks can be observed for occasional drivers, while non-drivers do not show it.

5.2 Comments according to types of drivers

Our main hypothesis that older persons feel significantly safer in classical intersections equipped with traffic lights than in double-lane roundabouts has been substantiated by the collected data, as was explained in more detail in the previous section.

Results for regular drivers show that marks for one-lane roundabouts and classical intersections are comparable, so that the older drivers do not reject roundabout as an idea; they just do not feel safe enough when there are more than one lane. In fact, in the largest city L the average mark for the roundabout type is significantly higher than for the classical type of intersection. In cities M and C this phenomenon does not occur.

For other two categories, i.e. occasional drivers and non-drivers, the obtained results seem to show that they have about the same feeling about the one-lane roundabout and the classical type of intersection with perhaps one exception. In the smallest city C occasional drivers rated roundabouts lower with the probability approximately 88%. It is not easy to judge, without repeating the experiment for this subcategory with a larger sample, if this is just due to chance or not. If not, a possible explanation would be that older persons dislike any changes in their environment. Since the introduction of one-lane roundabouts was rather a recent event in C, perhaps those who used them just a few times do not think that this is an improvement of the previous situation, when traffic lights were still used, despite the fact that traffic counts show improved capacity.

6. Conclusion

Many different studies show that the average age of the population in developed countries in general, and also in Slovenia in particular, is increasing. Their lifestyle is also becoming more active, which means that the percentage of older drivers in the population of all drivers is also increasing. Many different studies have shown that elderly drivers are more frequently involved in specific types of accidents, especially at intersections.

The present study concentrated on the evaluation of safety of elderly drivers, at various types of intersections, from their own perspective. Various statistical analyses of obtained data were performed. The most important finding was that we may claim with high degree of probability, that the average person of over 60 years of age feels more unsafe at double-lane roundabout intersections than they would feel if the same intersection had been equipped with traffic lights.

Elderly traffic participants will always cause more accidents or be part of them due to hazardous factors. Challenge, arising from many different studies and researches, is in studying what measures and solutions can reduce the risk of the elderly participants.

Educational institutions (driving schools, school centres etc.) have already taken measures in informing the elderly participants about the traffic novelties (via web pages, booklets etc.) Car manufacturers are trying to do similar (with door mirrors on both sides of the car, ABS systems, driver's seat height adjustment, electric windows, semicircular turning of driver's seat, gear handle adjustment etc.). But at the same time traffic experts, especially road infrastructure designers, will have to accept the fact that the percentage of the elderly population involved in traffic is increasing all the time.

When planning traffic areas for elderly drivers it is very important that the infrastructure serves its function and that its user can predict how other drivers will react, especially at multi-lane road intersections. A driver must have enough time to make decisions and to act according to the rules and anticipations. Traffic signalization should be placed where a driver needs it and also have enough time to identify and consider the signals. Solutions should be made that would lower the risk for the elderly traffic participants.

Dr. **TOMAŽ TOLLAZZI**
E-mail: tomaz.tollazzi@uni-mb.si
Dr. **MARKO RENČELJ**
E-mail: marko.rencelj@uni-mb.si
Mag. **VLASTA RODOŠEK**
E-mail: vlasta.rodosek@uni-mb.si
Dr. **BORUT ZALAR**
E-mail: borut.zalar@uni-mb.si
Univerza v Mariboru, Fakulteta za gradbeništvo
Smetanova 17, 2000 Maribor, Republika Slovenija

POVZETEK

PROMETNA VARNOST STAREJŠIH VOZNIKOV V PROMETU V RAZLIČNIH TIPIH NIVOJSKIH KRIŽIŠČ

Veliko število študij kaže, da se starost prebivalstva povečuje. To velja tudi za Evropsko unijo, hkrati pa tudi za Slovenijo. Statistične analize kažejo, da se v državah Evropske unije življenjska doba prebivalstva letno povišuje. V Sloveniji je 21,6% populacije starejše od 60 let. Dejstvo je, da je večina teh ljudi udeležencev v prometu, predvsem v cestnem prometu. Članek prikazuje rezultate študije, katere osnovni namen je bil analiza dejanske varnosti starejših udeležencev v cestnem prometu v Sloveniji. Raziskava je imela dva osnovna cilja. Prvi cilj je bil ugotoviti, ali se starejši udeleženci v obstoječih prometnih razmerah počutijo varne. Drugi cilj je bil usmerjen v ugotavljanje varnosti starejših oseb v različnih tipih nivojskih križišč, kjer so udeleženi v cestnem prometnem dogajanju kot pešci, kolesarji in vozniki. Rezultati anketiranja so pokazali, da se največje število starejših oseb, ne glede na to, ali so to pešci, kolesarji ali vozniki motornega vozila, najbolj varno počuti v semaforiziranih križiščih in najmanj varno v dvopasovnih krožnih križiščih.

Starejši udeleženci v prometu bodo zaradi dejavnikov tveganja vedno med tistimi skupinami udeležencev cestnega prometa, ki pogosteje povzročajo nesreče oziroma so v njih udeleženi. Izziv, ki izhaja iz opravljenih študij in raziskav, je povezan predvsem s proučevanjem ukrepov in rešitev, s katerimi lahko vplivamo na zmanjšanje tveganja starejših udeležencev v prometu.

KLJUČNE BESEDE

prometna varnost, nivojska križišča, krožna križišča, starejši vozniki

LITERATURE

[1] Traffic Safety Facts 1999. DOT HS 809100. NHTSA, U.S. Department of Transportation, 2000

[2] www.epp.eurostat.ec.europa.eu

[3] *Population projections of the United States by Age, Sex, Race, Hispanic Origin, and Nativity: 1999 to 2010*. U.S. Bureau of the Census, U.S. Department of Commerce, 2001

[4] **Daigneault G.**, **Pierre J.**, **Frigon J.**, *Previous convictions or accidents and the risk of subsequent accidents of older drivers*, Accident Analysis and Preventions, Vol. 34, 2002

[5] **Bukljaš Z.**, **Čuljak I.**, **Zovak G.**, *Using traffic conflict method in evaluating traffic safety at the reconstructed intersection*, Promet Traffic & Transportation, Vol 14, 3/2002, pp. 135-139.

[6] **Zebec S.**, **Zelenika R.**, **Zecevic S.**, *Measuring the intellectual capital of international carries as logistic operators*, Promet Traffic & Transportation, Vol. 19, 2/2007, pp. 103 - 114

[7] **Kerle A.**, *Older Participants in Traffic*, Faculty of Civil Engineering Maribor, 2002

[8] www.stat.si

[9] **Šteiner S.**, **Herbaj E.**, *Older persons in traffic*, 9th Slovenian Congress on Roads and Traffic, Portorož, October 2008. Ljubljana: DRC - Society for Road and Traffic Research of Slovenia, 2008

[10] **Blomquvist L.H.**, **Peters B.**, *Recent European research on older drivers*, Accident Analysis and Prevention, Vol. 32, 2000, pp. 601-607

[11] **Burkhardt J.E.**, **McGavock A.T.**, *Tomorrow's Older Driver who? How Many? What Impacts?*, Transportation Research Record 1693, Paper No. 99-1501, pp. 62-70

[12] **Dulisse B.**, *Older Drivers and risk to other road users*, Accident Analysis and Prevention, Vol. 29, 1997, pp. 573-582

[13] **Eck. R.W.**, **Winn G.**, *Older-Driver Perception of Problems at Unsignalized Intersections on Divided Highways*, Transportation Research Record 1818, Paper No. 02-2365, pp. 70-77

[14] **Lobjois R.**, **Cavallo V.**, *Age-related differences in street-crossing decisions: The effect of vehicle speed and time constrains on gap selection in an estimation task*, Accident Analysis and Prevention, Vol. 39, 2007, pp. 934-943

[15] **Lord D.**, **Schalkwyck I.**, **Chrysler S.**, **Staplin L.**, *A strategy to reduce driver injuries at intersection using more accommodating roundabout design practices*, Accident Analysis and Prevention, Vol. 39, 2007, pp. 427-432

[16] **Mori Y.**, **Mizohata M.**, *Characteristics of older road users and their effect on road safety*, Accident Analysis and Prevention, Vol. 27, 1995, pp. 391-404