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CRASHES COMPARISON BEFORE AND AFTER SPEED CONTROL CAMERAS INSTALLATION: CASE STUDIES ON RURAL ROADS IN LITHUANIA AND ITALY

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ABSTRACT

The study focused on the appraisal of the effectiveness of fixed speed control cameras regarding the reduction in crashes on the main study road in Lithuania. The task is to install the same technical reliable and validated solutions on homogeneous road sections in Italy that reflect the same geometric, traffic features as well as driver speed behaviour than those observed in Lithuania. The case studies were Via Baltica in Lithuania and S.P.430 in the Southern Italy. Three main roads belong to Via Baltica (A5, A8, A10) where a total of 191 crashes occurred during five years (2009−2013) of study with 276 injuries and 69 deaths. A total of five fixed speed cameras were placed on A5 road, two on A8 road and four on A10 road. After the installation of the speed control cameras, it was observed in two years a reduction in the number of crashes with deaths (51%) and injuries (27%) as well as a decrease in the crash rate values (19%). The case study in Italy was S.P.430 that consists of fourteen homogeneous road sections on basis of the curvature change rate evaluation and administrative government. A total of 138 crashes with 246 injuries and 20 deaths were recorded in 2009−2013 on a total length of 73 km almost. According to Italian methodology based on the calculation of crash rates for homogeneous road sections, the crash levels have been associated with each study road section. It was observed *that 79% of the sections are characterized by a low crash level and the remaining 21% by a severe crash level. S.P.430 road sections with a severe crash level are potential locations with speed control cameras. As speed control cameras are missing in S.P. 430, there si no a remarkable reduction in the number of the crashes during the years as happened in Lithuania by similar infrastructural, land context, driver speed behaviour features between two cases study.*

Key words: Rural Roads, Speed Control Cameras, Crashes

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1. INTRODUCTION AND LITERATURE REVIEW

One way to compensate for human information processing limitations is to design the roadway environments by the driver expectations; the user's behavior is difficult to predict as it is influenced by human [1-3], infrastructural [4-6] and environmental [7-9] factors. The design consistency refers to the conditions whereby the roadway geometry does not violate driver expectations [10]. As such, most evaluations of the highway geometric design consistency are based on operating speed profile analysis, which relates safety with speed variability Castro et al [11]. Examples of working systems are provided, as well as guidelines for implementation in Dell'Acqua et al [12-15], Esposito et al. [16-17] and Capaldo and Grossi [18]. Many researchers have dealt with the calibration and validation of the operating speed prediction models (85th percentile speed) on the tangent segments and on circular curves [19-29] by analyzing the impact on the driver speed behaviour of several explanatory geometric and no-geometric variables (i.e. road section length, curvature, distance from nearby intersections, pavement distress, presence of the residential driveways, ecc.). Furthermore approaching a curve and leaving the curve behavior has been carefully studied for detecting the deceleration and acceleration rates Russo et al. [30]. Experimental researchers found that as design consistency increases, the number of crashes decreases significantly. The consistency prediction model is used during the design process or during the evaluation process for highways for changing the road alignment and selecting countermeasures for improving road safety conditions [31-33]. Hasan [34] identified road dangerous situations on roads by using a classification tree based model; two traffic indices types have been formulated to aid the hazard mitigation strategies: traffic flow and vehicle speed only. Gintalas et al. [35] evaluated the quality of design solutions in terms of traffic safety in the objects of Gravel Roads Paving Programme (Programme) through the use of the design method applied in West European countries, which is based on safety criteria and it enables to evaluate traffic safety not only on the existing but the designed two-lane suburban roads. Dangerous road sections were identified, and the analysis of the real or the predictable accident rates on these sections was carried out. Celik and Senger [36] determined risk factors affecting the fatal versus non-fatal accidents in a rural region of Turkey, during 2008-2012, considering variables associated with the individual, the environment, and the motor vehicle. Dell'Acqua et al. [37] have plotted risk-type density diagrams to examine the safety conditions of different road scenarios where particular safety problems on the road network might arise. Afterwards, it was also observed that the age and gender of drivers considered together further refines how the infrastructural factors can contribute to crashes. Structural road interventions and/or safety awareness campaigns are planned to reduce the injury crash rate for each gender and road scenario: the awareness campaigns cannot be generalized but must be organized by age and gender, because the crash dynamics alter as these factors change, with consideration for the varying psychological traits of the driver groups [38]. It is envisioned that a complementary relationship would then exist between design speed, operating speed, and posted speed limits [39]. Most engineering approaches on the speed limit setting are based on the 85th percentile speed that enables to identify thresholds for an acceptable speed behavior and an unsafe speed behavior that causes a highest probability of the crash risk. Sensors to monitor prevailing traffic and/or weather conditions, as well as the input from transportation professionals and law enforcement, can help to identify an appropriate enforceable speed limits that might be clear on dynamic message signs [40]. Hoye [41] analysed the effects of the speed cameras that were installed between 2000 and 2010 in Norway through a before-after empirical Bayes study. On road sections between 100 m upstream and 1 km downstream of the speed cameras a statistically significant reduction of the number of injury crashes by 22% was found. Čygaitė et al. [42] provided an overview of the impact of vehicle speeds on road safety and the effects of safety improvement measures. Excess speed is one of the largest road safety problems causing the increased risk of road crashes. Possibilities for the implementation of sectorial vehicle speed enforcement system on the national roads of Lithuania have been presented. Benekohal et al. [43] investigated the effectiveness of speed photo enforcement (SPE) by radar in reducing speeds in work zones in the United States. It was observed that the reduction of the mean speed varied from 3.2 mph to 7.3 mph. The percentage of vehicles exceeding the speed limit near SPE was reduced from about 40% to 8% for free-flowing cars and from 17% to 4% for free-flowing heavy vehicles. Near the SPE van, none of the cars exceeded the speed limit by more than 10 mph, and none of the heavy vehicles exceeded it by more than 5 mph. Woo et al. [44] examined the effectiveness of SMDs (speed-monitoring displays) with the enforcement cameras on the speed reduction. Speed data of free-flowing vehicles were collected before and after the SMD and the enforcement cameras were installed. Speed data were also collected with the SMD turned off and then on again. The results showed that mean speeds of vehicles were significantly reduced after SMD and camera installation. Lee et al. [45] investigated the effectiveness of the speed-monitoring displays (SMDs) for speed reduction in school zones. The analysis of the results of the speed distribution showed that the number of speeding vehicles was greatly reduced after the SMD was installed, and the 85th percentile speed also decreased from 54.3 km/h to 46.3 km/h and 45 km/h in the short-term and the long-term studies, respectively.

2. DRIVING SPEED CONTROL SYSTEMS

2.1. Tools in Europe

Driving speed control systems are divided in two main groups:

- Stationary systems supervised by the police agents that enable to stop offenders for speeding while the violations are recorded;
- Speed cameras where the police control is missing and they can be unmovable or mobile type with or without support of variable message signs.

The speed cameras are hidden from the view of the drivers to check real driving performance downstream of a warning sign of a speed control section or clear visible to get lower speed at a specific location associated with a warning sign. Table 1 shows an overview of the effects on the crashes reduction of mobile and fixed cameras that are hidden or visible to drivers [46].

Table 1 Overview of the safety effects of speed cameras (SafetyNet 2009)

Road type	Method type	Effect on crashes
Urban	Fixed speed cameras	minus 28%, all crashes
Rural	Fixed speed cameras	minus 18%, all crashes
Urban	Fixed speed cameras	minus 22%, personal injury collisions
Urban	Mobile speed cameras	minus 22%, personal injury collisions
Rural	Fixed speed cameras	minus 33%, personal injury collisions
Rural	Mobile speed cameras	minus 15%, personal injury collisions
Rural	Fixed speed cameras	minus 20%, injury crashes
Rural	Mobile hidden speed cameras	minus 21%, injury crashes involving a motor vehicle
Highways	Mobile speed cameras	minus 25%, daytime unsafe speed related crashes
Highways	hidden speed cameras (extra effect above visible cameras)	minus 11%, all crashes

2.2. Tools in Lithuania and Italy

In Lithuania, the Administration began to install speed control cameras at the most dangerous road sections on basis of point where speeding is recorded. A total of 139 fixed MultaRadar S580 cameras type (Figure 1a) and 11 mobile MultaRadarC cameras type (Figure 1b) were placed in Lithuania.

1a Fixed camera 1b Mobile camera

Figure 1 Speed control cameras in Lithuania

Speed cameras record time, vehicle speed, travel direction and vehicle type; the tools works for temperatures between -32C to +50C. It is associated with an electronic anti-vandal system which records any destruction attempts and it sends real-time vandal alerts to Public Police Security Service.

In Italy, speed control devices are divided into three main categories as follows:

- Autovelox device. This speed control system involves different tools type such as follows: 1. mobile laser detectors; 2. fixed laser detectors; 3. video equipment that allows to assess the speed of the travelling vehicles through a camera usually placed on board the cars of the Traffic Police. As clarified above, the laser detectors can be mobile types (laser on a tripod beside the highway – Figure 2a, laser gun – Figure 2b, on board car equipment – Figure 2c) and fixed types (hidden camera in a metal box – Figure 2d and a visible camera on the top of a pile – Figure 2e). Mobile lasers that are placed on a tripod remain often hidden from the view of drivers that might alter their speed since they see the tool. More broadly, the detector emits and receives a pair of laser beams and it records the time, instantaneous vehicle speed, vehicle length and both travelling directions for each vehicle;

- Vergilius (Figure 2f) system. The speed control system named “Vergilius” is placed more on rural roads than on other types of highways. The tool detects on one hand the instantaneous speed, as made by the laser detectors, and on the other hand the average speed, as the Tutor system makes on the freeways. “Vergilius” device differs from “Tutor” device because sensors inside the road pavement are missing to collect data and just cameras exist on the top of the portals to record measurements;
- Tutor system (Figure 2g) allows to estimate the average speed of vehicles on the freeways and it makes clear some travel information to drivers. The device consists of sensors embedded in the asphalt and portals with cameras; it makes possible to assess the average speed on road sections’ lengths between 10 km and 25 km. Tutor device works both during nighttime and under all weather conditions. The average speed is calculated by using travel time between two consecutive portals. Speed data lower than the limits are removed from the database. This speed control system was installed on more than 2500 km of highways length where the number of the fatalities was the highest than the remaining zones.

2a Laser on a tripod

2b Laser gun

2c On board car equipment

2d Hidden camera in a metal box

2e Visible camera on the top of a pile

2f Vergilius system

2g Tutor system

Figure 2 Speed control systems

3. DATA COLLECTION

The total length of the road network in Lithuania with reference to the only freeways and rural highways covers almost 21252 km in Lithuania and 26587 km in Italy. The number of the habitants in Lithuania is about 3 million while almost 60 million of people live in Italy. No tunnels are built in Lithuania because the most of roads cross flat terrains. In 2013, the total number of crashes on the freeways and rural roads in Italy was 44789 with 1964 deaths and 72738 injuries. It was observed a reduction of the crashes number and fatalities from 2012 to 2013 as follows (based on the Italian National Institute of Statistics data):

- decrease of 3.7% for crashes;
- decrease of 3.5% for injuries;
- decrease of 9.8% for deaths.

Based on the Lithuanian Road Administration under the ministry of Transportation and Communication data, during 2013, in Lithuania it was observed a total of 3391 road crashes with 256 deaths and 4007 injuries for the study road network as explained above. An increase of the crashes number and injured people it was observed from 2012 to 2013 as follows: a. increase of 2.68% for crashes; b. increase f 1.39% for injured people.

During the same study period it was observed a reduction in deaths of 15.23% almost. A comparison between Lithuania and Italy of the total number recorded in 2013 of the deaths and injuries over the respective total number of the habitants gave as results a normalized number of deaths and injuries greater on the study Lithuanian network than that analyzed in Italy (Figure 3).

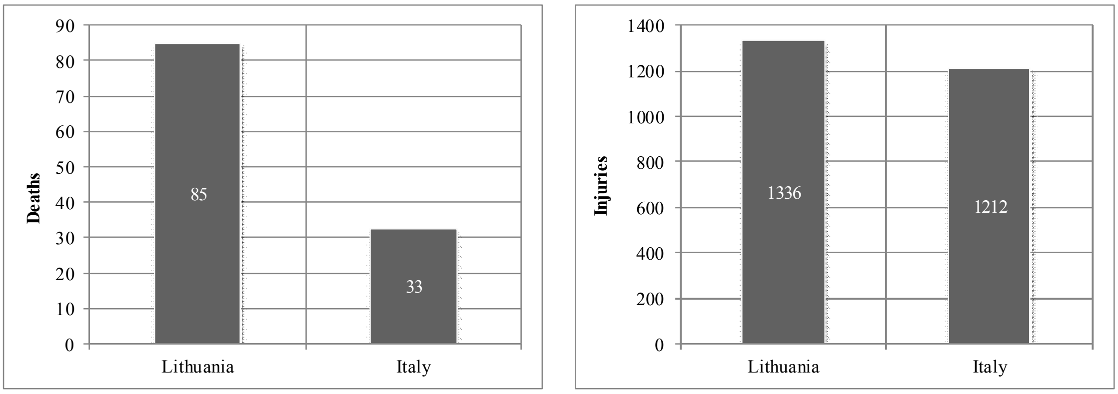

Figure 3 Number of deaths and injuries over million habitants in 2013

3.1. I Case Study: "Via Baltica" in Lithuania

The European highway E67 is called "Via Baltica"; it begins in Prague in the Czech Republic and ends in Helsinki in Finland passing through Poland, Lithuania, Latvia and Estonia. It is the most important road connecting the Baltic countries and it mostly crosses flat terrain where thick pristine forests of fir trees live behind on the edge.

Lithuania road E67 is flanked by a national numbering A4 Vilnius – Varėna – *Grodno (territory of the Republic of Belarus) that continues from Warsaw through all Baltic states to Tallinn. The road consists of three main roads A5 Kaunas – Marijampolė – *Suvalkai (territory of Poland), A8 Panevėžys – Aristava – Sitkūnai and A10 Panevėžys – Pasvalys – *Ryga (territory of Latvia) (Figure 4). One lane for each travel direction with paved shoulders characterize the cross dimension. The speed limit is largely 90 km/h.

Figure 4 Via Baltica's layout in Lithuania

Table 2 shows a synthetic overview of the main geometric, traffic and crash features of the study road sections on Via Baltica road infrastructure. From 2009 to 2013 a total of 191 crashes occurred, with 276 injuries and 69 deaths. The highest number of crashes occurred during the nighttime (58%), while during the daylight hours occurred 42% of total crashes. It was observed that the main crash type was the collision with car (59%); collisions with pedestrian occurred in 21% of the total cases and collisions with bicycle or animal occurred in 19% of the total cases. Table 2 shows how the number of crashes, injuries and deaths on A5 road is twice than the remaining study roads. Control speed cameras have been placed on the rural road: five have been installed on A5 road, two on A8 road and four on A10 road. More analyses were focused on road sections near at grade intersections where a speed limit of 70 km/h exists on Via Baltica. This value reflects an overall existing speed limit on the study Italian rural road equals to 80km/h.

Table 2 Overview of the main geometric, traffic and crash features of Via Baltica road sections

Features	Mean value		
Carriageway width, m	9.00		
Lane width, m	3.50		
Shoulder width, m	1.00		
AADT, vpd	8644		
Road section	**from 2009 to 2013**		
	crashes	**injuries**	**deaths**
A5	103	151	34
A8	45	68	15
A10	43	57	20

The first location is placed on A5 road at 67.60th km (Figure 5a) where during a two years of the study (from 2010 to 2011), a total of two crashes were recorded with four injured people. The results confirmed that no crash occurred after the speed camera was installed. The second study area was near a oil station between two following local at grade intersections (Figure 5b) from 53.1 km to 53.8 km on A8 road. During a study of four years (from 2009 to 2012) a total of five crashes have been recorded with six injured people and one death. The results confirmed that one crash occurred with one injured person after the speed camera was installed. The last investigated location is located at 59.70th km on A10 road (Figure 5c) where a total of two crashes during a two years-study (from 2010 to 2011) occurred with four injuries and four deaths. The results confirmed that no crash occurred after the speed camera was installed.

5a A5 section 5b A8 section 5c A10 section

Figure 5 Control speed cameras on road sections in Via Baltica

3.2. II Case Study: S.P. 430 in Italy

The highway S.P. 430 is one of the most important two-lane rural roads in the Southern Italy (Figure 6). The total length is 72.65 km; it begins in Capaccio and ends in Sapri Bussentino; the road is located on flat/rolling area with a vertical grade of less than 8%, approximately. Table 3 shows a synthetic overview of the main geometric, traffic and crash features on the study road. Some geometric elements of S.P. 430 are as follows: a. a total of 99 circular curves with a curve radius between 250 m and 3000 m; b. a total of 77 tangents with a maximum length of 1757 m; c. a total of 17 tunnels with a length between 40 m and 1368 m; d. a total of 48 viaducts with a minimum length of 32 m and a maximum length of 717 m.

The climbing lanes exist when the vertical grade is equal or greater than 6%; they run along Capaccio-Sapri direction covering 12.25 km while in the opposite direction the total length is 10.95 km. It was observed that the main crash type was single-vehicle run-off-road crashes (51%); head on side collisions occurred in 37% of the total cases and rear-end collisions occurred in 12% of the total cases.

6a cross sections type

6b Speed control device powered with alternative energy

Figure 6 S.P. 430 study rural road in Italy

Table 3 Overview of the main geometric, traffic and crash features on S.P. 430

Geometric and traffic features	
Carriageway width, m	10.50
Lane width, m	3.75
Shoulder width, m	1.50
Annual Average Daily Traffic, vpd	6000
Crash features	
Number of crashes from 2006 to 2010	138
Number of injuries from 2006 to 2010	246
Number of deaths from 2006 to 2010	20
Crashes during nighttime	38%
Crashes during nighttime hours on wet road surface	21%
Crashes during nighttime hours on dry road surface	17%
Crashes during daylight hours	62%
Crashes during daylight hours on wet road surface	31%
Crashes during daylight hours on dry road surface	31%

According to Highway Safety Manual (HSM) of American Association of State Highway and Transportation Officials by 2010 procedure, homogeneous road sections have been identified on S.P. 430 through the characterization of the curvature change rate parameter. First of all, HSM defines a roadway section as a section of continuous traveled way that provides two way operation of traffic, that is not interrupted by an intersection, and consists of homogenous geometric and traffic control features. A roadway section begins at the center of an intersection and ends at either the center of the next intersection, or where there is a change from one homogeneous roadway section to another homogenous section. The curvature change rate (CCR in gon/km) is defined as the sum of the absolute values of angular changes in the horizontal alignment divided by the total length of the road section. A homogeneous roadway section is characterized by an almost constant slope and it includes or not includes more than one tangent and circular curve; the curvature change rate is defined low - when CCR is less than 50 gon/km, medium - when CCR is less than 400 gon/km and greater than 50gon/km, high - when CCR is greater than 400 gon/km [30]. S.P. 430 was divided in fourteen homogeneous road sections according to CCR parameter (Table 4). The study that is addressed to driver speed behavior investigation on rural roads belongs to a wider research program under way from several years now [47-53]. Research management, special problems, new approaches, future issues and innovations, not limited to rural roads are addressed in [54-59].

4. RESULTS

To assess the safety level of the traffic conditions at each road segment investigated on S.P. 430, a procedure that has been developed by the Italian National Research Council CNR n.13465, 11/09/1995 - Criteri per la classificazione della rete delle strade esistenti ai sensi dell' art.13, comma 4 e 5 del Nuovo Codice della Strada - has been implemented. The method consists of several steps as follows:

- calculating the crash rate Ti of each road section i-th defined as the total number of crashes during the study period (n) per year per km per 106 vehicles (crash frequency over traffic exposure);
- calculating the mean value of the crash rates (Tm) of the road sections belonging to the homogeneous sections;
- calculating the threshold values of the crash rates for each road homogeneous section i-th under Poisson distribution of the crashes as follows:

$$lower\lim it \Rightarrow \quad T_{i,lower} = T_m - 1.645 \cdot \sqrt{\frac{T_m}{(365 \cdot \sum_i L_i \cdot \sum_{j=1}^{n} AADT_j)} \cdot \frac{1}{2 \cdot (365 \cdot \sum_i L_i \cdot \sum_{j=1}^{n} AADT_j)}} \tag{1}$$

$$upper\lim it \Rightarrow \quad T_{i,upper} = T_m + 1.645 \cdot \sqrt{\frac{T_m}{(365 \cdot \sum_i L_i \cdot \sum_{j=1}^{n} AADT_j)}} + \frac{1}{2 \cdot (365 \cdot \sum_i L_i \sum_{j=1}^{n} AADT_j)} \tag{2}$$

- defining the crash level of each investigated homogeneous road section as follows:

$$T_i \le T_{i,lower} \text{ Low crash rate} \tag{3}$$

$$T_{i,lower} \le T_i \le T_{i,upper} \text{ Medium crash rate} \tag{4}$$

$$T_i \ge T_{i,upper} \text{ Severe crash rate} \tag{5}$$

Table 4 shows a summary of the crash rates and crash level of each study road section on S.P. 430. The results have showed a percentage of 79% of the total number of the homogeneous road sections characterized by a low crash level and the remaining 21% by a severe crash level.

Table 4 Crash rates of the homogeneous road sections on S.P. 430

Section SP430	Length of the road section (km)	AADT (vpd)	Total number of crashes	Accident rate coefficient (T_i)	Crash level
1	4.033	8920	29	0.178	low
2	1.612	10925	3	0.093	low
3	3.006	6554	10	0.278	low
4	3.500	6146	18	0.459	low
5	5.836	7877	7	0.495	low
6	6.034	5167	2	0.156	low
7	4.114	4663	13	0.371	low
8	4.592	3569	3	0.100	low
9	2.832	3336	1	0.145	low
10	2.118	7057	11	0.140	low
11	4.404	742	5	0.839	severe
12	3.016	1417	6	0.769	severe
13	2.084	443	6	3.561	severe
14	2.176	6016	24	0.305	low

The severe crash level has been observed on three homogeneous road sections where speed cameras control systems are not installed: S.P. 430_11; S.P. 430_12; S.P. 430_13 (Figure 7).

7a SP430 layout 7b SP430_11 7c SP430_13

Figure 7 Homogeneous road sections on S.P. 430 under severe crash rate level

5. CONCLUSIONS

This analysis is the first phase of a larger study that will be carried out step by step in the near future addressed to the evaluation of the speed camera control systems' effectiveness in the reduction of the crashes number.

The beginning of the analysis was an experimental investigation carried out in Lithuania; in particular, Via Baltica that is a two-lane rural road with an overall speed limit of 70 km/h has been the target.

The results confirmed the forcefulness and validity of the selected device as technical solution to be pursued and installed on other sites where geometric, traffic, infrastructural features are similar than those observed in Lithuania.

At the same time a crash analysis has been carried out on a two-lane rural road in Italy named S.P. 430 whose general features reflect those observed on Via Baltica.

A procedure available in the national guidelines that is based on the crash rates calculation has been performed and a crash level has been associated with each study road section.

It was observed how the sites where severe crash level is touched are avoid of speed control systems. Since road scenario on the most dangerous road sections belonging to S.P. 430 reflect those observed on Via Baltica, speed camera as control systems are suggested for improving safety conditions.

Future developments will be addressed on one hand to the data collection after the installation of the devices on Italian study sites and on the other hand on the analysis of the variation of the speed driver behavior before and after speed cameras control systems setting up.

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