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THE STUDY OF THE DYNAMICS OF TRAFFIC ACCIDENTS USING THE CONTROL CHARTS

The aim of this article is an attempt to use the control chart for the average to study the dynamics of traffic accidents in selected European countries. The study covered the three countries: Poland, Ukraine and Sweden for the period 1993-2008. The obtained results were compiled with the European average-annual number of accidents for 42 countries. The analysis confirmed that according to common opinion Sweden has the lowest average of accidents, while Ukraine oscillates around the European canon, which may be surprising, considering the fact that Ukraine is seen by many as a country with low and high culture of driving accidents. The analysis showed that the worst ranks shows Poland, which differs significantly from the European average in spite of the positive trend noticeable since 1997. It was also found that the liberalization of rules and increase the number of cars contributed negatively to the increase in the number of accidents (Ukraine), and exacerbation of traffic regulations had a positive impact on test feature (Poland). It should be emphasized that the website of the European Economic Commission, which the data were collected from has no information for subsequent periods. It is therefore difficult to determine whether the positive trend of Poland development remains at a similar level, and within the next four years, i.e. until 2012 it managed to get closer to the expected level in Europe. In the case of Ukraine the opposite trend can be observed, but again for the same reasons it is hard to determine whether the negative trend was prevented. It is also not possible to examine what impact on the development of the number of accidents in Poland and Ukraine had the organization of mass events such as Euro2012 and related with it multimillion-dollar expenditure on the improvement of road infrastructure.

Keywords: control charts, traffic accidents, dynamics, the average.

1. INTRODUCTION

Monitoring of socioeconomic processes is one of the essential tasks of the Department of Mobility and Transport of the European Commission. It aims at the qualitative improvement of the phenomena being observed, the maintenance of the observed positive trends, as well as counteracting the negative trends in terms of both time and space. Extensive use of econometric methods had been widely used here, in particular those related to the analysis of time series. However, the scientists are constantly looking for the alternative methods for the analysis of dynamic phenomena.

This work places emphasis on the attempt to use the control chart for the average in the study of the dynamics of traffic accidents in the three selected European countries in the period 1993-2008.

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2. CONTROL CHARTS – METHODOLOGY

Waler Shewhart is considered to be the father of control charts, who first adapted it to practical purposes in 1924[2] [1]. The basis for their use is the belief that the internal (natural) variability, characteristic for each process, can be controlled independently of external factors (non-accidental) which negatively affect the investigated phenomenon. Their appearance will force a change process and bring it up to standard.

Depending on the type of tested feature and the underlying process it is possible to choose from many types of control charts such as: the chart of average value and range chart (X and R), the chart for the average value and standard deviation (X and S), the chart for median and range chart (MR) and the special charts with the moving average (MA), cumulative sum (CUSUM), or similar for measurable features and immeasurable ones: the fraction of non-compliant chart (chart p or np) and for the number of non-compliance for one unit (chart z or u). In this work for the analysis, the charts for the average value had been used.

An important added value of his method is simple and clear presentation with diagrams maintenance, which resemble simple line graphs where the x-axis the number is plotted, while the y-axis the value of the collected sample. The scheme is supplemented by the top and bottom control line (*Upper and Lower Control Limit)* and the central line *(Central Line).* Customarily, it is assumed that the value of the control limits are a multiple of the standard deviation, while the central line is desired for a given process size around which the observed values of the sample[3] [2] should oscillate. The result of these annotations is presented below in Figure 1.

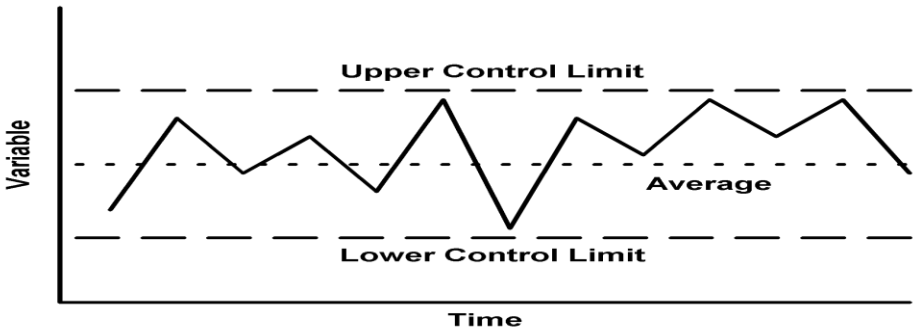


Fig. 1. The graphical presentation of the control chart with inlaying demonstrative control lines [4]

The analysis of control charts focuses on the controlling of the tested process for its stability. It is assumed that the process is under control if the observations do not exceed the control lines.

[2] M. Best i D. Neuhauser, „Walter A Shewhart, 1924, and the Hawthorne factory," *Quality and Saety in Health Care*, vol. 15, no 2, pp. 142-143, 2006

[3] M. L. Berenson, D. M. Levine i T. C. Krehbiel, Basic Business Statistics, Prentice Hall, 2012.

[4] Source: http://www.tangram.co.uk/

3. THE RESULTS OF THE ANALYSIS

Detailed analysis of the dynamics of traffic accidents with the usage of control charts have been conducted in case of two developing countries: Poland, a transit country between the Eastern Europe and the West, which is the member of the European Union; Ukraine, in which the road law is considered a significantly liberal and in contrast one of the Scandinavian countries, Sweden, considered to be highly developed, where the culture of driving and the quality of roads is at a high level, and the penalties for driving offenses are a deterrent high. In this case data derived from the Economic Commission for Europe (ECE)[5] had been used. Individual data had been compared with the average results for Europe.

In the first stage of the analysis the control chart for the average value for all 42 European countries had been used. Data downloaded from ECE were presented for each country on a monthly basis. To be able to adapt them for the purpose of control charts, the average values for each month had been determined and then the monthly average values had been aggregated to the annual average. The central line equals to 3.587 was determined as the average value determined for all subjects of observations. Upper and lower control line were taken as three times the standard deviation and are respectively 3.961,9 and 3.312,1[6].

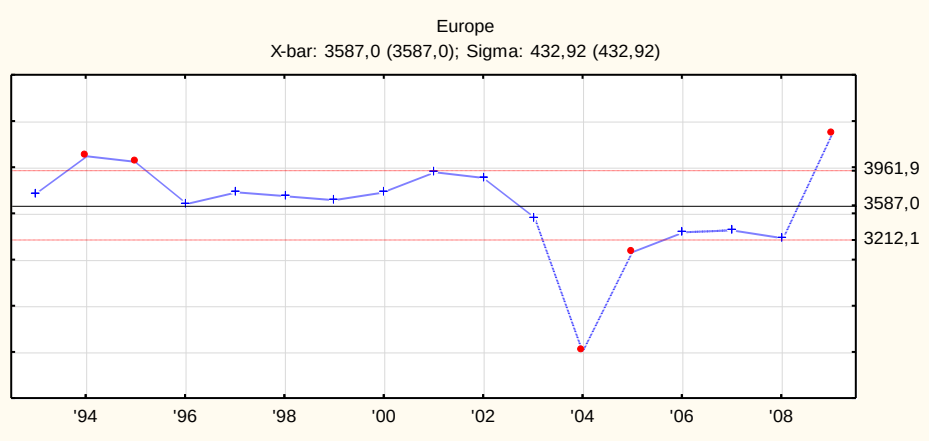
Figure 2 shows the graphical representation of the control chart for the average including all European countries. It is assumed that the process is out of control if the observation exceeds one of the limits, upper or lower. However, because of the nature of the tested features i.e., road accidents the fact that they exceed the top control line is alarming because the value below the lower control line indicates a positive development of the studied phenomenon. It is clear that the warning signal is generated for the years 1994, 1995 and 2009. The average of accidents in these years is more than four thousand. Countries which systematically overestimated the European annual average of accidents are: Poland, Portugal, Russia, Spain, Turkey, Italy, France and England. It is clear that the developed countries dominate on this list, what can be surprising, because in current opinion of many, in the developing countries the proportion of accidents is the highest, the culture of driving is low, the infrastructure is unsatisfactory. This is reflected even in the warnings for tourists who want to come to the territory of that country using their own car, while the developed countries are considered to be safe and friendly for drivers. The presence on the list such countries as England, Italy or France can be explained by a higher proportion of cars per capita which gives statistically a greater probability of the occurrence of an accident or collision than in the case of countries in which the amount of traffic is lower. According to data from the World Bank at the beginning of the 1990s an average on 1.000 residents in developed countries accounted for not less than 300 cars (in most Western European countries this number ranged between 400-500 with the exception of Germany and Italy where the percentage was above 500)[7].

[5] http://w3.unece.org

[6] Details of the techniques of calculation and design of control charts are available in:
[5]Levinson, W. A., 2011. *Statistical Process Control for Real-World Applications.* p.l.:CRC Press.
[6]Zontec, 2010. *The Book of Statistical Process Control.* Second Edition ed. p.l.:The Zontec Press Cincinnati.

[7] http://data.worldbank.org

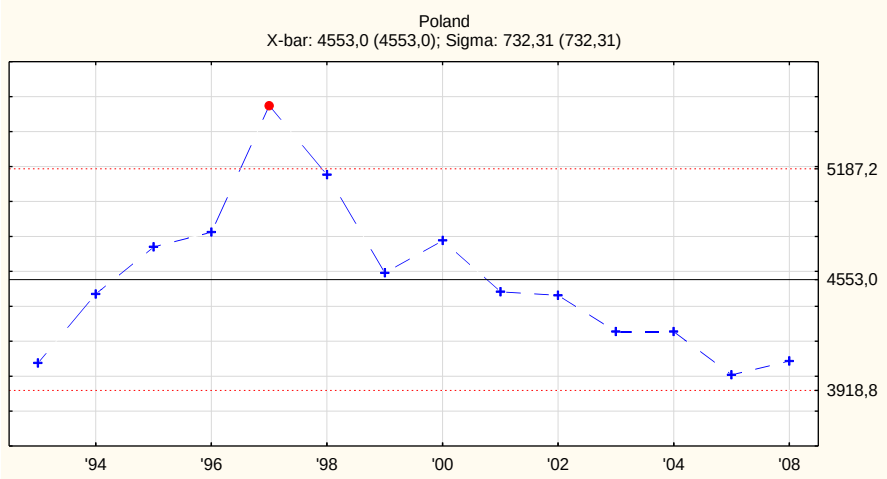
Fig. 2. The graphical presentation of the control chart for the average for Europe



The use of control charts for Poland (Fig. 3.) showed that the year 1997 turned out to be the critical one, where the average annual number of accidents was higher than 5.000. The observations for the remaining years oscillating around the average of 4.553 located in the critical area, also designated as three times the standard deviation – 5.187 and 3.919 respectively. A clear downward trend of the average number of accidents can be observed in the Republic of Poland, starting from the critical year 1997 which continues until the end of analyzed period. The reason for the decreasing trend in Poland may be the Law on Road Traffic passed on 20 June 1997, which among other things provided for the use of lights in autumn and winter, the use of seat belts in cars also in the back seat as well as far more effective fight against driving under the influence of alcohol and the prevention of alcoholism[8] [3].

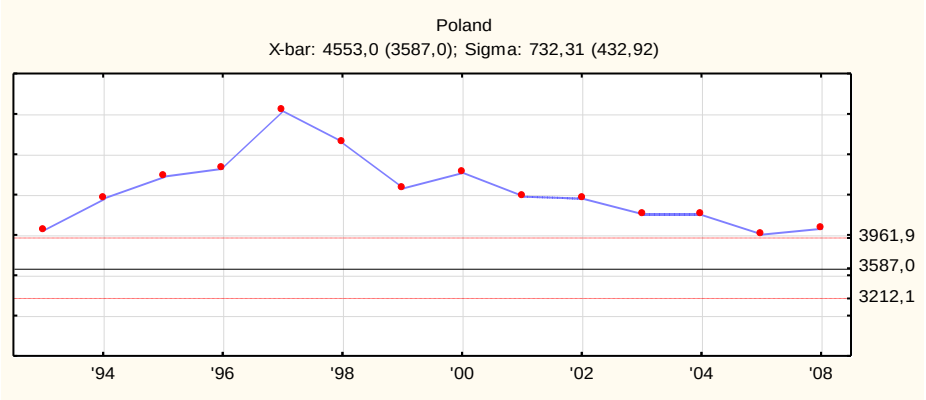
[8] J. Moskalewicz i J. Żulewska-Sak, „Alkohol w latach transformacji ustrojowej w Polsce. Raport z realizacji celu operacyjnego Narodowego Programu Zdrowia."

Rys.3. The graphical presentation of the control chart for the average for Poland



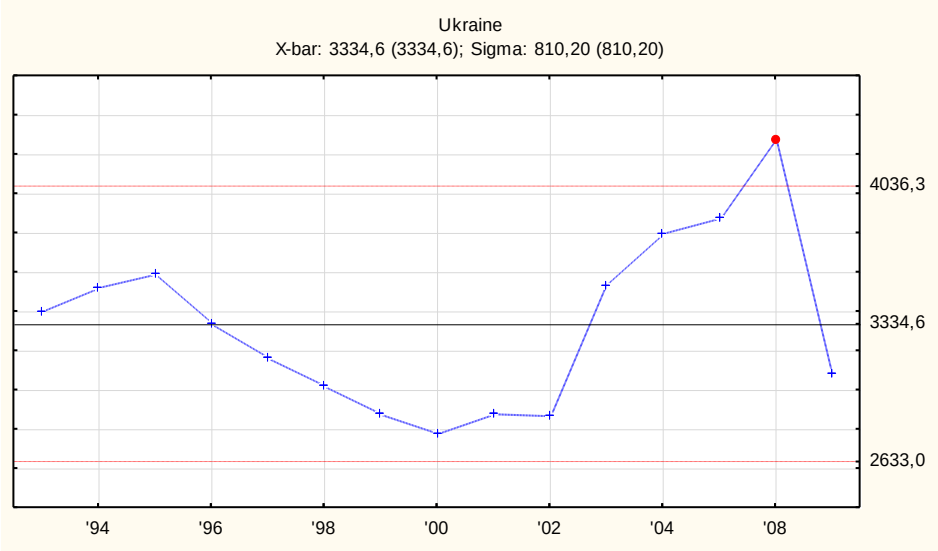
The results of the analysis for Poland May be appealing especially a positive development trend showing a decreasing number of accidents. However, the adoption of the European average equal to 3.587 as the central line and applying it to a control chart for Poland (Fig.4) shows clearly how far Poland from the Europe is. Even in the years where the number of accidents was below 4.000, i.e., in 1993 and 2007 the average number of accidents is not situated below the upper limit of the control set on the European database. The lack of database for subsequent periods does not allow to determine whether the positive downward trend resulted in the achievement of average at the acceptable European level.

Fig. 4. The graphical presentation of the control chart for the average for Poland where the central line is the average for Europe



A similar analysis was conducted for Ukraine (Fig.5 and 6). The results, however, significantly differ from those for Poland. The main difference is the central line (3.335), which is lower than the European average, but with a greater standard deviation. The Report of Ukraine from 2008 prepared by the Oxford Business Group[9] [4] as an important cause of the increase of accidents in Ukraine until 2008, the year in which the number of accidents has increased almost doubled compared with the year 2000, provides a significant increase in the number of cars and the liberalization of road regulations.

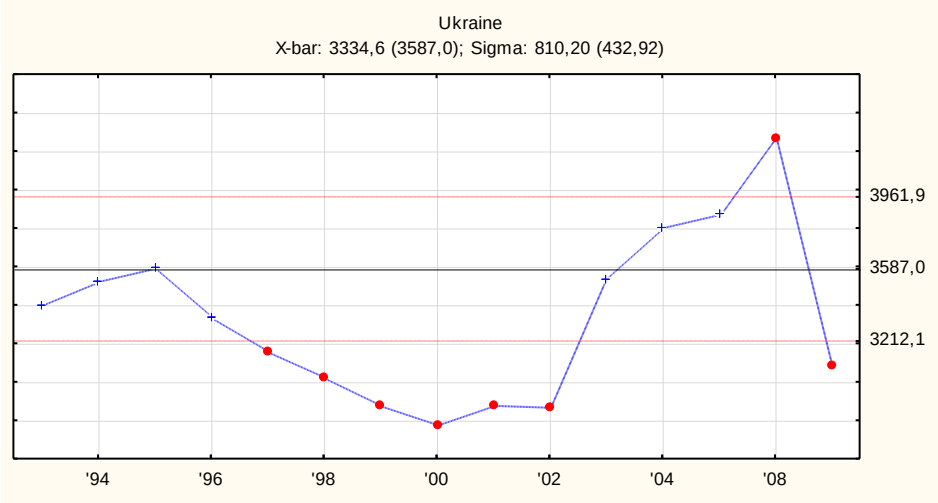
Fig.5. The graphical presentation of the control chart for the average for Ukraine



Comparing Ukrainian results with the European average and taking into account the fact that the annual average for Ukraine was lower than the European, it is not surprising that the modified control chart (Fig.6) is confusingly similar to the original chart and the only year in which there was the upper limit is the year 2008.

[9] „The Report Ukraine 2008," Oxford Business Group

Fig. 6. The graphical presentation of the control chart for Ukraine, where the central line is the average for Europe



In contrast, the control chart for Sweden has been generated (Fig.7), which presents the average annual number of accidents not exceeding the alarm values throughout the period considered. Only a slight increase in the number of accidents between 2001 and 2003 is noticeable. However, it is worth noting that due to the adopted scale (a small value of the standard deviation) the increase in the graph appears to be significant. Nominally, however, this is an increase of approximately 300 units, which nevertheless does not exceed the upper limit of control, defined at the level of 1.562. as can be seen after 2003 the growth was stopped and the average number of accidents remained at a stable level. Remaining at a high level and being continued the improved road safety program, combined with a very good state of the roads and a high driving culture result in this country having one of the lowest accident rates in Europe and in the world. This is reflected in the Figure 8., presenting the average of accidents for Sweden in the background of Europe, where evidently the two averages differ from each other and even the highest average values of accidents for Sweden are far below the critical value for the European average.

Fig. 7. The graphical presentation of the control chart for the average for Sweden

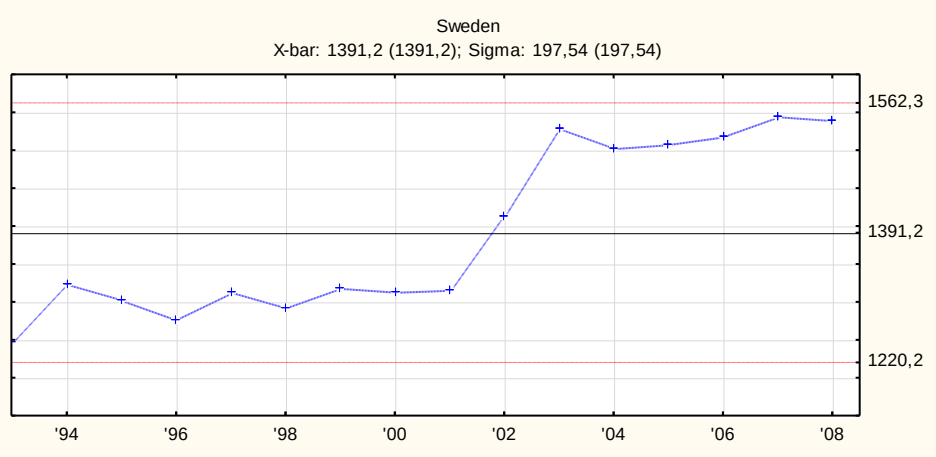
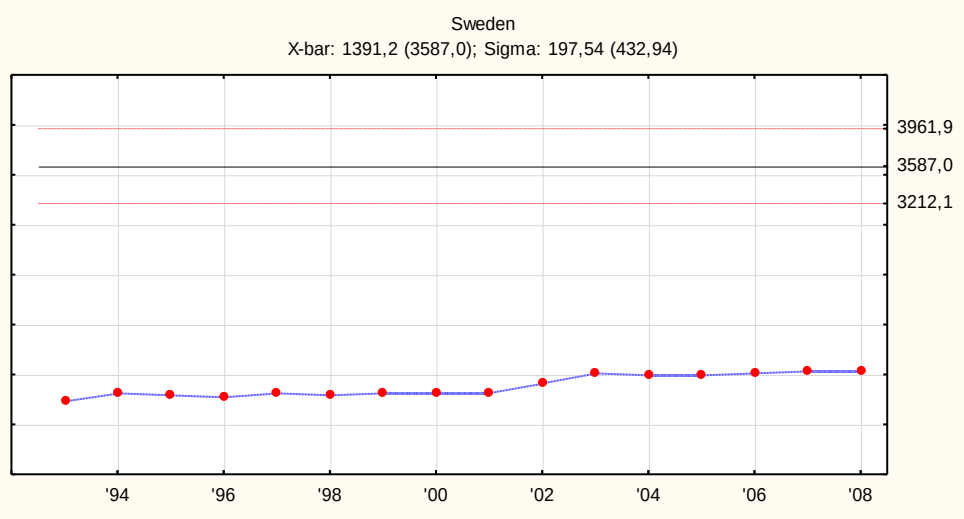


Fig. 8. The graphical presentation of the control chart for the average for Sweden, where the central line is the average for Europe



4. CONCLUSIONS

The aim of the work is an attempt to use the control charts for the average to study the dynamics of traffic accidents in selected European countries. The study covered three countries: Poland, Sweden and Ukraine in the period 1993-2008. The obtained individual results were further combined with a European annual average number of accidents, calculated as the average number of accidents for 42 countries. The analysis confirmed that in accordance with the general opinion that Sweden has the lowest

average of accidents while the Ukraine oscillates around the European Union, which may be surprising considering the fact that Ukraine is seen by many as a country with low driving culture and high rate of accidents. The presented results, however, contradict this thesis. The worst in their rank is Poland, which differs significantly from the European average, despite the positive trend noticeable since 1997. It was also found that the liberalization of regulations and the increase in the number of cars, negatively contributed to the increase in the number of accidents, while tightening the regulations on the roads traffic had a positive impact on the study. It should be emphasized that the website of the European Economic Commission, from which the data for analysis had been downloaded, does not have the data for subsequent periods. Therefore, it is difficult to determine whether the positive trend for the development of Poland remains at a similar level, and within the next four years i.e., until 2012 it managed to get close to the expected European level. In the case of Ukraine, the opposite trend can be observed, but again for the same reasons it is not possible to determine whether the negative trend has been prevented. It is also impossible to examine what impact on the number of accidents in Poland and in Ukraine had the organization of mass event which was Euro 2012, when during the preparations for the championship, both governments put a great emphasis on the development of road infrastructure, however, because of summer months and the organization itself there was heavy traffic on the roads of both countries.

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BADANIE DYNAMIKI WYPADKÓW KOMUNIKACYJNYCH Z ZASTOSOWANIEM KART KONTROLNYCH

Celem pracy jest próba zastosowania kart kontrolnych dla średniej do badania dynamiki wypadków komunikacyjnych w wybranych krajach europejskich. Badaniem objętych zostały trzy kraje: Polska, Ukraina i Szwecja, na przestrzeni 1993-2008 roku. Otrzymane indywidualne wyniki zostały zestawione z europejską średnioroczną ilością wypadków, obliczoną na podstawie średniej dla 42 krajów. Analiza potwierdziła, że zgodnie z powszechną opinią, Szwecja charakteryzuje się najniższą średnią wypadków, natomiast Ukraina oscyluje wokół kanonu europejskiego, co może dziwić, zważywszy na fakt, że Ukraina widziana jest przez wielu jako kraj o niskiej kulturze jazdy i wysokiej wypadkowości. Analiza wykazała, że najgorzej plasuje się Polska, która znacząco odbiega od europejskiej średniej, mimo pozytywnego trendu zauważalnego od 1997 roku.

Stwierdzono dodatkowo, że liberalizacja przepisów oraz wzrost liczby samochodów, negatywnie przyczyniły się do wzrostu liczby wypadków (przypadek Ukrainy), natomiast zaostrzenie przepisów o ruchu drogowym miało pozytywny wpływ na badaną cechę (przypadek Polski). Należy podkreślić, że strona Europejskiej Komisji Gospodarczej, z której pobrano dane, nie dysponuje danymi za kolejne okresy. Trudno zatem stwierdzić, czy pozytywna tendencja rozwojowa Polski utrzymuje się na podobnym poziomie i w przeciągu czterech kolejnych lat, tj. do roku 2012 udało jej się zbliżyć do oczekiwanego poziomu europejskiego. W przypadku Ukrainy obserwować można tendencję odwrotną, jednak znowu z tych samych powodów nie jest możliwym ustalenie, czy negatywny trend został zastopowany. Nie jest również możliwe zbadanie, jaki wpływ na rozwój liczby wypadków w Polsce i na Ukrainie miała organizacja masowej imprezy jaką było Euro2012 i związane z nią wielomilionowe wydatki na poprawę infrastruktury drogowej.

Słowa kluczowe: karty kontrolne, wypadki komunikacyjne, dynamika, średnia.

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