Turkish Journal of Engineering

COMPARATIVE STUDY OF REGIONAL CRASH DATA IN TURKEY

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ABSTRACT
This study provides a comparative analysis of traffic safety in Turkey across the seven geographic regions over a 11 year time frame (2006 to 2016). The comparisons are performed in relative terms and absolute terms. Fatal and/or injury (FI) crashes per million population and per million registered vehicles were used to quantify safety. For the ordinal analysis, rates for the regions were ranked individually for each year as well as for the 11 years aggregated. An examination of the results indicated that the relative ranks of the regions were stable over the study period. Depending on the safety measure used, the relative rankings of regions varied. It means that a region ranked at the top (high crash rate) for one safety measure does not need to be ranked again at the top for other safety measure. For the cardinal analysis, the computed rates were used. These results were consistent with those from the ordinal analysis, but showed greater variability in the rates over time, which means that FI crash rates significantly increased over the time. A Geographic Information Systems based thematic maps were used to support these efforts.

Keywords: Comparative Safety Analysis, Crash Rates, Data Visualization, Traffic Safety

1. INTRODUCTION

Even though there has been significant public policy attention and improvements in traffic safety policies and practices in Turkey, 61 people died per billion vehicle-km in traffic crashes in 2016 (TGDH, 2017; TurkStat, 2018a). In spite of significant improvements in national highway network, there has been an increase in fatal and/or injury (FI) crashes over the last decade (TurkStat, 2018a). The distribution of crashes across the nation is also of importance to transportation system owners. National and local safety programs aim to reduce crashes and the severity of their outcomes within their jurisdictions. Development of geographically appropriate safety strategies requires estimating pertinent crash and exposure data at the relevant spatial scale. While data required to identify safety risks are collected at the local level, published databases are typically available only at larger scales. Thus, there is a need to deduce data at the local level (i.e., lower levels of spatial aggregation) from partially complete or surrogate datasets that are available at a higher level of aggregation.

FI crashes are reported by the traffic police and gendarmerie units according to their areas of responsibility in Turkey. Disaggregate statistics of these crashes are published annually by Turkish Statistical Institute (TurkStat). This aggregate database provides temporal and provincial distribution of the crashes as well as type of vehicles involved, classification of the crash locations as well as gender and age distribution of the crash victims. Due to the lack of disaggregate crash level data at the national level, province and regional variations of traffic safety have not been examined in detail. Recently, Atalay and Tortum (2015) compared the number of fatalities per traffic crashes and per kilometer of road network across the 81 provinces of Turkey. The results showed that number of fatalities per crash are higher in less developed provinces, whereas number of fatalities per length of road network are higher in developed provinces. In other study, Erdogan (2009) studied the provincial level differences in number of FI crashes and number of fatalities. Population and number of registered vehicles were used to quantify safety and results indicated that provinces with higher FI crashes and fatalities were located in the provinces that contain the roads connecting the İstanbul, Ankara, and Antalya provinces. However, there is no study focusing on traffic safety at the regional level in Turkey.

This study provides a comparative analysis of the FI crashes across the seven geographic regions in Turkey from 2006 to 2016 (additional information is provided in Appendix A). The comparisons are performed in relative terms and absolute terms. Since vehicle-km data are not available either province or regional level, number of FI crashes per million population and per million registered vehicles are used to quantify safety. The principal sources of data used in this study is TurkStat.

2. METHODOLOGY

Number of FI crashes per million population and per million registered vehicles were determined for each geographic region annually for the study period. A Geographic Information Systems based thematic maps were used to support these efforts.

Traditional statistical tests based on the normality assumption of the data. Since FI crash rates do not follow normal distribution either across the regions or over the years, nonparametric methods need to be used to study FI crash rates. An appropriate test to use for this purpose is the Kruskal-Wallis nonparametric test. In this study, hypotheses of the Kruskall-Wallis H test was that:

H_O: FI crash rates are the same for each region from 2006 to 2016
H_1: FI crash rates are not the same for each region from 2006 to 2016.

Based on the Kruskall-Wallis test, the null hypothesis, H_o, is to be rejected at the (100-α) percent level of confidence if the test statistic, H, falls in the critical region $H > \chi_\alpha^2$ with v = (k-1) degrees of freedom. To control the familywise type I error in Kruskall-Wallis H test; the probability of rejecting at least one pair hypothesis given all pairwise hypotheses are true, adjusted p-values are calculated and used to make the decision for each pair. The following equations was used to calculate adjusted p-values for each of pairwise hypothesis. If the adjusted p-value is bigger than 1, it is set to 1.

$$p_{adj} = pK(K-1)/2 \qquad (1)$$

where; K = number of pairwise hypothesis, and p = significance level of pairwise hypothesis.

3. RESULTS

FI crash rates were calculated annually for each geographic region based on per million population and per million registered vehicles. The results are presented thematically in Tables B1 to B2 (see Appendix). It is noted that the numbers of the regions are given randomly. In these tables, a graded color pattern is used to indicate FI crash rates. The color gradation ranges from red to yellow or green. Dark red is used to indicate the higher FI crash rates and worse safety records, and dark green is used to indicate lower FI crash rates and best safety records. Lighter red, yellow and lighter green colors are used to achieve gradation.

Table B1 presents FI crash rates of each region per million population for each year during the study period. Table B2 presents FI crash rates of each region per million registered vehicles for each year during the study period. In addition, the average FI crash rates for each measure for the entire 11 year period as a whole are given in these tables. It is seen that FI crash rates for regions significantly increased for each measure from 2006 to 2016. Furthermore, Table B1 and B2 clearly indicate the stability of the relative FI crash rates of regions across the years. They show that regions that tended to have lower FI crash rates, had lower crash rates across the years; and, regions that tended to have higher FI crash rates, had higher crash rates across the years.

Kruskall-Wallis pairwise comparisons implied that FI crash rates per million population are not the same across the regions from 2006 to 2016 (i.e. H = 31.50 > $\chi_{0.05,9}^2$ =12.59). Fig. 1 and 2 present box plot and 95% confidence interval of FI crash rates of regions per million population. It is seen that FI crash rates in Central Anatolia Region (Region 5), Mediterranean Region (Region 4) and Aegean Region (Region 2) seems

relatively higher than the others. FI crash rates in Southeastern Anatolia Region (Region 3) and Eastern Anatolia Region (Region 6) seems relatively lower than the others.

Fig. 3 presents graphical Kruskal-Wallis multiple pairwise comparisons. The number below each region represents the average rank of regional FI crash rates over the 11 years period. Fig. 4 provides Kruskal-Wallis tests results for significant pairwise comparisons. However, most of them are not significant based on adjusted p-value (see Fig. 3). In Fig. 3, yellow lines represent the significant pairwise comparisons based on adjusted p-values. FI crash rates per million population for Central Anatolia Region (Region 5) and Aegean Region (Region 2) are significantly higher than Southeastern Anatolia Region (Region 3) and Eastern Anatolia Region (Region 6); for Mediterranean Region (Region 4) is significantly higher than Southeastern Anatolia Region (Region 3).
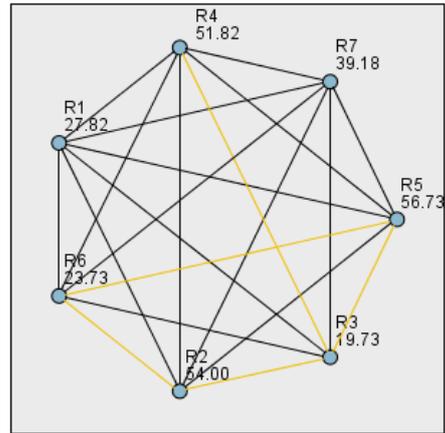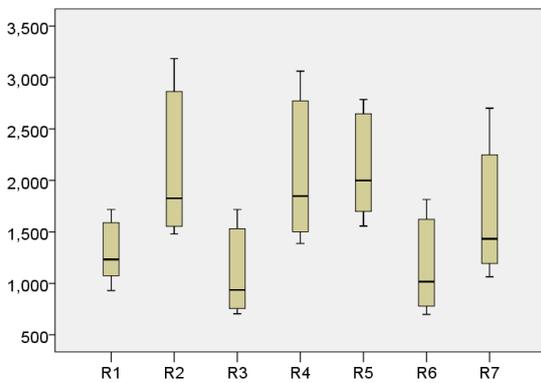

Fig. 1. Box plot of FI crash rates for regions per million population

Fig. 2. 95% CI of mean FI crash rates for regions per million population
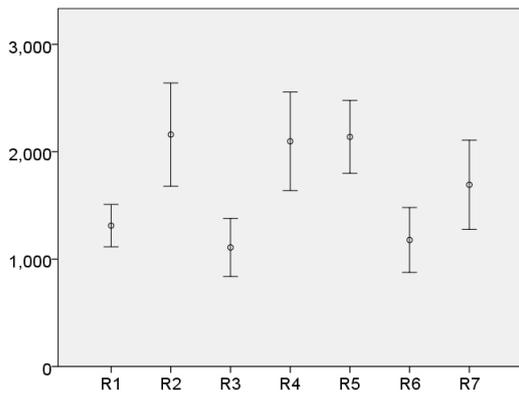
Fig. 3. Kruskal-Wallis multiple pairwise comparisons of FI crash rates per million population

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
R3-R5	-37.000	9.539	-3.879	.000	.002
R3-R2	34.273	9.539	3.593	.000	.007
R6-R5	33.000	9.539	3.459	.001	.011
R3-R4	-32.091	9.539	-3.364	.001	.016
R6-R2	30.273	9.539	3.173	.002	.032
R1-R5	-28.909	9.539	-3.030	.002	.051
R6-R4	28.091	9.539	2.945	.003	.068
R1-R2	-26.182	9.539	-2.745	.006	.127
R1-R4	-24.000	9.539	-2.516	.012	.249
R3-R7	-19.455	9.539	-2.039	.041	.870
R7-R2	14.818	9.539	1.553	.120	1.000
R6-R1	4.091	9.539	.429	.668	1.000
R7-R4	12.636	9.539	1.325	.185	1.000
R4-R2	2.182	9.539	.229	.819	1.000
R7-R5	17.545	9.539	1.839	.066	1.000
R3-R1	8.091	9.539	.848	.396	1.000
R4-R5	-4.909	9.539	-.515	.607	1.000
R6-R7	-15.455	9.539	-1.620	.105	1.000
R2-R5	-2.727	9.539	-.286	.775	1.000
R3-R6	-4.000	9.539	-.419	.675	1.000
R1-R7	-11.364	9.539	-1.191	.234	1.000

Fig. 4. Kruskal-Wallis multiple pairwise comparisons of FI crash rates per million population

Kruskall-Wallis pairwise comparisons implied that FI crash rates per million population are not the same across the regions from 2006 to 2016 (i.e. H = 44.98 > $\chi^2_{0.05,9}$ =16.92). Fig. 5 and 6 present box plot and 95% confidence interval of FI crash rates of regions per million population. It is seen that FI crash rates in Eastern Anatolia Region (Region 6) seems relatively higher than the others. FI crash rates in Marmara Region (Region 1) seems relatively lower than the others. Fig. 7 presents graphical Kruskal-Wallis multiple pairwise comparisons. Furthermore, Fig. 8 provides Kruskal-Wallis tests results for significant pairwise comparisons. However, most of them are not significant based on adjusted p-value. FI crash rates per million registered vehicles for Eastern Anatolia Region (Region 6) are significantly higher than Marmara Region (Region 1), Eagan Region (Region 2) and Mediterranean Region (Region 4). In addition, FI crash rates per million registered vehicles for Marmara Region (Region 1) are significantly lower than Southeastern Anatolia Region (Region 3), Central Anatolia Region (Region 5) and Black Sea Region (Region 7).
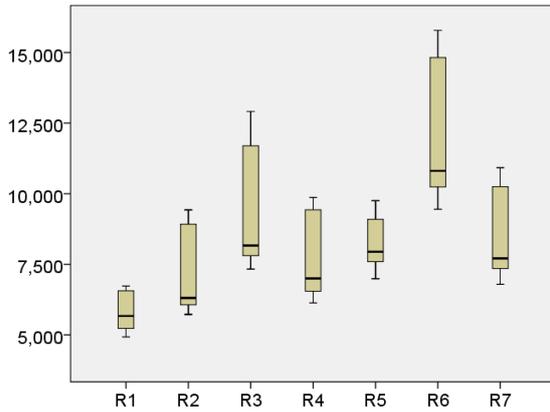

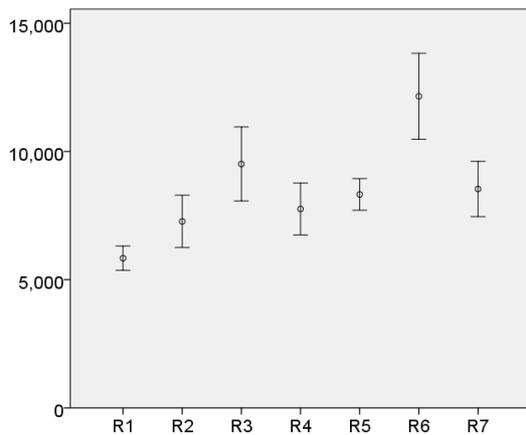Fig. 5. Box plot of FI crash rates for regions per million registered vehicles

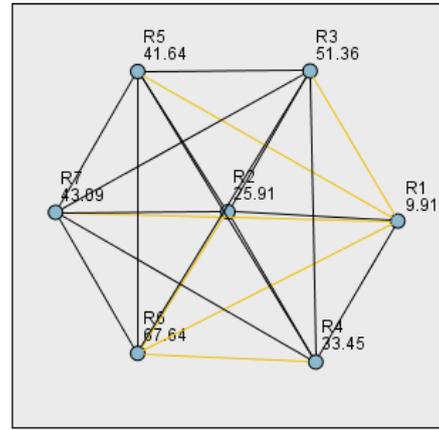Fig. 6. 95% CI of mean FI crash rates for regions per million population.

Fig. 7. Kruskal-Wallis multiple pairwise comparisons of FI crash rates per million registered vehicles

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
R1-R3	-41.455	9.539	-4.346	.000	.000
R2-R6	-41.727	9.539	-4.374	.000	.000
R1-R6	-57.727	9.539	-6.051	.000	.000
R4-R6	-34.182	9.539	-3.583	.000	.007
R1-R7	-33.182	9.539	-3.478	.001	.011
R1-R5	-31.727	9.539	-3.326	.001	.019
R5-R6	-26.000	9.539	-2.726	.006	.135
R2-R3	-25.455	9.539	-2.668	.008	.160
R7-R6	24.545	9.539	2.573	.010	.212
R1-R4	-23.545	9.539	-2.468	.014	.285
R7-R3	8.273	9.539	.867	.386	1.000
R5-R3	9.727	9.539	1.020	.308	1.000
R4-R3	17.909	9.539	1.877	.060	1.000
R1-R2	-16.000	9.539	-1.677	.093	1.000
R4-R5	-8.182	9.539	-.858	.391	1.000
R5-R7	-1.455	9.539	-.152	.879	1.000
R2-R4	-7.545	9.539	-.791	.429	1.000
R3-R6	-16.273	9.539	-1.706	.088	1.000
R2-R5	-15.727	9.539	-1.649	.099	1.000
R4-R7	-9.636	9.539	-1.010	.312	1.000
R2-R7	-17.182	9.539	-1.801	.072	1.000

Fig. 8. Kruskal-Wallis multiple pairwise comparisons of FI crash rates per million population

Fig. 9 and 10 provide thematic maps based on the average ranks of the provinces for each of the safety measures used in this study. In these maps, the red colored provinces have the highest rates while the green colored provinces have the lowest rates. An examination for Fig. 1 to 2 reveal some interesting patterns in the spatial distribution of the relative safety ranks of the regions. Overall, it can be seen that Marmara Region (Region 1) tend to have best safety records. Relative safety records of Aegean Region (Region 2), Eastern Anatolia Region (Region 6) and Southeastern Anatolia Region (Region 3) are significantly different for million population and million registered vehicles measures. For instance, Eastern Anatolia Region (Region 6) has the best safety records for FI crash rates per million population, however, it has the worst safety records for FI crash rates per million registered vehicles.
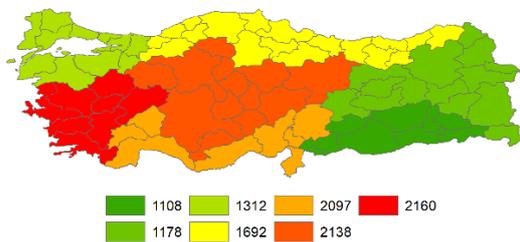

1108	1312	2097	2160
1178	1692	2138	

Fig 9. Average FI crash rates per million population for regions from 2006 to 2016

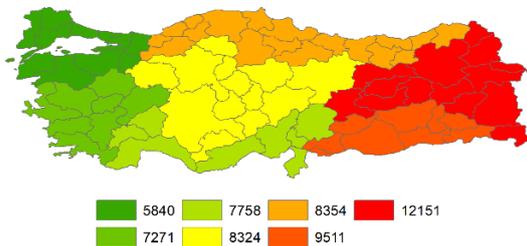|			
5840	7758	8354	12151
7271	8324	9511	

Fig. 10. Average FI crash rates per million registered vehicle for regions from 2006 to 2016

4. CONCLUSION

This paper summarized efforts of and findings from a study to examine regional level FI crash trends and perform comparative analyses of safety records 2006 to 2016. The comparisons were performed in relative terms (ordinal scale or based on rates) and absolute terms (cardinal or rank ordered scale). Two safety measures were used to evaluate safety: million population and million registered vehicles. Data were obtained from publications maintained by TurkStat.

An examination of the results indicated that the relative ranks of the regions were stable over the study period for each safety measure. Non-parametric statistical tests and thematic maps used to support comparative analyses. Specifically, the Kruskal-Wallis nonparametric test was used in this study. The results showed that the FI crash rates are not the same across the regions. Furthermore, the analyses also revealed that depending on the safety measure used, the relative rankings of regions

varied (i.e., a region ranked at the top (high crash rate) for one safety measure does not need to be ranked again at the top for other safety measure). This figure is resulted from significantly different vehicle ownership rate across the regions in Turkey. For the cardinal analysis the computed rates were used. These results were consistent with those from the ordinal analysis, but it was showed that FI crash rates significantly increased over the time.

For broad macro level analyses a more representative vehicle-km measure is required to study relative safety records of regions. However, it is available only for national level in Turkey. Furthermore, if specific analyses are required, then safety measures should be defined based on the desired evaluations. For example, if the goal were to address rural safety, the measures should be computed using rural fatal and/or injury crashes, rural vehicle-km, and the extent of rural kilometers of road network. This paper explored methods to analyze regional differences in road traffic safety. The results document the validity and promise of the methods. These methods could be expanded for policy and operational analyses.

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Appendix A: Geographic Regions in Turkey

It is noted that the numbers of the regions are given randomly.

- Marmara Region (Region 1): Balıkesir, Bilecik, Bursa, Çanakkale, Edirne, İstanbul, Kırklareli, Kocaeli, Sakarya, Tekirdağ, Yalova.
- Aegean Region (Region 2): Afyon, Aydın, Denizli, İzmir, Kütahya, Manisa, Muğla, Uşak.
- Southeastern Anatolia Region (Region 3): Adıyaman, Batman, Diyarbakır, Gaziantep, Kilis, Mardin, Siirt, Urfa, Şırnak.
- Mediterranean Region (Region 4): Adana, Antalya, Burdur, Hatay, Isparta, Kahramanmaraş, Mersin, Osmaniye.
- Central Anatolia Region (Region 5): Aksaray, Ankara, Çankırı, Eskişehir, Karaman, Kayseri, Kırıkkale, Kırşehir, Konya, Nevşehir, Niğde, Sivas, Yozgat.
- Eastern Anatolia Region (Region 6): Ağrı, Ardahan, Bingöl, Bitlis, Elazığ, Erzincan, Erzurum, Hakkari, Iğdır, Kars, Malatya, Muş, Tunceli, Van.
- Black Sea Region (Region 7): Amasya, Artvin, Bartın, Bayburt, Bolu, Çorum, Düzce, Giresun, Gümüşhane, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, Trabzon, Zonguldak
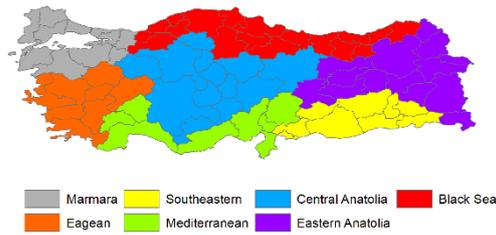

Fig. A1. Geographical regions in Turkey

Appendix B: FI Crash Rates

Table B1. FI crash rates for regions per million population

Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average 2006-2016
Marmara (R1)	930	1061	1051	1087	1091	1233	1376	1557	1621	1707	1718	1312
Aegean (R2)	1479	1564	1489	1544	1597	1826	2197	2766	2961	3183	3150	2160
Southeastern Anatolia (R3)	707	717	706	794	834	936	1153	1538	1564	1718	1524	1108
Mediterranean (R4)	1388	1481	1432	1522	1608	1848	2164	2749	2796	3061	3020	2097
Central Anatolia (R5)	1565	1678	1558	1720	1803	2000	2371	2675	2621	2745	2786	2138
Eastern Anatolia (R6)	699	749	726	808	942	1017	1159	1558	1688	1815	1797	1178
Black Sea (R7)	1065	1181	1093	1207	1304	1433	1608	2192	2304	2529	2702	1692

Table B2. FI crash rates for regions per million registered vehicle

Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average 2006-2016
Marmara (R1)	4927	5378	5141	5265	5191	5669	6098	6666	6715	6731	6456	5840
Aegean (R2)	6276	6278	5725	5846	5852	6305	7263	8859	9175	9428	8979	7271
Southeastern Anatolia (R3)	8163	7839	7329	7771	7616	8077	9414	12098	12058	12916	11335	9511
Mediterranean (R4)	6626	6673	6130	6346	6469	6997	7802	9571	9403	9867	9459	7758
Central Anatolia (R5)	7636	7826	6986	7502	7551	7943	8989	9754	9214	9202	8963	8324
Eastern Anatolia (R6)	10189	10294	9449	9871	10621	10811	11614	14783	15399	15784	14859	12152
Black Sea (R7)	7384	7710	6788	7189	7313	7483	7935	10243	10255	10651	10920	8534