Designation of Reliable Junction Locations by Junction Risk Factor with Geostatistical Analyst

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Abstract: Geostatistical Analyst (GA) has used recently in continuous surface mapping includes also Kriging applications. The data obtained from the Junction Risk Factor (JRF), recently developed for controlling and predicting traffic jam for whole road network, were evaluated to localize the problematic junctions. The JRF was handled with actual junction related geometric and traffic flow rate data instead of statistical analyses including previous years' accident data. The input data used by JRF are independent and depends on junction properties.
The data from JRF analyses are then provided GA surface maps here to estimate the local problematic junction positions which can be reevaluated or replanned to decrease future traffic jams.

Keywords: Junction Risk Factor, Kriging, Prediction maps, Probability maps, Traffic accident, Traffic jam.

I. INTRODUCTION

Inner city or urban traffic can doubtlessly be considered one of the biggest problems in developing cities. Urban traffic has its importance in supplying transitions between the urban citizens and their vital functions. Especially in cities which are developing and have the population density in their centres, the present traffic sometimes can not respond to the need. Since damaging or fatal accidents occur in urban areas due to heavy traffic, new searches for solutions to the trouble have been brought about. The financial damage and the casualties have been increasing swiftly and traffic jams and their effects on both citizens and the environment have become a major problem [1].

A report from the World Health Organization (WHO (2010)[2] on road traffic accidents and injuries estimated 1.24 million people are killed in road crashes each year According to estimations of the World Bank (WB) traffic accidents will be the third most frequent reason of deaths in 2020.

The Turkish Statistical Institute (TUIK) facts reveal that 1 296 634 traffic accidents, 2878 of which resulted in mortality (3750 deaths), 102 344 of which resulted in injuries (268 070 injuries) and 1 143 082 of which resulted in economical damage, occurred in Turkey in 2012.

A questionnaire done by 800 people whose relatives lost their lives in traffic accidents in European countries revealed that 37% of those had tendency to commit a suicide and 64% of those had depression in subsequent 3 years. Further, another questionnaire applied in Turkey revealed that 50% of 240 people whose relatives lost their lives in traffic accidents suffered from insomnia and 39.2% suffered from hysteria in addition to depression [3].

A review of the previous literature found that accident prediction models for urban roads were studied by [4] used Getis-Ord Gi statistics to identify spatial patterns of different types of weather-related crashes. [5] also studied spatial relationships between local spaces and global space. [6] used different statistical methods to draw more kinds of maps. [7] studied urban park design. [8] studied pedestrian circulation maps and [9] also studied traffic lights junction management.

In GIS studies, new approaches were used by ([10]; [11]; [12]) in applying GIS to environmental simulation models and by [13] for geographic representation. [14], [15], [1], [16],[17], [18], [19], [20] studied risk maps and [21] also studied a key factor in regional urban planning.

The variables of JRF are independent of each other, and changing one never affects the other. This structure shows the superiority of JRF. over others.

Because of the irregular distribution of junction points, mapping by traditional interpolation techniques is insufficient to evaluate the accident dataset. It is not the main purpose of this study to determine the hot spots. The main aim is to produce continual surface risk maps for the new roads and settlements for future planning. Therefore, risk maps are the fundamental products which consider all JRFs [22].

As a result, the aim is to demonstrate the appropriateness of using GA for vehicle traffic movements.

II. STUDY AREA

Konya is not only the largest province of Turkey in terms of territorial size but also has the longest road network, with a 3782 km state road in a country with a total of just 385982 km of roads. It is eighth worst in terms of accident rates, third in terms of accident fatality rates, and fifth terms of numbers of injuries, according to statistics for 2013. In a seven year period, a total of 2281 accidents occurred; there were 21 accidents with fatalities, 343 accidents with injuries, and 2102 accidents with only damage.

To define 129 junctions, digitisation and analyses were performed using maps with a scale of 1/25 000. In this process, besides all accident numbers, junction criteria, dates, times, and types of vehicle data were recorded in the main dataset.

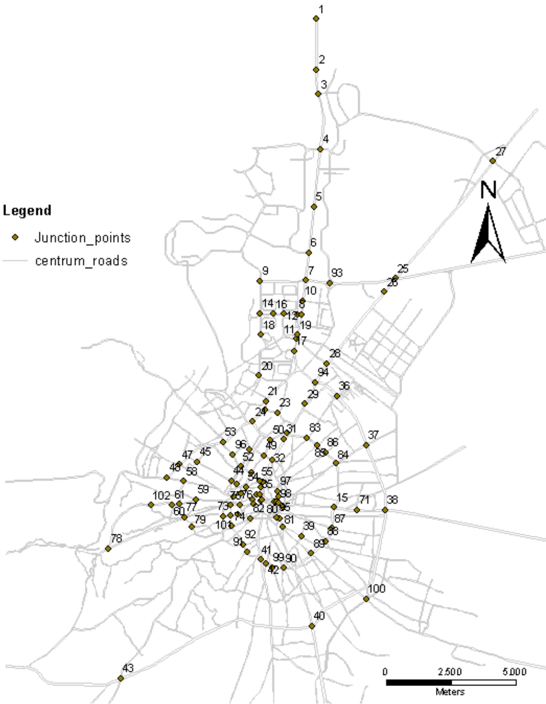


Fig. 1 129 junction points in the city centre of Konya.

III. GENERATED ALGORITHM

The main target here is to calculate JRF values for each junction. The JRF at a junction is a value computed at the point of each traffic light and is gained after these calculations are summed. Furthermore, it is accepted that all other risk factors (ORF) will be added into that coefficient. However, because of the ORF which have the same effect at all other junctions, like drunk drivers, weather conditions or the faults of drivers or vehicles, these were not included in the formulization. The main intent here is to investigate the effects of the certain factors that cause accidents. In this manner, these factors can also provide alterations to present roads and can inform the authorities to take them into consideration. An analysis which will be performed according to the accidents can provide us with the result on urban roads. However, only by making an analysis and presentations considering the accidents can help to find the accident ratio of the junction instead of revealing the troubles. As a result of finding real and valid solutions, a model which can provide the most effective way to reach the target must be used, instead of finding out which junction is the most dangerous or at which junction the most accidents occurred [1].

Factors that affect the formulization:

Numerical factors: The number of routes that cross the junction is named a numerical factor. The number of roads of the junction affects the total JRF.

Interval factors: These factors must be examined in two groups: first, the average number of vehicles passing through the road in a day and, second, the waiting duration at the red light.

Data related to length: These can also be examined in two groups as the width of the road and the distance from the previous traffic or warning light.

Data related to slope: Since the city of Konya was settled on flat land, the slope was accepted as ineffective and it has not been included in the calculation.

In accordance with that,

$$JRF_i = \sum_{i=1}^{\mu} \frac{l_i \cdot n_i \cdot \lambda_i}{S_i \cdot \eta_i} \quad (1)$$

If a value is to be evaluated: here, μ : the number of traffic lights at the junction, l_i : the distance from the previous traffic or warning light, n_i : roads crossed at the junction, λ_i: average number of cars that will pass in a day, S_i: the width of the road and η_i: the coefficient of traffic flow.

For η_i

$$\eta = \frac{\delta}{t_R} \quad (2)$$

can be written. δ is the number of cars waiting at the red light and δ effects η_i directly proportionally; t_R is the duration of the red light which effects η_i inversely proportionally.

$\lim_{t_R \to \min}(\eta) \to \max$ and $\lim_{\delta \to \min}(JRF) \to \max$: the maximum value is valid for controlled transitions.

The mean coefficient of traffic flow is maximum in controlled transitions. Figure 2a is an example of possible junction variations that can affect the practice in that way; in these situations, $\lambda_i = \eta_i$ so the formula changes to:

$$JRF_k = \frac{l.n}{S} \quad (3)$$

Furthermore, here, JRF_k is the controlled transition junction risk factor.

At the junction in Figure 2b, JRF is to be calculated with the 5 movement. While there is no problem in calculating the first 4 values, there is a controlled transition at the point of 5.

So, $\lim_{t_R \to \min}(\eta) \to \max$. to clear the indefinite value $t_{R\min} = 1sn$ is taken so

$\delta \to \min$ and $\lim_{\delta \to \min}(JRF) \to \max$

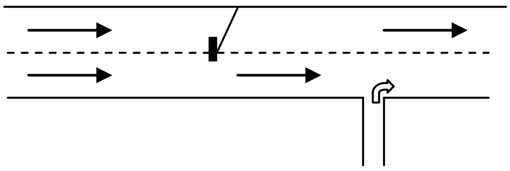
JRF_k at point 5 will be calculated by formula (3). As a result,

$JRF = JRF_1 + JRF_2 + \ldots JRF_{k1} + JRF_{k2} \ldots$ can be written.

Here, the values of l_i, n_i, λ_i increase to JRF. Therefore, these values expose traffic jams or risks of traffic accidents. As far as possible, these values must be decreased. If it is not possible to lessen some values of the variables, the S_i or η_i value must be increased. In this situation, the most practical solution is to increase η_i or achieve a minimum t_R.

For the present heavy roads and junctions, if it is impossible to change the route to other nets of road, the value of l_i must be shortened or the t_R value increased.

Figure 2(a) shows controlled movement model and 2(b) shows junction model with four roads to generate the JRF.



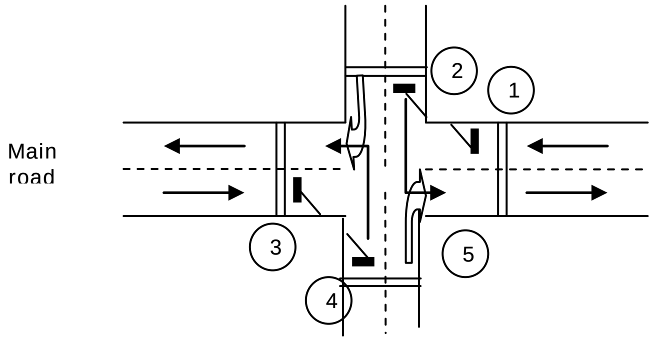


Fig. 2(a). Controlled movement, Fig. 2(b). Junction model with four roads

In this phase all JRF values can be calculated and then evaluated by GA.

IV USING OF GA BY KRIGING INTERPOLATOR FOR JRF

According to [23] kriging is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. It is very flexible and allows the user to investigate graphs of spatial autocorrelation. Kriging uses statistical models that allow a variety of map outputs including predictions, prediction standard error, standard error of indicators, and probability. The flexibility of Kriging can require a lot of decision making. Kriging assumes that the data comes from a stationary stochastic process. A stochastic process is a collection of random variables that are ordered in space and/or time such as elevation measurements. The selection of a Kriging method is based on the autocorrelation of a variable between two points that is formulated as follows:

$$Z^*(u) = \sum_{a=1}^{n(u)} \lambda_a(u) Z(u_a) + \left[1 - \sum_{a=1}^{n(u)} \lambda_a(u)\right] m$$

where, $Z^*(u)$ is the ordinary Kriging estimate at spatial location u, $n(u)$ is the number of the data used at the known locations given a neighbourhood, $Z(u_a)$ are the n measured data at locations u_a located close to u, m is mean of distribution, $\lambda_a(u) =$ weights for location u_a computed from the spatial covariance matrix based on the spatial continuity model.

Geostatistical procedures, known as kriging, require an understanding of the principles of spatial statistics and provide statistically unbiased estimates of surface values from a set of control points. Kriging is a generic term adopted by geostatisticians for a family of generalised least-squares regression algorithms [24].

Kriging interpolation techniques have proved to be popular in many areas such as agriculture, mining, geology, environmental science, building, cartography, risk management, and so on.

V. APPLICATION AND RESULTS

First of all, the characteristics of the data must be evaluated. Table 1 shows the histogram values, and Figure 3 shows a QQPlot graphic for JRF.

Table I. Histogram values calculated by JRF.

Histogram values			
Min	0.0024	Skewness	1.214
Max	2.1091	Kurtosis	3.6046
Mean	0.4644	1st Quantile	0.0488
Std. Dev.	0.4972	Median	0.1851
3rd Quantile	0.7933		

If the mean and median values are close, it can be said that the data have a normal distribution. A histogram shows whether distributions of data are symmetrical or not. Symmetrical data can be realized with a Skewness value close to zero. According to the values in Table 1, our data are not normally distributed or exactly symmetrical. However, a normal QQPlot also allows us to compare the data with a normal distribution. Figure 3 shows that it is plausible that the data have a normal distribution with a few extreme points. Transformations can be used to make the data normally distributed and satisfy the assumption of equal variability of the data. However, transformation was not necessary for this study because of the negative effects on statistical results.

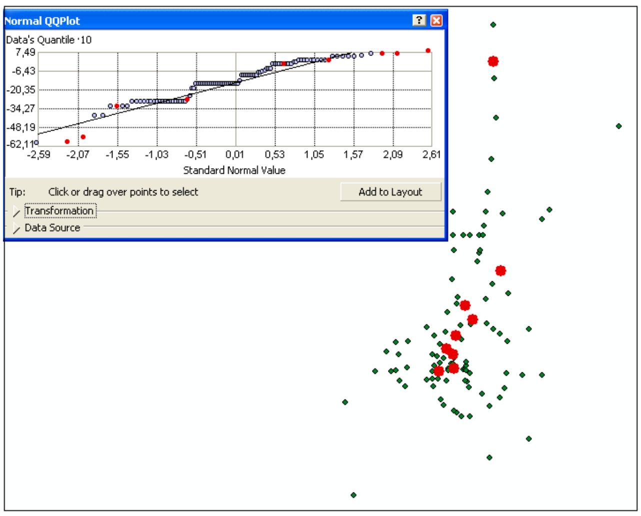


Fig. 3 Example of a QQPlot graphic for junctions with JRF

This stage investigates whether or not there is a trend. According to Figure 4, there is a trend in the direction of 349°. This illustrates the general tendency of JRF. The trend of an upside-down “U” shape shows that there is a global trend. This trend can be removed using the second interpolation option.

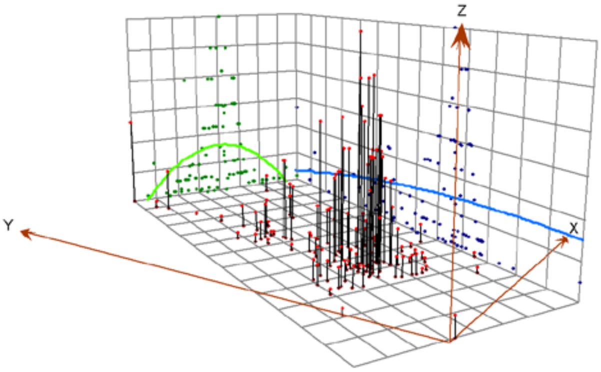


Fig.4 Trend analysis graphic for JRF

Table 2 shows all geostatistical values constituted with all AC. All values which are important to show AC and to plan for the future are in shown the table. To carry out mapping with the help of the Table2, the rules must first be considered primarily as below.
The best map can be produced with the trial and error method by changing parameters. Transformations are not applied but there is anisotropy.

Table II. All calculated statistical values required for interpretation.

Statistical values	JRF	
	With nugget effect	Without nugget effect
Trend	Log.	Log.
Anisotropy	✓	✓
Major range	23547.6	3807.90
Minor range	1 2554.2	3807.98
Nugget	0.20766	0
Sill	0.25080	0.25086
Nugget sill ratio	0.822	-
Mean	-	0.01141
Root-Mean-Square	0.0235	0.44401
Average Standard Error	0.4572	0.27493
Mean Standardized	0.4692	-
Root-Mean-Square	-0.0433	0.01309
Standardized	0.9714	1.700

Two effects may influence the results. One of them is the global trend and the other is anisotropy. When a study is carried out on a two dimensional surface, sometimes the semivariogram and covariance functions must be investigated not only according to distance but also according to direction. This is called anisotropy. Anisotropy is determined by random errors, and it is different from a global trend.

Figure 5 shows prediction maps produced by JRF values with the most problematic eleven junctions (a), and a prediction map without the nugget effect (b). Furthermore, probability maps can be produced in respect of threshold values that are exceeded or not exceeded. A related example is shown in Figure 5(c). The indicator prediction value shows the probability of exceeding a threshold value. The most important maps to interpret to prevent traffic accidents are of this type. Figure 5(d) was produced using covariance values.

Representations of maps illustrated using Equal Interval techniques have generally been used for probability maps to clarify extreme values so far. Therefore, all maps are produced using this method.

For the correct interpretation of the values shown in the table, the following rules must be taken into consideration [22].

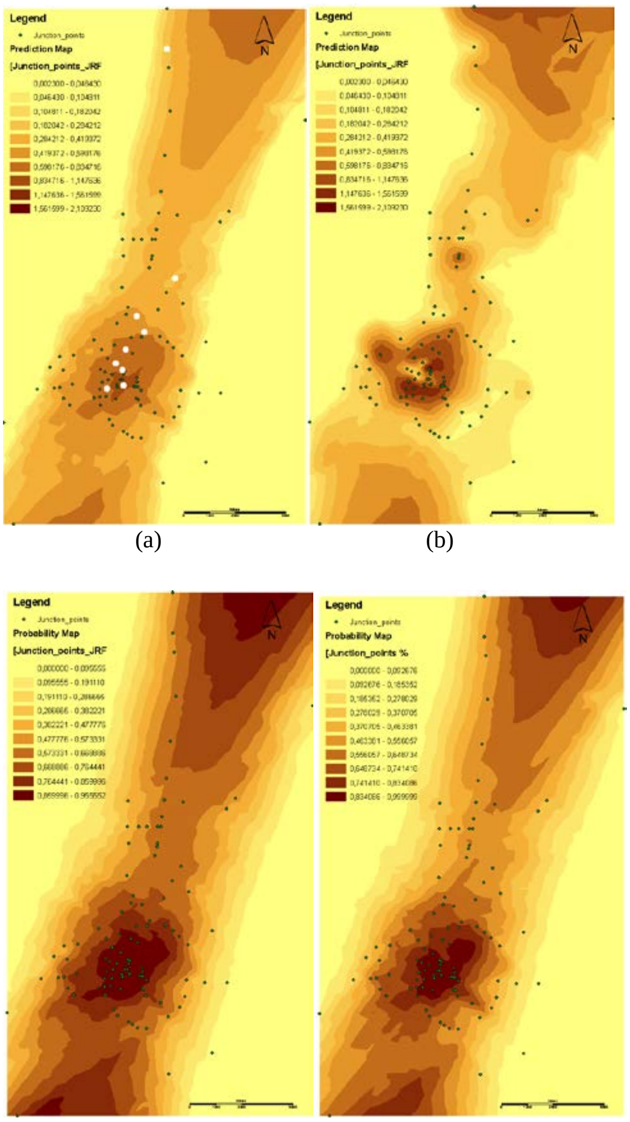


Fig. 5 Result maps: (a) prediction map, (b) prediction map without nugget effect, (c) probability map, (d) probability map for JRF values greater than the mean

VI. SUMMARY AND DISCUSSION

Here, the main purpose is to reach the minimum JRF value. All the directly proportional variables and inverse ratio variables that form the denominator of the model must be taken into account singly. For new junctions which will be built, the indispensable values will be protected but all other variables must be modified optimally. For instance, if it is not possible to change the width of a road and the number of vehicles, the most appropriate period for a red light must be adjusted. Finally, the smallest numerator or the biggest denominator value must be found by regulation as far as possible. This calibration will adjust the coefficient of traffic flow. So, the risk of accidents can be reduced and traffic flow can become untroubled. In the light of these suggestions, each of the 129 junction points in Konya has been evaluated and the 27 most dangerous junctions' results are given in Table 3. Suggestions for all the characteristic junctions are shown in the table. For instance, five suggestions for six junctions, three suggestions for three junctions, and two different suggestions for sixteen junctions are given in the table. In reality, the results could be observed in the city. The variables do not alter from one country to another. So, the JRF model can easily be used in other areas by GA.

In conclusion, the analysis of accidents can be carried out with the help of the new algorithm. Factors that affect the accidents are the variables that make up the formula. With the newly developed algorithm, defining the exact criteria for the prospective roads must be done by considering the variables of the formula.

If the method is evaluated alongside GA, it can be said that deterministic and geostatistical methods are examined with two groups in GA. These methods are basically similar as the data for nearby points are close. On the other hand, when the mathematical and statistical methods are used together, geostatistical methods are not only used as interpolation methods but also give an opportunity for interpretation. The method also gives information about the reliability of predicted areas. Therefore, deterministic applications were not performed in this study. This study has tried to understand the reliable and risky zones. As a result, in the light of the calculated values, result maps were produced with the aim of helping to create new city road models. Maps which have statistical value and can be visualised will of greater help to city planners [22].

This study has tried to understand the characteristics of traffic accidents.

The study gives different results from others concerning GA applications for traffic accidents in the literature. In addition, it differs from other studies in that it uses not only the total number of accidents but also different traffic accident criteria.

Table III. Suggestions for the junctions which have high JRF values are mentioned according to the variables of the formula.

Suggestions for the junctions which have big value more than mean	Junction numbers (total 25)			
	6	3	4	12
l_i must be shortened	√	√		
n_i must be controlled	√			
λ_i must be controlled	√		√	√
S_i must be optimized	√	√	√	
t_R time must be set for η_i	√	√		√

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