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GIS based surveillance of road traffic accidents (RTA) risk for Rawalpindi city: a geo-statistical approach

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Abstract

Identification of previously existing traffic accident hotspots is the first step to ensure future road safety. The study focused on providing GIS based geo-statistical surveillance for the road traffic Accidents (RTA) in Rawalpindi for five years (2009-2013) to determine the high risk areas or hotspots. For this purpose, spatial autocorrelation (Moran's I test), standard deviational ellipse (SDE) and hotspot (Getis-Ord Gi*) analyses were performed on the data obtained from the Punjab Emergency Service Department (Rescue 1122). Spatial clusters and hotspots identified during the research were mostly in the northern and northeastern part of the study area encompassing both commercial and residential areas of the city, with majority of accident hotspots being near schools, hospitals, airport and highways. The study proposed that serious steps should be taken to improve the road safety conditions in these areas and focus of emergency response providers (ERPs) should be directed there. Furthermore, the integration of GIS based expertise in the Emergency department should be ensured for regular surveillance of shifts in hotspots.

Keywords: Geo-statistical; hotspot; road traffic accidents (RTA); spatial autocorrelation; standard deviational ellipse (SDE).

1. Introduction

Road traffic accidents (RTAs) are most common emergencies of present day and age. With the passage of time, the incidence of RTA has significantly increased in Pakistan (Butt, 2013; Hyder *et al*., 2006). This alarming rate is due to lack of public awareness and observation of traffic rules and regulations. According to Pakistan Bureau of Statistics (PBS), approximately 9000 road accidents were reported to police every year since 2011. On average, these accidents were responsible for killing over 4500 people (Sikander *et al*., 2015).

Mounting frequency of these RTAs makes it necessary for a quick and efficient emergency response system, especially the ambulance facility, to be there for catering these accidents (Abbasi *et al*., 2013). Therefore, for the provision of apt and timely response for these traffic accidents faced by Pakistan, there is a need of strong inter and intra-national collaboration and fund allocation as well as well-organized and highly trained emergency first response (EFR) providers.

Several major factors involving timely acquisition of the requisite information, lack of resources and infrastructure and contingency planning hinder the timely and efficient EFR provision. Numerous initiatives have been taken worldwide to develop such incident response measures that will deal with each incident in a timely and effective manner. This requires, among other things, deployment of appropriate response units to the incident locations.

GIS tools provide a proactive approach for early identification of the emergency hotspots and lead to less resource utilization. Studies disclose that GIS tool is very effective for both first responders and emergency management, especially in terms of resource management. The specific applications of GIS having the potential to play a key role in the emergency response improvement (ERI) comprise spatial autocorrelation (Prasannakumar *et al*., 2011), hotspot detection (Amri & Sitanggang, 2015; Thariqa & Sitanggang, 2015), spatial centrographic analysis (Lee, 2009) and density analysis (Erdogan *et al*., 2008).

The significance of integrating GIS in emergency management is thus evident through the amount of literature published every year exemplifying its applications in supplementing the aforementioned necessities for ERI.

The main objective of the research was to make use of emergency response data to develop maps of incident service locations for years 2009-2013. The specific objectives however included:

- To provide geo-statistical surveillance for the identification of past and current service locations and map these locations for hotspot identification

- To create Ellipse maps of RTA incidences to delineate the shifts in the pattern of incidences in an area over time to ensure provision of improved first response service

2. Materials and methods

2.1. Study area

Rawalpindi city, commonly known as Pindi (Figure 1), was the study area of the current research work. It lies between 33° - 28' and 33° - 48' latitudes and 72° - 48' and 73° - 22' longitudes and is administratively divided in to two tehsils: Rawal and Potohar. Rawalpindi is one of the historic cities in Potohar plateau and covers 250 square kilometer area with a population of about 2.2 million.

Currently Rescue 1122, alternatively known as Punjab Emergency service, is providing rescue and first aid services to the victims of RTA in the city. The organization has 5 service stations and 2 keypoints, located in different parts of the city and has meager resources available for emergency first response provision, including 14 ambulances, 2 special vehicles, 2 recovery vehicles, 2 rescue vehicles, 9 fire vehicles and 1 water rescue van (Abbasi *et al*., 2013).

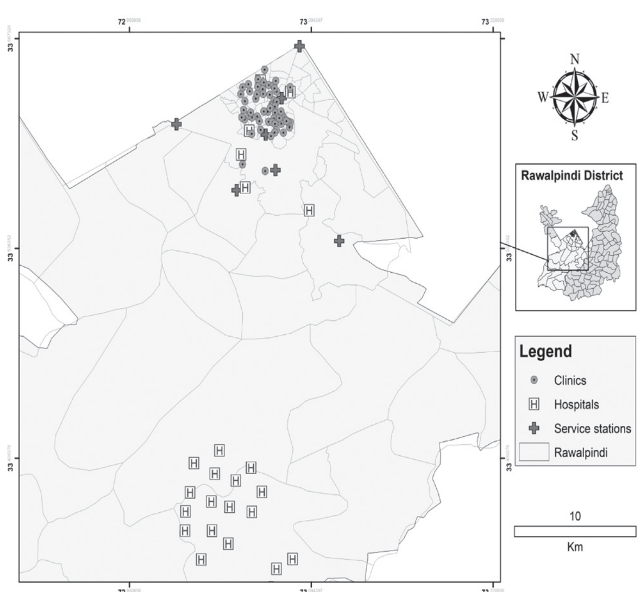

Fig. 1. Study area map showing service stations of 1122

2.2. Data collection and processing

As shown in Figure 2, the first step of research methodology was a unit level data collection from the headquarters of Rescue 1122, Rawalpindi. This data, containing the emergency data in form of call record (caller and victim directory), was obtained from all the rescue stations at work in the city. The information was processed in Microsoft Excel 10 to prepare and extract data on RTA victims on the basis of which GPS locations of victims' addresses were acquired. The final sheets were then added to ArcGIS for further analysis.

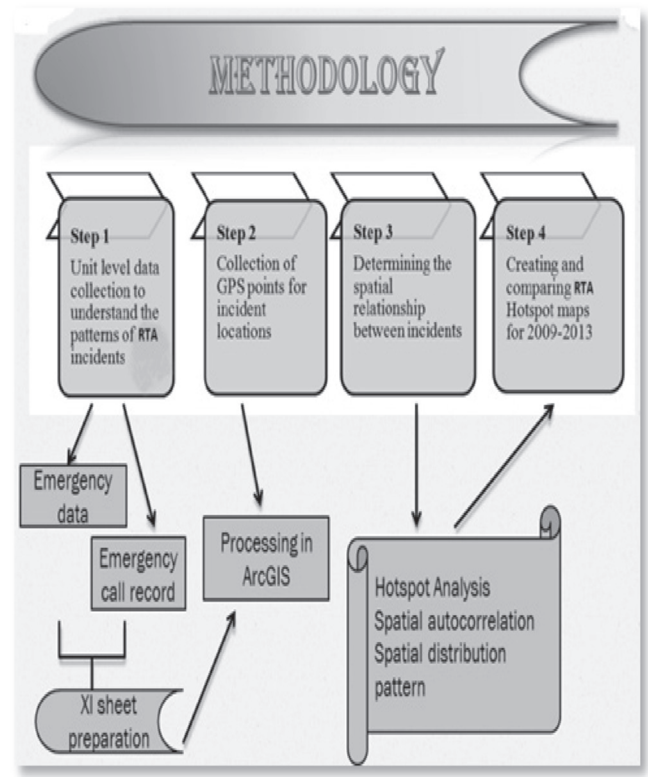

Fig. 2. Flowchart for the research methodology

2.3. Geo-statistical analysis of emergency data

The Geo-statistical analyses performed on the data comprised spatial autocorrelation analysis

(Moran's I test), hotspot analysis (Getis-Ord Gi*) and centrographic statistics (standard deviational ellipse and mean center).

2.3.1. Centrographic analysis (standard deviational ellipse)

Mapping incidents is the first step in any spatial analysis, which is why standard deviational ellipse and mean center analysis were performed on the data to determine and map the directional distribution trend of RTA cases for the study duration. Standard deviational ellipse (SDE) parameter was calculated for RTAs for each year from 2009-2013 and overlaid to compare the extent of RTA incidents and their global position. SDE parameter takes into account spreading of features in one direction than in another farther from a specified point (Ebdon, 1991).

2.3.2. Spatial autocorrelation analysis (Moran's I test)

Spatial autocorrelation analysis or Moran's I statistic determines the characteristics of the global pattern by estimating existing correlation among spatial observations (in this case RTA incidents). The pattern could either be random, dispersed and clustered based on the association between features (Fang *et al*., 2006; Boots & Getis, 1998). The statistical significance of the observed clustering or dispersing in the features is assessed by 'Z' score value. Positive value of the score indicates towards significant clustering while negative gives an indication of dispersion.

2.3.3. Hotspot analysis (Getis-Ord Gi*)

Getis-Ord Gi* statistics generally identify the locations over the whole study area as hotspots, cold spots or mild spot locations with statistical significance. Where, hotspots are the areas more prone to a particular incident or are the high risk areas for an incident to occur. Z-score statistics are calculated for every feature in a dataset and statistically significant positive Z-score (having larger value) represents intense clustering (hotspots). Nevertheless, the detection of hotspot can still be valuable even if data do not reveal clustering (Feser *et al*., 2005; Wu *et al*., 2004; Getis & Ord, 1992).

3. Results

For determination of contemporary status of RTA occurrences via GIS, the emergency callout data for 2009 to 2013 was collected and processed. Various analyses were performed on the data to determine the pattern of emergencies. The total cases of RTA reported for the duration of 20092013- were 22828 of which 88% (20053) were reportedly males, whereas 12% (2759) were females. In 2009, 2559 cases were accounted and this number augmented to 4255 in 2010 and followed the increasing trend in subsequent years too, with 4770 reported in 2011 and 5016 and 6228 for 2012 and 2013 respectively.

The result of centrographic statistical analysis for RTA incidents for each year (Figure 3) revealed that both urban and rural areas of Rawalpindi city were observed within SDE for each year. Global distributional patterns showed slight differences in the study period with gradual decrease in the ellipse area until 2011, which subsequently increased in 2012 and again decreased in 2013. This revealed that the RTA cases were widely distributed in 2009 as compared to all the subsequent years and showed an overall random distribution pattern.

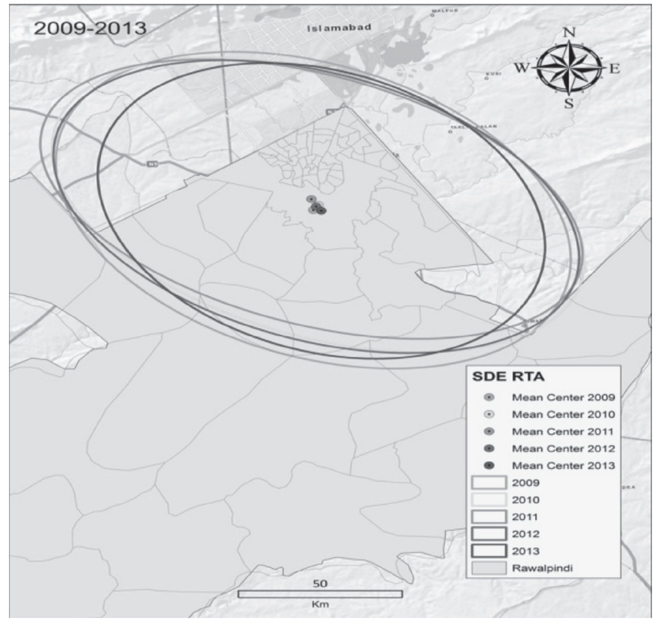

Fig. 3. SDE map showing distributional pattern of RTAs for study duration (20092013-)

Moran's statistic (I) weighted for 2009, 2010, 2011, 2012 and 2013 was 0.026 (Z-score= 1.44, P = 0.1), 0.008 (Z-score =0.65, P = 0.6), 0.0005 (Z-score = 2.44, P = 0.01), -0.003 (Z-score 0.84, P = 0.3) and -0.003 (Z-score = 0.38, P = 0.7) respectively. Thus, based on Moran's autocorrelation statistic, RTA cases for all the years, but 2011 had a random spatial distribution pattern (Table 1).

Table 1. Spatial autocorrelation statistics of RTA incidents

Years	Moran's I	Z Score	P Value	Pattern
2009	0.0260	1.44003	0.14986	Random
2010	0.0084	0.65778	0.51068	Random
2011	0.00053	2.44907	0.01432	Clustered
2012	-0.0034	0.8433	0.39906	Random
2013	-0.0038	0.38127	0.70301	Random

The RTA hotspots for each year from 2009- 2913 (Figure 4) were estimated by employing Getis-Ord Gi* statistic. Hotspots for RTA cases were mostly seen in northern, northwestern and northeastern parts of the study area. However, the specific hotspot locations for each year are tabulated in Table 2.

Table 2. Identified RTA hotspots for the years 2009 -2013

Years	Identified hotspot locations
2009	Rawal road, Westridge, Misriyal road, Choor chowk, British Homes, Sohan Pull, Faizabad, Faiz-ul-Islam, Seham road, Allahabad, Peshawar road, Peerwadhai Morr, PAF Chowk and Fouji Tower Chowk
2010	Rawal road, Rawat Chowk, Holy Family Hospital road, Westridge, Misriyal road, Choor chowk, British Homes, Faiz-ul-Islam, Seham road, Allahabad, Peshawar road, Peerwadhai Morr, PAF Chowk, Fouji Tower Chowk, Faizabad, Mandi Morr, Sohan Pull, and Mehrabad Chowk
2011	IJP road, Fauji Colony, Carriage Factory, Sohan Pull, Margallah Town, Westridge, Misriyal road, Mandi Morr, Peerwadhai Morr, Seham road, Rawal road, PAF Chowk, Choor Chowk and Allahabad
2012	Murree road, Faizabad, Sixth road, Islamabad Highway, Adyala road, Airport road, Askari 8, Bhabra Bazar, Karaal Chowk, Ayub Park, Police Line, Jinnah Park, Kachehri Chowk, Choor Chowk, Waris Khan Stop and Peshawar road
2013	Mall road, Rawat Chowk, Gawalmandi, Committee Chowk, Murree road, Liaqat Bagh Chowk, Sixth road, Double road, Highway road, Adyala road, Kachehri Chowk, Chandni Chowk, Airport, Karaal Chowk, Sohan Pull and DHA

Figure 4 revealed that RTA hotspots for 2009 and 2010 were located mainly in the same regions but their extent increased slightly in the later year. For 2011, the hotspots became more contained towards northwestern portion of the study area. The hotspot locations for 2012 and 2013 shifted slightly toward southeast direction however.

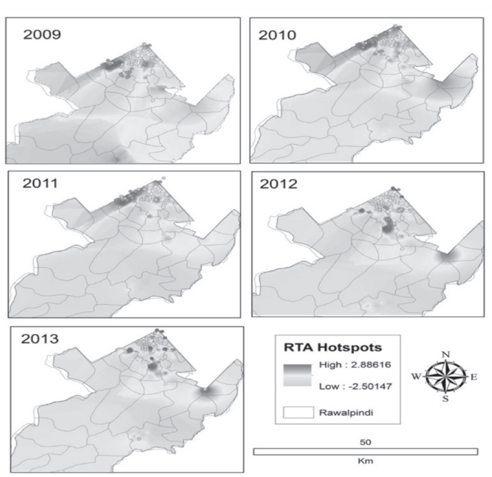

Fig.4 . Mapping of RTA hotspots and cold spots using Getis-Ord G* statistics during 2009-2013

Cold spot clusters for RTA incidents conversely were contained mainly in northern regions of the study area, including Tench Bhata, People Colony, R.A. Bazar and Kalma Chowk.

4. Discussion

The results obtained signified towards a considerable augmentation in the intensity of RTA cases for the duration of the study. Rescue 1122 dealt with the majority of the RTA cases in the city and has reportedly provided a response to such emergencies for the past decade (Saleem, 2014; The Express Tribune, 2014, 2013).

Mean centers for RTA cases displayed a similar displacement tendency throughout the study duration with slight differences in the angle of rotation. The size of ellipses ring contrariwise varied from year to year and was largest in 2011.

The spatial autocorrelation analysis (Moran's I test) for the current study suggested that RTA incidents only showed significant clustering in 2011. Other researchers also obtained results with no significant clustering in the data, but the results were still effective for hotspot detections (Fan & Myint, 2014; Hussain *et al*., 2013).

Significant RTA hotspots were pronounced in the areas with poor lighting and high-speed highways, dangerous U turns, complex intersections and extremely busy and congested roads. Most vulnerable roads of Rawalpindi with respect to RTA included Peshawar road, Rawal road, IJP road and Islamabad highway. Daily Times (2015) reported that DEO Rawalpindi also categorized these roads as most susceptible to accidents.

Additionally, significantly augmented risk areas of RTA injuries included roads near schools, local airport, gas stations, bus stops, pedestrian crossings and other suburban high-activity passageways. Similar results were obtained by Nasir *et al*. (2015), Ponnaluri (2012a, b), Clifton *et al*. (2009) and Coate & Markowitz (2004), while analyzing the hotspots for RTAs.

5. Conclusion and recommendations

This research presented an incorporation of different GIS based techniques for in-depth spatio-temporal analysis and geo-statistical surveillance of emergency response situations prevailing in Rawalpindi city. However, the main focus of the research was on RTA emergencies. The results indicated towards both spatial and temporal variations in the incidence of the RTA emergencies. Most of emergency hotspots were observed in Rawal tehsil with very few hotspots in Potohar region. The clustering of emergencies was also variable with significant clustering observed only in 2011. Furthermore, the incidents of emergencies augmented over time even as the hotspots became randomly distributed. Based on the research outcomes, it is recommended that the focus of Rescue 1122 be shifted to upper region of Rawalpindi city, where the majority of hotspots lie. The study further recommends incorporation of GIS based expertise in the emergency department to provide real time analysis for further improvement of emergency first response in the city as well as ensure proper resource allocation. The study could thus be used as a benchmark by EFR providers in the city and serve as a reference at both national and international levels with similar conditions.

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المراقبة القائمة على نظم المعلومات الجغرافية GIS لمخاطر حوادث المرور على الطرق (RTA) في مدينة روالبندي: نهج إحصائي جغرافي

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خلاصة

إن تحديد مواقع القيم المرتفعة للحوادث المرورية التي كانت موجودة سابقاًيُعد الخطوة الأولى لضمان سلامة الطرق في المستقبل. وركزت الدراسة على توفير المراقبة الإحصائية الجغرافية القائمة على نظم المعلومات الجغرافية لحوادث المرور على الطرق (RTA) في روالبندي لمدة خمس سنوات (2013-2009) لتحديد المناطق عالية المخاطر أو مواقع الحوادث ذات القيم المرتفعة. ولذلك، تم إجراء تحليل الارتباط الذاتي المكاني (دليل موران Moran's I)، والانحراف المعياري الاتجاهي (SDE) وتجمعات القيم المرتفعة (Getis-Ord Gi×) على البيانات التي تم الحصول عليها من قسم خدمة الطوارئ في البنجاب (الإنقاذ 1122). وكانت معظم التجمعات المكانية والقيم المرتفعة التي تم تحديدها أثناء البحث تقع في الجزء الشمالي والشمالي الشرقي من منطقة الدراسة وتشمل المناطق التجارية والسكنية في المدينة، حيث تقع غالبية القيم المرتفعة للحوادث بالقرب من المدارس والمستشفيات والمطارات والطرق السريعة. واقترحت الدراسة أنه ينبغي اتخاذ خطوات جادة لتحسين ظروف السلامة على الطرق في هذه الم

الطوارئ (ERPs) إلى هناك. وعلاوة على ذلك، ينبغي ضمان دمج الخبرة القائمة على نظم المعلومات الجغرافية في قسم الطوارئ من أجل المراقبة المنتظمة للتغييرات التي تطرأ على المواقع الساخنة.