USING GIS TO IDENTIFY VEHICLE CRASH HOT SPOTS AND UNSAFE CROSSROADS – A CASE STUDY OF KOLKATA, INDIA.

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KEY WORDS: Pedestrian crashes, Remote sensing, GIS, Hotspot analysis, Severity Index.

ABSTRACT

Urban road network in India has seen a dynamic expansion in last few decades. This expansion comes in terms of urbanization, increased vehicular ownership and increased mobility. Currently, Indian roads are responsible of carrying almost 90 percent of the country’s passenger traffic and 65 percent of its freight (The World Bank Report). However, there has been an increase of 32 % deaths since 2007, a tenfold increase as compared to 1970, owing to vehicle-pedestrian conflicts in India. Kolkata alone accounted for over 4000 crashes in 2016, making it the fifth city with most road crashes in India. Therefore, road safety has become one of the most urgent as well as challenging issues which demands maximum priority. This paper presents a GIS approach based on the spatial autocorrelation of pedestrian–vehicle crash data for identification and ranking of unsafe crossroads. The analysis took into consideration both the number and severity of the vehicle crashes to identify the most critical crossroads in the North division in Kolkata. The Severity index at each location was calculated using Equivalent Property Damage Only (EPDO) method and the statistical significance for Moran’s I statistic was calculated using z-score methods. Consequently, through spatial correlation statistical tool, the maximum distance threshold was identified where the z-score is maximum and statistically significant. Hotspots points were identified using Getis-Ord Gi* statistics. The results from the analysis reveals that the GIS based approach is capable of identifying and detecting spatial pattern of crash data which can be further used to detect and rank unsafe crossroads in the vehicle crash hot spot areas.

INTRODUCTION

India has the second largest road network in the world which is undergoing a continuous expansion. However, this has led to an increased number of road traffic accidents (Ministry of Road Transport & Highway, 2013). A study of 8 major Indian cities revealed that 84-93% of total deaths constituted of vulnerable road users (pedestrians, bicyclists, and motorized two-wheelers) (Mohan, 2016). In 2016, 1,50,785 people were killed, i.e. around 12 deaths per 100,000 people and as much as 4,94,624 people were injured in road crashes in India (Save Life foundation, 2016). This represents an increase of 32 % deaths since 2007 and a tenfold increase as compared to 1970. Despite being the second most populous country and almost 90 percent of its population depending on road for daily commutes, India has only contributed to 0.7% published researches on road traffic injuries worldwide and of which only one-third included statistical analysis and modelling (Mohan, 2016). Therefore, road safety has become one of the most urgent as well as challenging issues that demand maximum priority in India. Further, an effective technique must be designed for identifying the hazardous crash locations based on the accident statistics (Ministry of road transport and highway, 2015).

Kolkata is the capital of the state of West Bengal and largest city in eastern India. It accounted for over 4000 crashes in 2016, making it the fifth city with most road crashes in India (Save Life foundation, 2016). Residential areas in the city are densely populated and hence it experiences a high number of pedestrians, taxi’s, cars commuters. In 2016, Kolkata experienced 407 numbers of road crash fatalities of which 196 were pedestrians (48.15 %) (police, 2016). Figure: 1 shows the share of pedestrian fatalities in Kolkata for 2015 and 2016. Although there is a decrease in the number of pedestrian fatalities, it still constitutes of about 50% of the total road fatalities.
Kolkata traffic police are divided into 8 divisions, which are further divided into 7-8 police stations for better operation. In 2016, the South division experienced the most number of crashes (899) followed by South East division (484) and Eastern Suburban (457). North division saw a total of 316 crashes of which 46 were fatal, and 142 were serious. This study aims at developing a vehicle crash hotspot area map for the North division and then using it to identify the unsafe crossroads in the division which needs immediate mitigation measures.

**PROPOSED INTERVENTION METHODS FOR PEDESTRIAN SAFETY FROM LITERATURE**

A number of reactive as well as proactive measures can be found in literature to make an urban street network more pedestrian friendly and safer. Some of the Policy and Design guidelines implemented by the Indian government are National Urban Transport Policy (NUTP, 2006), National Mission on Sustainable Habitat (NMSH), United Traffic and Transportation Infrastructure (Planning & Engineering) Centre (UTTIPEC) and IRC Guidelines addressing pedestrians (IRC:132-2012).

From the literature it is evident that lack of proper infrastructure is one of the major cause of pedestrian related accidents followed my conflict with other modes of vehicles. Some of the policy options for pedestrian safety are provided below (Mohan, 2016)-

1. Reserving adequate space for non-motorized modes on all roads where they are present.
2. Banning free left turns at all signalized intersections thus allowing a safe time for pedestrians and bicyclists to cross the road.
3. Speed control in urban areas: maximum speed limits of 40-50 km/h on arterial roads need to be enforced by road design and police monitoring. Maximum speeds of 30 km/h in residential areas need to be enforced by judicious use of speed-breakers and mini roundabouts.
4. Traffic calming in urban areas and on rural highways passing through towns and villages.
5. Improvement of existing traffic circles by bringing them in accordance with modern roundabout practices and substituting existing signalized junctions with roundabouts.
7. Mandatory road safety audit for all road building and improvement projects.
8. Construction of service lanes along all 4-lane highways and expressways for use by low speed and non-motorized traffic.
9. Removal of raised medians on intercity highways and replacement with steel guard rails or wire rope barriers.
STUDY AREA AND DATA CONSIDERED

North division was selected as the study area for the analysis as it displays characteristics of a typical Indian urban street network. The division contains parts of both new and old Kolkata and hence the associated different street network designs. Moreover, number of accidents for different types of accidents are more or less fairly distributed and thus gives a better understanding of the effectiveness of the applied approach. The division is further divided into 8 police stations – Shyampukur, Jorabagan, Burtalla, Amjerstreet, Cossipore, Sinthee, Chitpore, and Tala. The accident data along with various other statistics were obtained from the official annual review of Kolkata traffic police for the year 2016. In the north division, Chitpore experienced the highest number of total crashes (63) and fatal crashes (12) while Sinthee recorded the lowest total crashes (5). Due to scarcity of data for vehicle-pedestrian crashes, the analysis has been done using overall vehicular crash data. Further it has been assumed that the critical junctions identified will be equally critical for pedestrians owing to its high share in the total fatalities.

METHODOLOGY

The methodology adopted for this study can be divided into the following subparts-

1. **Load the vehicle crash data and aggregate the data at each location.**
   The base map and vehicle accident points are loaded in the ArcGIS software. Each point represents single vehicle crash data. Each type of crash (fatal, serious, minor, and Collision) is separately indicated to exhibit their spread over the area.

2. **Compute severity index at each location.**
   To calculate the severity index "Equivalent Property Damage Only method (EPDO)" has been used. EPDO considers all levels of severity of crashes occurring at a site for deciding a site as critical. This severity index is used as the criterion for spatial analysis in this research.

3. **Examine the spatial patterns of the vehicle crash data.**
   In this research, the spatial Autocorrelation tool was used to compute Moran’s I statistics and z scores. The Spatial Autocorrelation (Global Moran’s I) tool measures spatial auto-correlation based on both feature locations and feature values simultaneously. Given a set of features and an associated attribute, it evaluates whether the pattern expressed is clustered, dispersed, or random. The tool calculates the Moran's I Index value and both a z-score and p-value to evaluate the significance of that Index. P-values are numerical approximations of the area under the curve for a known distribution, limited by the test statistic.

4. **Create a vehicle crash hot spots area map.**
   Getis-Ord G* statistic is used to identify vehicle crash hot spots in this study. The resultant Z score tells you where features with either high or low values cluster spatially. A feature with a high value is interesting, but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well.

5. **Identify the crossroads in the hot spot areas.**
   The crossroads data points were then loaded and crossroads in the hot spot zones were identified. Hotspot zones will be created using an interpolation tool in ArcGIS.

6. **Compute severity indices and rank unsafe crossroads.**
   Severity indices for the crossroads which are in the hot spot zones were calculated. Further, the crossroads were ranked according to decreasing severity index and finally, critical crossroads spots were identified for mitigation purposes (Truong, 2011).
RESULTS & DISCUSSIONS

The accident crash data was uploaded in the North zone boundary. Fatal, Serious, Minor, and collision crash data were added separately to show their spread over the area.

Figure 4: Crash points for the year 2016 (north division, Kolkata)

The Severity index at each location was then calculated using the EPDO method. The number of each type of crashes are multiplied by their equivalent property damage weight factors and added to calculate the EPDO cost for each site. For this study, the weights have been taken as follows (Bandyopadhyaya, 2011) –

\[
SI = 33.05X_1 + 14.98X_2 + 1.16X_3 + X_4 \quad \text{…………………………………………………………….. (equation 1)}
\]

Where, \(X_1\) = total number of fatal crashes, \(X_2\) = total number of serious injury crashes, \(X_3\) = total number of minor injury crashes, and \(X_4\) = total number of collision crashes (property damage only).

Figure 5: Distribution of severity indices

The statistical significance for Moran’s I statistics was calculated using z-score methods. Through spatial correlation statistical tool, the maximum distance threshold was identified where the z-score is maximum and statistically significant. The distance threshold of 200 m associated with maximum z score was chosen for the analysis using hotspot analysis and rendering tool. For the distance of 200 m, z score was found to be -2.04 with a statistical significance of 0.04. This indicates that the spatial distribution of high values and low values in the dataset is more spatially dispersed than would be expected if underlying spatial processes were random. Figure 5 shows the distribution of severity indices in the study area. Figure 6 represents the normal curve depicting the dispersed nature.
of high and low values in the data set. Hotspots points were identified using Getis-Ord Gi* statistics. It tells us about the spatial clustering of points with high or low values. Figure 7 shows the resultant identified hotspot points. It can be observed that the Jorabagan and Burtala region consists of clusters of points with high values, whereas Sinthee, Chitpore and Tala region consists of clusters of points with low values (cold spots). Further, based on the hotspot points, hotspot areas were identified on the map (Figure 7). From, the map the major crossroads in the hotspot areas were identified and subsequently their severity indices were calculated and ranked (Table 1).

![Figure 7: Hotspot on the map for all points](image)

**Hot spot areas on the map for all accidents**

![Figure 8: Hotspot areas on the map](image)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crossroads</th>
<th>Within 50 m</th>
<th>Severity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dani Ghosh Sarani – CR Avenue Road</td>
<td>4 6 2 0</td>
<td><strong>224.4</strong></td>
</tr>
<tr>
<td>2</td>
<td>Shri Aurobindo Sarani – Acharya Jagdish Chandra Bose Road</td>
<td>1 10 4 2</td>
<td><strong>189.49</strong></td>
</tr>
</tbody>
</table>

Table 2: Ranking of crossroads according to the severity index
<table>
<thead>
<tr>
<th></th>
<th>Street 1</th>
<th>Street 2</th>
<th>EPDO</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Sovabazar Street – CR Avenue Road</td>
<td>1 7 3 1</td>
<td>142.39</td>
</tr>
<tr>
<td>4</td>
<td>Sovabazar Street – Rabindra Sarani</td>
<td>1 4 4 1</td>
<td>98.61</td>
</tr>
<tr>
<td>5</td>
<td>Nimtala Ghat street – Rabindra Sarani</td>
<td>1 4 1 0</td>
<td>94.13</td>
</tr>
<tr>
<td>6</td>
<td>Shri Aurobindo Sarani – Cornwallis street</td>
<td>1 3 4 2</td>
<td>84.63</td>
</tr>
<tr>
<td>7</td>
<td>Nimtala Ghat street – Baishnab Seth Street</td>
<td>2 1 1 2</td>
<td>84.24</td>
</tr>
<tr>
<td>8</td>
<td>Nimtala Ghat street – Stand road</td>
<td>1 3 3 0</td>
<td>81.47</td>
</tr>
<tr>
<td>9</td>
<td>Dani Ghosh Sarani – Cornwallis street</td>
<td>0 5 3 3</td>
<td>81.38</td>
</tr>
</tbody>
</table>

**Upper Tail Critical Test**

Upper tail critical value is computed using the mean, standard deviation and Z value at a specified significance level and can be used to find accident black spots. Upper tail critical value at 5% significance level is calculated as –

\[
\text{Upper tail critical value} = \text{mean} + 1.645 \times \text{standard deviation} \quad (equation \ 2)
\]

This study uses this test to identify crossroads with observed EPDO values exceeding the calculated critical value. The critical value for obtained data set was calculated to be 202.99 using the mean and standard deviation of the dataset. From Table 1 it can be observed that the calculated EPDO value for DG Sarani-CR avenue intersection exceeds the critical value. Hence, it can be asserted that in the North division DG Sarani-CR avenue intersection is the most critical accident black spot and thus needs immediate intervention and mitigation measures to be employed. Further, it can also be observed that the first three ranked intersections have very high EPDO values with respect to the remaining intersections.

**Serious and Fatal accidents**

The above analysis considers all the accidents including minor and property damage to give the corresponding equivalent property damage costs that occurred in the year 2016 at the critically unsafe crossroads. Further, if only the cases associated with fatal crashes and serious injuries are taken into consideration it provides a more focused insight on the crossroads where most of the severe accidents occurred.

**Severity index for Fatal and Serious accidents**

![Severity indices for fatal and serious accidents](image_url)

**Figure 9:** Severity indices for fatal and serious accidents
The analysis was repeated with only Fatal and serious vehicle crashes and it was observed that the accident points in the region were randomly distributed. Thus, there was very less to none cluster formation as evident from figure 8 and 9. The critical zone was found to be located in the region under Shyampukur police station and western part of Chitpore. The crossroads under the hotspot regions were identified and ranked as done previously for all the points.

Table 3: Ranking of crossroads for fatal and serious accidents according to the severity index

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crossroads</th>
<th>Within 50 m</th>
<th></th>
<th></th>
<th></th>
<th>Severity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jatindra Mohan road – RG Kar road</td>
<td>3 8 4 0</td>
<td></td>
<td></td>
<td></td>
<td>223.6</td>
</tr>
<tr>
<td>2</td>
<td>Raja Mahindra road – Tara Shankar Sarani</td>
<td>4 3 1 2</td>
<td></td>
<td></td>
<td></td>
<td>180.3</td>
</tr>
</tbody>
</table>
Table 2 depicts unsafe crossroads ranked on the basis of their EPDO score for fatal and serious crashes. It can be observed that JM road – RG Kar road intersection has a high EPDO value closely followed by RM road – TS Sarani intersection. Apart from these, no other intersection had a significant EPDO value and thus have not been included in the table. Comparing the two tables we can deduce that JM road – RG Kar road intersection and DG Sarani – CR avenue intersection are the most unsafe intersections with 223.6 and 224.4 EPDO respectively in the zone requiring urgent implementation of mitigation measures to improve the situation.

CONCLUSIONS
This paper presents a GIS approach based on the spatial autocorrelation of pedestrian-vehicle crash data for identification and ranking of unsafe crossroads. The analysis took into consideration both the number and severity of the vehicle crashes to identify the most critical crossroads in the North division (Police station) in Kolkata. The results obtained from the analysis of the vehicle crash data indicate that the approach is capable of statistically detecting the spatial pattern of crash data which can be further used to detect and rank unsafe crossroads in the vehicle crash hot spot areas. The results of the vehicle crash analysis are pretty accurate owing to the use of well-designed spatial statistics that consider both their locations as well as attributes. Finally, the study overall provides a sound basis for identifying vehicle crash hotspots and identifying the critical unsafe crossroads, which can be further used to study the causal factors, determine effective mitigation strategies and policy changes.
REFERENCES

DETERMINATION OF CORRELATION BETWEEN STREET ACCESSIBILITY AND CRIMES USING SPACE SYNTAX NETWORK GRAPH ANALYSIS

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ABSTRACT:

Vancouver is the most densely populated city in Canada (Canada, 2017). Urban planning in Vancouver is characterized by high-rise residential and mixed-use development in urban centres, as an alternative to sprawl (Boddy, 2005). The style of planning has been termed as Vancouverism. Vancouver is classed as a Beta global city with very high scores for liveability (The Data Team, 2018). However, the crime rate in Vancouver has been increasing. As the city expands, crimes tend to increase with the increase in population which is one of the key challenges addressed by the urban planners and policymakers. Crimes should reduce along with the improvement of the living standard of the people. Questions such as what could be the causes of this phenomenon or the unsafety on the streets arise. Moreover, many prior researches have shown the presence of a spatial influence in crime incidents (Kakamu, Polasek, & Wago, 2008). Researchers also suggest that more accessible areas with high public awareness have a high probability of a criminal offense. Sometimes the results can be contradictory as seen in previous researches. In the present study, an effort has been made to test the hypothesis that crime takes place in an area less accessible or streets which are less connected and hence carry fewer pedestrians and to determine how pedestrian-street accessibility and connectivity influence crime rates. The study uses the space syntax street network method along with standard GIS workflows such as spatial join, nearest neighbour search and network graph analysis to bring the data to a common platform for the correlation analysis. Further on, Moran's I scores are also tested to check for a clustering or dispersal effect in the distribution of crimes. Pearson's coefficient tests have been used to show the correlation between the high/low accessible streets and crime incidents for the same streets. Positive clustering effects were observed in downtown Vancouver. A positive correlation ranging from 0.36 to 0.44 with 95% confidence was found between the crime incidents and the types of the street (arterial, secondary arterial, collector & residential).

Further research can be carried out to determine how different types of crime incidents and types of streets are correlated.

KEYWORDS:

Geographic Information System, Space Syntax Network Analysis, Pearson’s Coefficient, Urban Crimes, Pedestrian Accessibility

1. Introduction

As the cities are developing, crimes tend to increase with increase in population which is not desired by the urban planners and policy makers. Crimes should reduce along with the improvement of living standard of the people. What to could be the cause for such phenomenon? Is it the living standard that is encouraging people to do a crime? Has it become easier to do a crime? Do we need to re-plan our cities? All such questions have to be answered with a strong justification. Is crime correlated with how our cities are planned? This suggests that crime is spatially distributed based on various factors. One of the factors could be the land use type, say commercial, residential, industrial, etc. Researchers also suggest that more accessible areas with more public awareness have high probability of a criminal offence. Sometimes the results can be contradictory as seen in previous researches. This study is conducted to test our hypothesis that crime takes place in an area which is less accessible or streets which are less connected and hence carry fewer pedestrians and also to determine how street accessibility and connectivity influence any crime.

2. Study Area

Vancouver is a coastal seaport city in western Canada, located in the Lower Mainland region of British Columbia (Vancouver Wiki, n.d.). As the most populous city in the province, the 2016 census recorded 631,486 people in the city, up from 603,502 in 2011. Vancouver is consistently named as one of the top five worldwide cities for liveability and quality.
of life and the Economist Intelligence Unit acknowledged it as the first city ranked among the top-ten of the world's most well-living cities for five consecutive years. As of 2011, Vancouver is the most densely populated city in Canada. Urban planning in Vancouver is characterized by high-rise residential and mixed-use development in urban centres, as an alternative to sprawl. Vancouver is classed as a Beta global city. Vancouver also has one of the highest number of crimes in Canada.

3. Literature Review
To conduct this study various existing literature was referred. Research papers suggested, according to the Crime Pattern Theory crimes tend to occur in the regions which are more accessible and where there is more public awareness. The methodology used to approach the solution was the regression analyses. Integration and choice models of the space syntax methodology were the most suited models for this study (Summers & Johnson, 2017). Our study tries to determine the correlation between the accessibility of streets and the crimes happening on the streets for a cosmopolitan city like Vancouver, Canada. In the research paper titled “Examining the Relationship Between Road Structure and Burglary Risk Via Quantitative Network Analysis”, Toby Davies and Shane D. Johnson concluded that betweenness offers a more granular and objective means of measuring the street network than categorical classifications previously used, and its meaning links more directly to theory. The results provide support for crime pattern theory, suggesting a higher risk of burglary for streets with more potential usage. The apparent negative effect of linearity suggests the need for further research into the visual component of target choice, and the role of guardianship (Davies & Johnson, 2015).

4. Methodology
The data used in the following methodology was street networks and crime events for the city of Vancouver, Canada for the year 2017. Following were the steps involved in the methodology.

1. Space Syntax
The space syntax methodology was used as it is used to estimate how accessibility & connectivity varies across the street network. The space syntax for the street network was generated using the UCL depth map and space syntax for QGIS. The integration and choice values were identified for values of radii that are 800m and 1600m. The values for the radii were chosen keeping in mind the distance for which a person can walk or ride a bicycle. There are some limitations to this methodology. A few streets from the entire network were rejected during the process. This is because the space syntax metrics do not consider turns with larger angular deviations from an existing trajectory or path.
2. Geoprocessing

The crime events data was spatially joined with the space syntax using the intersect function. Also the street network file was spatially joined with the space syntax layer because during the process of space syntax generation there were several data losses. The correlation between the streets and the crime events was calculated in two ways,

i. All Crimes All Streets (ACAS)

ii. All Crime Sub Streets (ACSS)

This means the correlation was calculated between all the crime events type in the former way and the correlation was calculated between all the crime events type with all the sub street types. The sub street types include arterial streets, secondary arterial streets, collector streets and residential streets.

Individual layers were created to visualize the spatial distribution of the type of crime happening on the streets. The crime events had the following sub categories, namely, (a) vehicle collision involving injury (b) vehicle collision involving fatality (c) theft from vehicle (d) theft of vehicle (e) theft of bicycle (f) other theft (g) mischief (h) break into commercial places (i) break into residential places.
5. Results

The following results were achieved after calculating the Pearson’s correlation in two ways, that is, ACAS and ACSS.

- **Chr800m**: Choice Centrality (Betweenness) in a radius of 800 metres
- **Chr1600m**: Choice Centrality (Betweenness) in a radius of 1600 metres
- **Intr800m**: Integration (Closeness) in a radius of 800m
- **Intr1600m**: Integration (Closeness) in a radius of 1600m

<table>
<thead>
<tr>
<th>Street type</th>
<th>Chr80m</th>
<th>Chr160m</th>
<th>Intr80m</th>
<th>Intr160m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerial</td>
<td>0.25</td>
<td>0.24</td>
<td>0.42</td>
<td>0.39</td>
</tr>
<tr>
<td>Collector</td>
<td>0.23</td>
<td>0.16</td>
<td>0.45</td>
<td>0.42</td>
</tr>
<tr>
<td>Residential</td>
<td>0.21</td>
<td>0.2</td>
<td>0.24</td>
<td>0.32</td>
</tr>
<tr>
<td>Secondary Arterial</td>
<td>0.25</td>
<td>0.24</td>
<td>0.36</td>
<td>0.34</td>
</tr>
<tr>
<td>All Streets</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

6. Conclusion

Space syntax methodology of accessibility for Vancouver street networks didn’t show any major influence on the overall crime scenario in Vancouver with a Pearson’s correlation coefficient ranging between -0.01 and -0.02 which can be termed as no linear relationship.

We found moderate positive linear correlation between the no. of crimes and the integration score at 800m and 1600m for arterial streets, collector streets and residential streets with Pearson’s correlation coefficients ranging between 0.35 and 0.45.

The above research finding suggests that increasing accessibility in residential, collector and arterial streets is associated with increase in crimes in the city of Vancouver.

Limitations

The frequency of crime incidences was not normalized using the census data of the region and hence biases may get introduced since highly populated regions are likely to have more crimes. Space syntax methodology involves modelling human movement behaviour and hence more cultural and socio demographic parameters are required for explaining phenomena such as crime.

Way Forward

Model fitting using linear regression did not yield any significant results due to the discrete nature of the frequency variable with respect to accessibility parameter scores. More complex nonlinear relationships should be explored. Adding more variables such as land use, traffic volumes, socio-demographic parameters, etc. to the current study may yield better results.

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ASSESSMENT OF MORPHOLOGICAL CHARACTERISTICS OF MADURU OYA RIVER BASIN OF SRI LANKA USING GIS

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KEY WORDS: Hydrological Processes; River Morphometry; Soil and Topographical Conditions; Spatial Data

ABSTRACT: River basin is the entire land area supplying its water into a river and thus river network and its drainage area which can be explained through morphological characteristics control the hydrological processes occurring within the river basin. Hence, the present study attempted to assess the morphological characteristics of Maduru Oya river basin to upgrade the knowledge base of morphological characteristics of Maduru Oya River Basin of Sri Lanka and to identify its flood characteristics based on river Morphometry. The study was carried out using spatial data derived from Geographical Information System. Linear, areal and relief aspects of morphological characteristics of the basin were assessed and then soil, land use and terrain condition of the basin were examined to elaborate the findings. Results revealed that the Maduru Oya river basin has 6th order river network with a dendritic drainage pattern and moderate drainage texture. The obtained higher values of bifurcation ratio and all lower values of drainage density, stream frequency, elongation ratio, circularity ratio, form factor, length of overland flow, drainage intensity, relief ratio and relative relief revealed that this basin would generate a flatter peak of direct runoff for a longer duration and thus there is a less risk for both soil erosion and flooding within the basin. Further, permeable nature of main soil type, good vegetation and low relief which cover a major extent of the basin supported the findings of the morphological characteristics.

1. INTRODUCTION

Morphology is defined as the science of structure or form, and hence the geomorphology is the science of landforms; it is the interpretive description of the relief features of the earth (Worcester, 1948). Further, watersheds or river basins are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape (Abrahams, 1984). Generally, morphological characteristics of river basins are assessed through linear, areal and relief aspects (Pareta and Pareta, 2011).

Horton (1932) and Strahler (1957) have done the pioneering works on morphological assessments of river basins using conventional methods. However, in recent decades, morphological characteristics of many river basins in the world have been widely assessed by many researchers with the help of Spatial Information Technologies. Accordingly Entella River basin in Italy (Roth, et al., 1996) and Moscandro Torrent and Rio Cordon catchments located in the Eastern Italian Alps (Mao, et al., 2009) have been analyzed. Several Nigerian river basins viz, Asa (Jimoh and Iroye,2009), Calabar (Eze and Efiong, 2010), Ogunpa and Ogbere (Ajibade, 2010) and also Didessa River Catchment in Blue Nile Basin (Muluneh and Mamo, 2014), Guigou sub-watershed in Morocco (Aouragh and Essahlouci, 2014) have been morphometrically analyzed. Moreover, many of the Indian river basins viz, Kanhar (Singh and Singh, 1997), Chaka (Nag, 1998), Mehadrigedda (Narendra and Nageswara, 2006), Mohr (Thakkar and Dhiman, 2007), Gostani (Nageswara, et al., 2010), Manas (Nongkynrih and Husain, 2011), Yamuna (Pareta and Pareta, 2011), Shaliganga (Aravinda and Balakraishna, 2013), Dungra (Bera and J.Bandyopadhyay, 2011), Shetrunji (Wandre and Rank, 2013) and Ponnaiyar (Narmatha, et al., 2013) have been studied for their morphometric parameters and have given recommendations based on those parameters for sustainable planning and development of these river basins. However, in Sri Lankan context, a very few studies have been done and only Gin Ganga, Walawe Ganga, Menik Ganga and Kirindi Oya River Basins (Bandara, 2005), Kothmale Reservoir Catchment (Senadeera, et al., 2007), Randenigala Reservoir Catchment (Senadeera, 2014) Gal Oya River Basin (Withanage, et al., 2014) and Kala Oya River Basin (Withanage, et al., 2016) have been assessed for their morphometry.

Therefore, this study was done to upgrade the knowledge base of morphological characteristics of Maduru Oya River Basin of Sri Lanka and to identify its relation with flood characteristics. Maduru Oya river basin is one of the 103 major river basins located in Sri Lanka. The river is the 8th longest river in Sri Lanka (National Atlas of Sri Lanka, 2007).
2. MATERIALS AND METHODS

River basin boundary of the selected Maduru Oya River Basin of Sri Lanka was digitized based on the River Basins Boundary Map published by Department of Agrarian Services, Sri Lanka (2012) and then it was verified with the help of contour map published by Survey Department of Sri Lanka (2007). The digital layers of the hydrological network and land use pattern of the river basin were obtained by digitizing topographic map sheets (38, 39, 43, 44, 45, 49, 50, 55, 56, 63) in 1:50,000 scale published by Survey Department of Sri Lanka (2007). Further, the digital layer of soil types of selected basin was prepared by scanning and digitizing the Soil Map available in National Atlas of Sri Lanka (2007). The Digital Elevation Models and slope maps were generated using Shuttle Radar Topography Mission (SRTM) data obtained from http://earthexplorer.usgs.gov. The ArcGIS-9.3 software package was used in preparing digital layers used in the study and all the maps were prepared in Sri Lanka National Grid based on TM coordinate system.

The linear, areal and relief aspects of morphological parameters were assessed using GIS Software analysis tools and different morphometric analysis models available in the scientific literature of Geomorphology (Table 1).

Table 1: Methods used for the morphometric analysis

<table>
<thead>
<tr>
<th>Morphometric Parameter</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linear Aspects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stream Order (U)</td>
<td>Hierarchical rank</td>
<td>Strahler (1964)</td>
</tr>
<tr>
<td>Number of Streams (N_U)</td>
<td>N_U = N_1 + N_2 + ... + N_6</td>
<td>Horton (1945)</td>
</tr>
<tr>
<td>Stream length in km (L_U)</td>
<td>L_U = L_1 + L_2 + ... + L_6</td>
<td>Horton (1945)</td>
</tr>
<tr>
<td>Mean stream Length (L_{U\text{Mean}})</td>
<td>L_{U\text{Mean}} = L_1 + L_2 + ... + L_6</td>
<td>Strahler (1964)</td>
</tr>
<tr>
<td>Bifurcation Ratio (R_B)</td>
<td>R_B = N_U / (N_U + 1)</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>Stream length Ratio (R_L)</td>
<td>R_L = L_U / L_U - 1</td>
<td>Horton (1945)</td>
</tr>
<tr>
<td><strong>Areal Aspects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area in km² (A)</td>
<td>Area calculation</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>Perimeter in km (P)</td>
<td>Perimeter calculation</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>Length of the basin in km (L_B)</td>
<td>Length calculation</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>Drainage density (D_D)</td>
<td>D_D = L_U / A</td>
<td>Horton (1932)</td>
</tr>
<tr>
<td>Stream frequency (F_S)</td>
<td>F_S = N_U / A</td>
<td>Horton (1932)</td>
</tr>
<tr>
<td>Circulatory ratio (R_C)</td>
<td>R_C = 12.57 * (A/P²)</td>
<td>Miller (1953)</td>
</tr>
<tr>
<td>Elongation ratio (R_E)</td>
<td>R_E = 2 / (L_B * √(A/π))</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>Form factor (F_F)</td>
<td>F_F = A / L_B²</td>
<td>Horton (1932)</td>
</tr>
<tr>
<td>Drainage texture (D_T)</td>
<td>D_T = N_U / P</td>
<td>Horton (1945)</td>
</tr>
<tr>
<td>Length of overland flow (L_O)</td>
<td>L_O = 1 / D_D * 0.5</td>
<td>Horton (1945)</td>
</tr>
<tr>
<td><strong>Relief Aspects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basin relief in m (H)</td>
<td>H = Z - z</td>
<td>Strahler (1957)</td>
</tr>
<tr>
<td>Relief ratio (R_H)</td>
<td>R_H = H / L_B</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>Relative Relief (R_{HP})</td>
<td>R_{HP} = H * 100 / P</td>
<td>Melton (1957)</td>
</tr>
</tbody>
</table>

Further, areal share of the different soil and land use types spread in the river basin were calculated as percentages using the information produced by the attribute tables of the digital layers with soil types and land use. Moreover, terrain conditions of the selected basin were identified by preparing elevation and slope maps.
3. RESULTS AND DISCUSSION

3.1. Linear Aspects

Table 2 shows the stream orders (U) obtained according to Strahler’s (1952) classification and the number of streams in each order \( N_U \) of the studied Maduru Oya river network. Figure 1 also evidences that 1369 stream segments of Maduru Oya river network is extending up to 6\(^{th}\) order showing a dendritic drainage pattern which is characterized by irregular branching of tributary streams in many directions and at almost any angle usually less than 90\(^{0}\) as explained by Garde (2006).

<table>
<thead>
<tr>
<th>Stream Order (U)</th>
<th>( N_U )</th>
<th>( L_U ) (km)</th>
<th>( L_{UM} ) (km)</th>
<th>( R_B )</th>
<th>( R_L )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>995</td>
<td>700.16</td>
<td>0.7</td>
<td>-</td>
<td>1.84</td>
</tr>
<tr>
<td>2</td>
<td>283</td>
<td>366.72</td>
<td>1.3</td>
<td>3.52</td>
<td>1.87</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>165.07</td>
<td>2.43</td>
<td>4.16</td>
<td>2.06</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>90.04</td>
<td>5</td>
<td>3.78</td>
<td>4.37</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>87.49</td>
<td>21.87</td>
<td>4.5</td>
<td>3.79</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>83</td>
<td>83</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1369</td>
<td>1492.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The decreasing \( N_U \) with the increasing \( U \) in the basin confirm the Horton’s (1945) and Strahler’s (1957) findings. Gregory and Walling (1973) have found that the increasing order of network is associated with greater stream flow values.

The stream length \( (L_U) \) is one of the significant features of the basin, as it reveals surface runoff characteristics. Usually, the total lengths of stream segments are highest in the first order streams, and it decreases as the stream order increases (Horton, 1945) and Maduru Oya river basin also shows similar pattern (Table 2). The mean stream length of each order \( (L_{UM}) \) is a characteristic property related to the drainage network components and its associated basin surfaces. The obtained \( L_{UM} \) values (Table 2) of the basin are increasing with increasing order confirming Strahler’s (1964) findings on \( L_{UM} \).

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Figure 1: Strahler’s Stream Orders of Maduru Oya River Basin
The \( R_B \) is a dimensionless property and generally ranges from 3.0 to 5.0 (Strahler, 1957) and the \( R_B \) values of all 6 orders of the studied river network are within this range (Table 2). According to Chorley, et al. (1957) when bifurcation ratio is low, the risk of flooding is higher, particularly of parts and not the entire basin. Hence, the almost higher \( R_B \) values together with the elongated shape of the studied river basin would result a lower and extended peak flow, which will reduce the risk of flooding within the basin.

As Horton (1945) stated that the stream length ratio (\( R_L \)) tends to be constant throughout the successive orders of a basin. But, the \( R_L \) values of the studied basin are varying among the orders without showing any consistency (Table 2). According to Singh and Singh (1997) changes of stream length ratio from one order to another order indicate their late youth stage of geomorphic development in the streams of the area.

### 3.2. Areal Aspects

The areal aspects are the two dimensional properties of a basin that basically explain the shape parameters. The basin shape has a significant effect on stream discharge characteristics and finally on the flood characteristics of the basin. Table 3 shows the results of the calculated different areal aspects of the studied river basin.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area in km(^2) (A)</td>
<td>1481.00</td>
</tr>
<tr>
<td>Perimeter in km (P)</td>
<td>290.00</td>
</tr>
<tr>
<td>Length of the basin in km (L_B)</td>
<td>91.4</td>
</tr>
<tr>
<td>Drainage density (D_D) in km/km(^2)</td>
<td>1.01</td>
</tr>
<tr>
<td>Stream frequency (F_S)</td>
<td>0.92</td>
</tr>
<tr>
<td>Drainage texture (D_T)</td>
<td>4.72</td>
</tr>
<tr>
<td>Length of overland flow (L_O)</td>
<td>0.5</td>
</tr>
<tr>
<td>Circulatory ratio (R_C)</td>
<td>0.22</td>
</tr>
<tr>
<td>Elongation ratio (R_E)</td>
<td>0.48</td>
</tr>
<tr>
<td>Form factor (R_F)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

The \( D_D \) indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channels for the whole basin (Horton, 1932). According to Strahler (1964), \( D_D \) values may be 1 km/km\(^2\) through very permeable rocks, whereas they increase to over 5 km/km\(^2\) through highly impermeable surfaces. And also low \( D_D \) is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover and where relief is low. A high \( D_D \) is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low \( D_D \) leads to coarse drainage texture while high \( D_D \) leads to fine drainage texture (Strahler, 1964). The \( D_D \) of the basin is low (Table 3) according to Strahler (1964) and it has resulted from a permeable land surface (Figure 2) with good vegetation cover (Figure 3) and less slope (Figure 4) prevailing in the basin as also explained by Nag (1998).

The stream frequency (\( F_S \)) introduced by Horton (1932) is an indicative of stream network distribution over the river basin. Kale and Guptha (2001) have found that the \( F_S \) value may range from less than 1 to 6 or even more depending on the lithology of the basin. In the present study, the \( F_S \) value of the basin (Table 3) is less than 1.0 indicating a low value. This reveals that the basin possesses a low relief and almost flat topography as stated by Horton (1932) and also as confirmed by the identified low relief conditions of the studied basin (Figure 4).

The drainage texture (\( D_T \)) is one of the important concepts of geomorphology which means the relative spacing of drainage lines. The \( D_T \) depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. According to Smith (1950) the \( D_T \) depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. Further he explained that, the soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate. Smith (1950) has classified the drainage texture into five different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). Based on this classification, Maduru Oya has a coarse drainage texture and it is also confirmed by the resulted low \( D_D \) (Table 3) as explained by Strahler (1964).
The length of overland flow (L₀) refers to the length of the runoff of the rain water on the ground surface before it gets concentrated into definite stream channels (Horton, 1945). The overland flow is higher in the semi-arid regions than in the humid and humid temperate regions; in addition, absence of vegetation cover in the semi-arid regions is primarily responsible for lower infiltration rates and for the generation of higher surface flow (Kale and Gupta, 2001). Thus the resulted low L₀ value (Table 3) gives evidences for the existence of good vegetation cover (Figure 3) in the basin.

The circularity ratio (R₉) explained by Miller (1953) and elongation ratio (Rₑ) explained by Schumm (1956), are very significant indices in the analysis of the basin shape which helps to give an idea about the hydrological character of a drainage basin. The resulted R₉ value of the studied basin is 0.22. Miller (1953) has also described that the R₉ ranging from 0.4 to 0.5 indicates strongly elongated and prevailing permeable homogenous geologic materials. Higher the value of R₉, greater the circular shape of the basin and vice-versa. Moreover, Strahler (1964) has stated that the elongation ratio (Rₑ) runs between 0.6 and 1.0 over a wide variety of climatic and geologic types and further he has classified the basins with the help of the elongation ratio viz, circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (less than 0.5). According to this classification, Maduru Oya belongs to the elongated category (Table 3). Hence, both R₉ and Rₑ confirm that the studied river basin is elongated in shape, which produces a low discharge of runoff and availability of highly permeable sub soil conditions as also evident by Figure 2. According to Singh and Singh (1997) these types of elongated basins develop flatter peak of flows for longer durations and thus there are less chances for the generation of flash floods.

The form factor (R₉) is the quantitative expression of drainage basin outline form (Horton, 1932). The values of form factor would always be less than 0.7584 (for a perfectly circular basin). Smaller the value of form factor, more elongated will be the basin. The R₉ value of the studied basin is 0.18 (Table 3) indicating that the basin is elongated in shape further.

### 3.3. Relief Aspects

Table 4 shows the results of the analyzed relief aspects of the studied river basin.

#### Table 4: Relief Aspects of Maduru Oya River Basin

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin relief in m (H)</td>
<td>900</td>
</tr>
<tr>
<td>Relief ratio (R₉)</td>
<td>0.01</td>
</tr>
<tr>
<td>Relative relief (Rₑ₉)</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Schumm (1956) has stated that relief ratio (R₉) is a measure of the overall steepness of a river basin and it is an indicator of the intensity of the erosion process operating on the slope of the basin. Low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope. The R₉ of the Maduru Oya river basin is 0.01 (Table 4) and thus this river basin is morphometrically less susceptible to soil erosion.

The relative relief (Rₑ₉) is an important morphometric variable used for the overall assessment of morphological characteristics of the terrain. Based on Melton’s (1957) classification (low = 0 – 100; moderate = 100 – 300 and high = above 300), the Rₑ₉ value of the river basin belongs to low relative relief category (Table 4) and it is confirmed by Figure 4.

### 3.4. Soil Conditions

Figure 2 shows the areal extent of different soil types available in Maduru Oya river basin. The prominent soil types in the basin are Reddish Brown Earths and Immature Brown Loams; rolling and hilly (35%) and Reddish Brown Earths and Low Humic Gley Soils (26%), Soils on Old Alluvium (13%) and Non Calcic Brown Soil and Low Humic Gley Soils (11%). According to Handbook of Soils of Sri Lanka (1972) these soils can be considered as moderately permeable soils which have promoted the infiltration and percolation processes within the basin and thus confirming the less values resulted for D₉, D₇ and L₀ of the basin.
3.5. Land Use Conditions

As evident by Figure 3, the studied river basin has 68% of natural vegetation and 14% cultivated lands as its main land use types reveling that it has a good vegetation cover of 82% of its total land area. Hence, its available land use promotes more infiltration of water to the soil and reduces risk for both soil erosion and flood within the basin also confirming the results obtained for assessed morphological characteristics of the basin.
3.6. Terrain Conditions

Figure 4 shows that most of the area of Maduru Oya basin is within less than 100 m elevation and the highest point is also below 900 m. This provides evidences on low relief condition confirming the results of morphological characteristics of the basin.

Figure 4: Elevation Map of Maduru Oya River Basin

4. CONCLUSIONS

Data derived using GIS are very helpful to assess morphological characteristics of river basins effectively. Linear, areal and relief aspects studied on Maduru Oya river basin revealed that basin owes a dendritic drainage pattern, moderate drainage texture together with a 6th order river network. A lower and extended peak flow of runoff would be generated within the basin due to having higher bifurcation ratio and all lower values of drainage density, drainage texture, stream frequency, length of overland flow, elongation ratio, circularity ratio, form factor, relief ratio and relative relief reducing the risk for both soil erosion and flooding. Further, permeable nature of main soil types available in the basin, covering more parts of the basin area with a good vegetation and low relief condition of the basin confirmed the studied morphological characteristics of Maduru Oya river basin.

5. REFERENCES


Handbook of Soils of Sri Lanka, 1972, Soil Science Society of Ceylon, Land Use Division, Irrigation Department, Colombo 7.


Multicriteria Analysis for Flood Mapping of Sungai Pahang

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Abstract: The occurrence of floods is a natural disaster incidence that depends on the geographical, physical and rainfall. This study aims to investigate the geospatial analysis of flood in Sungai Pahang, Pahang. The objectives of the study are i) to analyse the use of factors for multi criteria analysis, and ii) to prepare a flood hazard mapping in Sungai Pahang, Pahang. Method used for this study is a multi-criteria analysis using Geographical Information System. Four important factors were used in this research; distance from the river, gradient, land cover and height of the land form. The finding show that the highly dense areas (such as Pekan and Kuantan) located close to the river are located inside the highest susceptible areas, which can give a high loss to the inhabitants in those particular areas. Thus, the recommendation suggests that determination of flood-prone areas of flood level 1 (protected area), level 2 (moderate sensitive rank), level 3 (controlled development area) and level 4 (development area) can be implement by the local authority in practice of development planning work.

Keywords: flood map, multi criteria, Geographical Information System (GIS).

Introduction

Flooding in Malaysia is worsening, with the huge spending towards material and life loss. The incidence of floods as either monsoon floods or flash floods is a natural disaster incident whose main feature depends on geographical, physical and local factors, especially rainfall. Flood incidents involve property loss as well as loss of life and natural assets. In terms of environmental conservation, flood events also involve the destruction of natural resources such as wildlife and forestry. Malaysia has had several disaster incidents involving the loss of lives and property damage on a large scale such as major floods in Pahang, Kelantan and Terengganu (2014). In order to mitigate the flood problem, several methods were applied by using GIS as the main platform. The method such as multi-criteria decision making (MCDM), Simple Additive Weighting (SAW), Monte Carlo AHP approach and weighting approach.
Multi-criteria decision making (MCDM) used for flood management by providing several alternatives. Several researchers that have conducted this kind of method are Ahmadisharaf et al. 2015 and Tang et al (2018). There are also a massive application by using this technique, such as flood risk mapping (Marco, 1994; Sinnakaudan, Ab Ghani, Ahmad, & Zakaria, 2003; Tam, 2014), flood hazard zoning (Nur Aisyah Sulaiman, Thuaiatul Aslamiah Mastor, & Samad, 2015; Rahmati, Zeinivand, & Besharat, 2016), flood risk assessment (Priest et al., 2016) and flood mitigation strategies.

The AHP method is widely used to develop the relative weighting of criteria for specific variables. The steps including i) producing criteria weight samples, ii) perform uncertainty analysis and computing multiple realizations of the susceptibility assessment and iii) perform sensitivity analysis (Tang, Zhang, Yi, & Xiao, 2018). The result shows an average (AVG) susceptibility map and the standard deviation. Another technique is the ordered weighted averaging (OWA) is a family of multi-criteria aggregation technique (Tang et al., 2018), which provides a general class of parameterized aggregation operators between the minimum and maximum. There are also research that used several methods; i) Spatial Multicriteria Evaluation technique, ii) Pairwise Comparison (Analytical Hierarchy Process-AHP) and iii) Ranking Method (Yahaya, 2008). This research purpose is to examine how sensitive the choices are to the changes in criteria weights. This research found that MCDA techniques using GIS technology have proved to be powerful methods to generate hazard maps with a good degree of accuracy.

The review of literature has identified the main factors that are contributed to flooding. The factors of flood analysis was derived from i) flow accumulation, rainfall density, elevation, geology, land use and slope (Kourgialas & Karatzas, 2016) and all of these factors are overlaid together to determine the final flood risk map. The paper also stated that correlation analysis with different weights for each factor was applied to minus the major and minor effect of flood generation. There is other paper (Tang et al., 2018) had mentioned the six conditioning factors were selected for flood susceptibility mapping are digital elevation model, slope, distance from the river, maximum three-day precipitation, topographic wetness index, Soil Conservation Service Curve Number. A study in Semarang, had identified factors such as data of rainfall, drainage, land use, and topography (Setyani & Saputra, 2016). A local study in Johor Malaysia had include these factors that contributed to flood, such as rainfall distribution, slope, distance from river, land use, drainage density and road density (Nur Aisyah Sulaiman et al., 2015). An AHP methods used by this researcher, whereas using 10 variables are for a flood analysis; flow accumulation, annual rainfall, slope, runoff, land use/cover, elevation, geology, soil type, distance from the drainage network, and drainage density (Mahmoud & Gan, 2018).

Factors of human activities; unplanned rapid settlement development, uncontrolled construction of buildings in general and major land use changes can influence the spatial and temporal pattern of hazards (Pradhan, 2009). Topography is an important role to process flooding map. Two factors that is related to topographic factors are elevation and slope.
of the low elevation are more prone to flooding than areas at high elevations because water flows downhill. Steep slopes tend to retard infiltration and continue increased risk of flooding. In general, the greater the precipitation intensity, the greater the resultant overland flow and waterflow, and the greater the resultant flooding (Tang et al., 2018). Other than topography, rainfall is also an important factors that contributing to flood. Flood usually occurs during the monsoonal season is the season where majority of rainfall amount. This is the time when the average annual rainfall become higher than the other period. (Tang et al., 2018) has reported that heavy monsoon rainfall on the 4th to 6th August 2012 caused destructive flooding in Gucheng County.

The objective of this study are hence twofold; i) to analyse the use of factors for multi criteria analysis, and ii) to prepare a flood hazard mapping in Pahang. Method used in this study is the multi-criteria analysis by distributing weightage according to the guidelines provided in the Environmental Sensitive Area (ESAs) Sensitivity.

Environmental Sensitive Areas (ESAs)

Environmentally Sensitive Areas (ESAs) are natural features that identified as areas at greatest risk. It has become the hope of the government to protect and preserve these fragile areas from any development depending on its level of sensitivity (Asmawi & Paiman, 2016). The Manual of Standards and Guidelines provided by the Town and Country Planning Department, Federal Malaysia, the definition of Environmentally Sensitive Areas (ESA) is a "special area that is very sensitive to any activity or development and need to be preserved for its heritage value, preserve life and minimize support disaster risk due to land use changes". Table 1 shows the rank distribution using ESA Sensitivity.

<table>
<thead>
<tr>
<th>High Sensitive Rank:</th>
<th>Moderate Sensitive Rank:</th>
<th>Low Sensitive Rank:</th>
<th>Outskirt of ESA:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protected Area</td>
<td>Limited Development Area</td>
<td>Controlled Development Area</td>
<td>Development Area</td>
</tr>
<tr>
<td>No development of urbanization and agriculture, except sustainable logging and works involving conservation and preservation, limited eco-tourism activities and any eco-tourism related support and authorized research and development (R &amp; D) activities without affecting the nature of carrying capacity.</td>
<td>No development of urbanization except recreational area/tourism activities based on minimal environmental impact; waterbodies and forest waste are allowed without affecting the nature of carrying capacity.</td>
<td>Only restricted development subject to compliance with specific requirement as in the guidelines set out for development such as housing, industrial and business involving low or moderate density only.</td>
<td>This area is suitable for all development by taking into account the land use zoning and following the terms and guidelines.</td>
</tr>
</tbody>
</table>

(Source: (PLANMalaysia@Pahang, 2017))
Study area

The state of Pahang is located at the east coast of Peninsular Malaysia is exposed to heavy rainfall and strong winds from the South China Sea. This situation is influenced by the winds of the Northeast Monsoon at the end of the year. Every year, the monsoon flood incidents are recorded in Pahang had resulted in the residents being forced to move to the relief center while waiting for the floods to recede. The environment is also affected by floods such as agricultural areas which have decreased production and livestock that destroyed from floods. The neighbouring state of Pahang includes Kelantan (north), Perak (west), Negeri Sembilan (south west), Johor (south) and Terengganu (north east). The Pahang River Basin and the Kuantan River, which covers an area of 2,860,000 hectares, constitute 70% of the total area of Pahang State. The Pahang River is located in the interior of Pahang State in the west and north of the state. Amongst the main towns along the river are Jerantut, Temerloh and Pekan. Fig. 1 shows the River Basins in Pahang.

![Pahang river basin and the Pahang river](Source: PlanMalaysia@Pahang, 2017)

Methodology

The susceptibility defined as ‘flood prone areas’ includes factors of climate, geography, distribution of rainfall, natural irrigation system and etc. The combination of all factors resulted the flood prone areas mapping and this mapping helps in the integrated land use planning in the Pahang River Basin areas. The used of thematic layers modelling has a weightage for each
factors through GIS processing. In order to recognised the susceptibility areas, five factors used in this research.

The rainfall data was gathered from Meteorological Department. The annual mean of rainfall amount are collected from 2000 until the recent one (2015). All MET station located in Pahang was collected, and also include the neighbouring states; such as Perak, Selangor, Negeri Sembilan, Johor, Terengganu and Kelantan. Graph based analysis were used in this research; using mean maximum and minimum annual temperature from 2011 to 2015 and rainfall datasets.

The method adopted in this research was using multi-criteria analysis using weightage according to ESAs. Ranks was distributed according to the definition of Sensitivity Areas according to the definition of each ESAs; protected areas (Rank 1), limited development area (Rank 2), controlled development area (Rank 3) and development area. Two types of final maps were generated; the ARI 1 year (yearly event) and ARI 100 year (extreme event).

The factors are selected from the review done from the previous studies. These are, i) land use, ii) slope and iii) elevation and iv) distance from the river. The land use data was collected from the Department of Planning, Malaysia. The slope and elevation are derived from the Digital Elevation Model (DEM) datasets that was downloaded from ForestWatch.com. Each of these factors are presented in a form of grid map and the method of preparing all of the grid is different. The slope and elevation can be derived from the Digital Elevation Model (DEM data), but the rainfall was derived from the annual mean of rainfall distribution from neighbouring meteorological station.

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data gathering</strong></td>
<td><strong>Graph based analysis</strong></td>
</tr>
<tr>
<td>Rainfall and</td>
<td>Adopt weighting for each factor</td>
</tr>
<tr>
<td>temperature - MET</td>
<td>Overlay of maps according to rank</td>
</tr>
<tr>
<td>station</td>
<td>Analysed map according to scenario</td>
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<tr>
<td>Land Use - from</td>
<td></td>
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<tr>
<td>Planning</td>
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<tr>
<td>Department</td>
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<tr>
<td>Topography and</td>
<td></td>
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<tr>
<td>Elevation - DEM</td>
<td></td>
</tr>
<tr>
<td>data from</td>
<td></td>
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<tr>
<td>Forestwatch.com</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: The methodology of this research
Every factor were mapped in the format of grid file and each rows of the factors were recorded using the calculator tool according to the categories ESA Sensitivity, as it was divided into three different sensitive rank. All of the factors are overlaid to produce a flood susceptibility map. Two types of final maps were generated; i) map with flood area ARI 1 year and ii) map with flood area ARI 100. ARI 1 year is the occurrences of flooding for 1 year and ARI 100 year represent occurrence of flooding for 100 year. The map shows a level of exposure that refers to generate a distribution of flood-prone areas according to different levels.

<table>
<thead>
<tr>
<th>Flood Factor</th>
<th>Susceptibility Rank 1 (Highest)</th>
<th>Susceptibility Rank 2 (Moderate)</th>
<th>Susceptibility Rank 3 (Low)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography condition and DEM</td>
<td>&lt; 300 m</td>
<td>301-600 m</td>
<td>601-800 m</td>
</tr>
<tr>
<td>Slope Classification</td>
<td>&lt; 15°</td>
<td>16-30°</td>
<td>31-40°</td>
</tr>
<tr>
<td>Land Use Types 2015</td>
<td>Urbanization</td>
<td>Infrastructure</td>
<td>Forest</td>
</tr>
<tr>
<td></td>
<td>Residential</td>
<td>Road</td>
<td>Agriculture</td>
</tr>
<tr>
<td></td>
<td>Commercial</td>
<td></td>
<td>Open space</td>
</tr>
<tr>
<td>Distance from the River</td>
<td>&lt; 500m</td>
<td>500m-1,000m</td>
<td>1,001-1,500 m</td>
</tr>
<tr>
<td>Flood Area ARI 1 Year and ARI 100 Year</td>
<td>ARI 1 year</td>
<td>ARI 100 year</td>
<td>-</td>
</tr>
</tbody>
</table>

(Source: PlanMalaysia@Pahang, 2017).

**Climate Change Trends and Rainfall**

The Malaysian Meteorological Department has five (5) meteorological stations in Cameron Highlands, Jerantut, Kuantan, Muadzam Shah and Temerloh. The lowest temperature was recorded at Cameron Highland, which is about 15 degrees Celsius, which is a highland area. While four (4) meteorological stations in low land area recorded a reading of about 23 degrees Celsius. Analytical trends for minimum temperatures at all meteorological stations show that they are increasing in five (5) years. Surprised result showed from the trend of minimum temperature of Cameron (0.16) that was increasing faster compared to the increased of minimum temperature of Kuantan (0.11). This finding show that the Urban Heat Island (UHI) has occurred faster in Cameron Highlands.
In general, the average annual rainfall in Peninsular Malaysia is 2,500 mm/year. The annual average rainfall trends in Pahang State for the period 2011-2015 showed a decrease in all the meteorological stations (Fig. 4). In 2011, there were three (3) stations recording more than 2,500 mm/year but in 2015 only weather station in Cameron Highlands had rainfall over 2,500 mm/year. High number of rain flows remain in the monsoon season at the end of the year. Figure 5 shows the pattern of annual rainfall in Pahang State and its surrounding meteorological station. In general, it also shows the trend of decreasing the amount of annual rainfall.

Figure 3: The minimum temperature in Pahang from 2011 to 2015. (Source: PlanMalaysia@Pahang, 2017).

Figure 5: The annual rainfall distribution in Pahang from 2011 to 2015. (Source: PlanMalaysia@Pahang, 2017).
Four types of maps were produced; land use map, distance from the river map, the elevation and slope map. The land use mapping shows that the forest located at the high elevated areas at the north part of Pahang. The river map shows that the pattern of the river are from the uphill areas at the North west side of Pahang. This analysis has been designed to create polygon of distance from river and streams to differentiate the solution of each of these ranks.

![Land Use Map](source.png) ![Distance from River Map](source.png)

**Figure 6:** The land use map (left) and distance from river map (right).
(Source: PlanMalaysia@Pahang, 2017)

The elevation and slope map shows the high land values (Cameron Highlands) at the North West side of Pahang (Fig. 7). According to several reports (Barrow, Chan, & Masron, 2008; Razali, Syed Ismail, Awang, Praveena, & Zainal Abidin, 2018) claimed that many flash flood problems had occurred in Cameron Highlands due to clearing of land for agriculture activities. Thus, it causes mudflow from the upstream areas to the downstream areas. The sedimentation loads are trapped along the river. This process makes the volume of the river decrease because the depth of the river becomes small, as a result, the water will overflow from the river and the flood continuous to the lower stream areas.
Figure 7: The elevation map (left) and slope map (right)
(Source: PlanMalaysia@Pahang, 2017)

Figure 8: The ARI 1 year (left) and ARI 100 years (right).
(Source: PlanMalaysia@Pahang, 2017)
Fig. 8 shows the flood susceptibility according to different susceptible; according to ARI 1 year (yearly) and 100 years (extreme cases). The susceptible rank includes susceptible rank 1 (highest), susceptible rank 2 (moderate), susceptible rank 3 (low), while other areas are those areas that have no exposure to flood. This spatial distribution is referring to the environment factors and geography that linked with the riverine monsoon flood that usually happens at the end of the year. The finding in the form of plan is important as to assist the authority to prepare the flood prone risk management plan.

Conclusion
This research concludes that GIS and Remote Sensing can assist the planner to prepare maps for the mitigation of flood prone areas. Especially those urban areas such as Kuantan, Pekan and Temerloh, a careful examination of the urban areas need to be crucially been done as the location of these urban areas close to the river. The upper areas, such as Cameron Highlands can give a negative impact to the environment if a clearing activities been done without proper mitigation.

References


IDENTIFICATION OF OPTIMUM PATH FOR SERVICE AREAS USING GIS BASED NETWORK ANALYSIS: A CASE STUDY OF JAIPUR

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Abstract: Network Analysis aims at finding solutions to routing problems related to Transversibility, rate of flow, and network connectivity. It helps in identifying optimum locations for services to be provided. The current work basically is a smart city road network analyses and only OSM (open street maps) data of approximately accuracy has been used for this study. In the present study, distribution of ATMs of different banks, Hospitals, fire stations and police stations of Jaipur city area have been selected for network Analysis. This kind of study is very uncommon for even highly developed metro cities of India like Hyderabad, Patna, Bangalore, Jaipur etc., During data observation noticed that Axis Bank ATMs and HDFC Bank ATMs are well distributed while that of UCO & ICICI ATMs are poorly distributed. The Fire Station Services are well distributed through-out the city but most of the North West area has no availability of emergency fire station service with in the radius of 3.5 km approximately. The security of citizens which depends on police service is very high in the centre of city but north and south portion of city is not well covered with police stations. The road network and connectivity in the study area is of appreciable standard. If this sort of study is undertaken for the area with very high resolution data of fine accuracy level and supplemented with extensive field surveys costly enterprise, the study can be of immense applicability to Public Transport Corporations, Health service providers, Emergency Response agencies, security services.

Keywords: GIS, Network Analysis, Service Area, Road Network and Optimal Route

Introduction:
GIS can used in emergency service management through network analyses. It is an effective tool for determining service vehicle response routing and solving the emergency vehicle to find out shortest path. It Also consider the time taken by the traffic conditions with real time data or with reference of historical traffic data. The shortest path algorithm applied to a routing problem in a transportation network can calculate the path with minimal travel cost or least impedance from an origin to a destination. Depending on the type of cost, the shortest path can be referred to as the shortest, fastest, or most optimal path or route. There are several impedance factors that can affect emergency services and vehicle response times. They include distance, travel time, and traffic congestion as a result of variations in traffic flow related to the time of today. Traffic jamming is a most considerable problem in urban areas and it will be an effective obstacle for
emergency response. Connectivity of road network also matters in the solution of calculating shortest route. The concept roam around finding out the best route /optimal route by considering all entities of road network dataset giving optimistic results to reach the destination. This analyses helps in finding out the necessary service area location in every zone by which emergency service will be available to the entire city almost equally.

**Study Area:**
Jaipur is the capital and the largest city of the of Rajasthan state of India. It was founded on 18 November 1727 by Jai Singh II, the ruler of Amer after whom the city is named. Coming to its population statistics as of 2011, it had a population of 3.1 million, making it the tenth most populous city in the country. Since the road network is distributed towards major cities of country and fully surrounded by tourist areas the traffic congestion is higher than imaginary values and this city is also under smart city mission. So, it is the most suitable study area to apply network analyses which is one of the ten largest and famous cities of india. Following figures shows the map of indian administrative boundaries and Rajasthan Fig(1), Boundary of Jaipur city Fig(2).

**Classification Of Roads:**
Road classification based on the factors like materials used, location & function, traffic type, width etc., Here, we also considered these factors and classified roads as residential, primary, secondary, trunk, service, living streets as shown in Fig(3). These classified roads again have so many subtypes like national highways, state highways, district –rural–village roads. Since the Jaipur area road network is very large and it’s difficult to show the analyses in map, we are selecting some portion of north east of the city shown in Fig(4) as study area even though analyses done on whole Jaipur city road network.
Fig(3): Map of Classified roads

Fig(4): NORTH-EAST of Jaipur

Fig(5): Methodology/Work Flow
The scope of this research was to find out if time-varying travel times derived from historical traffic data applied to road network edges would affect the response times and routes of emergency vehicles within the study area. The overall approach and objective of this study were segmented into two parts or elements for better understanding. The first part was to successfully develop a network dataset for study area and perform the optimal route analysis between required locations, which can tell the travel time cost to reach destination. Analyses without a well-built functioning road network would be difficult to undertake. The second part was to know the travel time cost for service areas by adding point data layer. This can provide a good estimation of the performance of different congestion avoidance strategies in a realistic setting. This chapter discusses the technical aspects of the research including an explanation of the data. Collection of data is the first challenge of the analyses for network analyses we need both road network and starting/destination point in the form of line data and point data respectively. Road network data used in this analyses is downloaded through OSM (open street maps) which is freely available data. Data obtained from OSM is opened in arcMAP10.5 Desktop. Create a feature class of the road network data. This feature class data Which is saved in geodatabase in the form of shapefile. Through this shape file built a network dataset of the road data.

1.1 Creating Network Dataset:
Go to the shapefile of road network data and start creating network dataset. Creating the network dataset give you show many options of modelling turns manually or else turns will be generated by default turns. Then it continues to the connectivity where the connection will be choose by any-vertex due to restricted turns data shortage. After considering the attributes of road network which are applicable for analyses like length, one-way, restrictions, minutes etc., after finishing new network dataset is created successfully.

1.2 Collection Of Point Data:
Point data is nothing but the x , y co-ordinates of service area locations. Here we are considering ATMs, HOSPITALS ,FIRE STATIONS AND POLICE STATIONS as service areas. Google earth explorer is the best option of collecting point data. in google earth explorer you can search for a category like ATMs for examples, it shows the top results of ATM locations in Jaipur city. This data you can download in the form of kmz file. Similarly, collection of all required point data is collected through google earth explorer. Now this kmz file is processed in ArcMap 10.5 with the help of conversion tools which can convert kmz file into shape file. This shape file is now saved to the work space.

1.3 Cleaning & Preparation Of Data:
Cleaning of data is nothing but considering the data which is in the boundary of Jaipur city and omit the data outside the city boundary layer. Applying topology to the road data also comes under cleaning of data. Preparation of data is nothing but adding the required fields to the attribute table, in this data we considered speed values depends on Indian normal traffic based on road types. Considering primary roads passes through the city road network maximum speed limit is given as 45kmph and secondary highway is city outskirt highways as 60kmph and residential (built-up area) with heavy flow of traffic speed limit is restricted to 30kmph and others as follows in Table1.
<table>
<thead>
<tr>
<th>SL.NO:</th>
<th>ROAD TYPE</th>
<th>SPEED(kmph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RESIDENTIAL</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>PRIMARY</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>SECONDARY</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>SERVICE</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>TERTIARY</td>
<td>35</td>
</tr>
<tr>
<td>6</td>
<td>TRUNK</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>UNCLASSIFIED</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 1: Maximum speed limit of vehicles based on road type

1.4 Performing The Analyses:
Now, we are all set to perform the analyses for this enable network analyst extension in arcMAP10.5 Desktop and open the network dataset file which is directly open in the network analyst extension.

(a) New Route (Optimal Route):
Finding new route or shortest route between two points in which one is considered as starting and other is considered as your destination. After enabling network analyst you can see a network analyst window on screen. This extension has so many options like shortest route, service are, closest facility etc., you can add your graphic pick locations through create network location tool which is in network analyst extension. With that you can add your graphic pick on the network dataset, you can change your graphic pick with the help of move network tool and replace it at required location as shown in Fig(6). Finding route is not only between two points, you can add random points or locations. The results for a three point route solving in which one point is considered as starting point and one as destination remaining third point act as pickup location of one more person in the optimal route.

(b) New Closest Facility (Service Area):
Calculating Closest Facility is nothing but choosing the nearest location of any emergency service this type of routing is very use full in emergency cases as mentioned above. Network analyst plays major role in emergency management and saving lives. Consider a fire accident happen suddenly in a shopping mall at the centre of city. Then we can give our location and find out which is nearest fire service location and know the time taken for fire men to reach the incident location. Analyses of service area results as following map Fig(7). Finding the closest hospital to an accident Fig(8), the closest police stations to a crime scene Fig(9), and the closest ATM Fig(10) from any required location are all examples of closest facility (service area) problems will be solved. When finding closest facilities, you can specify how many to find and whether the direction of travel is toward or away from them. Once you've found the closest facilities, you can display the best route to or from them, return the travel cost for each route, and display directions to each facility for example as shown in Fig(11). Additionally, you can specify an impedance cutoff beyond which Network Analyst should not search for a facility.
Fig(6): Nearest/optimal route between two points map

Fig(7): Nearest fire station service analysis map
Fig(8): Nearest hospital service analysis map

Fig(9): Nearest police station service analysis map

Fig(10): Nearest ATM service analysis map
Results and Discussion:
There is no final result in these type of analyses. it gives the directional information along with time taken to reach the destination after solving the route with direction window of network analyst Fig(11).

![Route Direction and Travel Time Window](image1)

Fig(11): Route Direction and Travel Time Window

Still it finds out the black zones where emergency services are to be provided and suggest connectivity of road network which would be better to reach incident areas. as discussed, in Jaipur city north west area is no having that much emergency service facilities like fire stations, police stations when compared to rest of the city. in numbers there is no fire station from (75.737932, 26.936870) Decimal Degrees this location with radius of 3.5 km shows in the following map Fig(12).

![Fire Station Service Non-Availability Map](image2)

Fig(12): Fire Station Service Non-Availability Map
References:


