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ASSESSMENT OF HUMAN EXPOSURE TO TRAFFIC BORNE PROBLEMS IN KARACHI

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ABSTRACT

Karachi being the metropolitan city is circumscribed by various traffic problems including Road Traffic Accidents (RTAs), noise pollution and air pollution. These problems are making negative impacts on life of people by triggering different chronic diseases. It is aimed to find out the percentage area and proportionate population under different level of threat.

Field surveys were conducted to collect data which was subsequently geocoded and processed in GIS environment than overlay analysis were made to find out the level of threat. Spatial autocorrelation technique along with Z-statistic and P-Values were also calculated. 42%, 36% and 22% of Karachi's total population is under high, medium and low threat to these above mentioned problems respectively. However, 5%, 15% and 80% area of the city is suffering from high, medium and low risk respectively. Mass transit system is strongly needed to be launched within the city to reduce the negative outcome of traffic.

Key Words: Risk Assessment, Vehicular Traffic, Noise Pollution, Air Pollution, Road Traffic Accidents, GIS, Spatial Autocorrelation, joint count statistics, Vulnerable, IDW, urban environment.

INTRODUCTION

Traffic problems are growing with the rapid urbanization and increased mobility (McMichael, 2000, Van Wee, 2007, Moudon, 2009). The developed urban centers across the globe are experiencing numerous traffic borne problems that have negative impact on the inhabitants of urban areas (Chepesiuk, 2005, Bluhm *et al*., 2007). Noise pollution, air pollution and road traffic accidents (RTAs) are some of the adverse outcomes of vehicular traffic causing monetary losses and health problems. These problems are adversely affecting the life of people of urban areas especially in developing countries of the world (Mehdi, 2002). The three major problems are discussed at length in this paper.

Firstly, traffic noise is one of the major causes of hypertension, auditory problems and even mortality (Sommer *et al*., 2000). Moreover, RTAs and hypertension are rated tenth and eleventh cause of death in the world respectively (WHO, 2011). In Madrid eighty percent of all environmental noise exposure is attributed to traffic resulting in cardiovascular diseases (Tobías *et al*., 2015). Moreover, vehicular noise is responsible for increasing the number of cardiovascular risks to exposed people in Sweden as well (Bodin *et al*., 2009, Babisch, 2006). Noise pollution is also responsible for disrupting sleep and affects mental and emotional responses (Muzet, 2007). Extreme levels of noise are hazardous to earshot of man, nearly 20% European and particularly 74% Spanish population is being seriously disturbed by high noise level (Brainard *et al*., 2004). However, lower extreme of noise (45-55 dBA) could also be harmful to people (Ising and Kruppa, 2004).

Secondly, air pollution is an inherent by-product of combustion process from vehicular traffic on road (Caiazzo *et al*., 2013) causing serious threat to human health (Krzyzanowski *et al*., 2005) inflicting a number of circulatory diseases (Foraster *et al*., 2011) and mental stress (Van Eeden *et al*., 2001). Proximity to road in urban environment is an important indicator to measure the risk of air pollution road accident severity (Blincoe *et al*., 2014, HEI, 2010). Vehicular traffic on road causes air pollution which leads to mental stress that eventually results in cardiovascular diseases (Van Eeden *et al*., 2001) because presence of carbon monoxide reduces the oxygen carrying capacity of blood (Fullerton *et al*., 2008). Similarly, air pollutants from traffic sources in urban environment could result in the problem of eye irritation to death, especially in developed parts of the world, i.e. in USA and in Western European region (Cohen *et al*., 2004). Air pollution accounted for 4% deaths and 0.6% burden of diseases across the globe (WHO, 2009). Moreover, fuel combustion from vehicle cause loss of monetary asset of around 1 million PKR in Karachi (Ali *et al*., 2014).

Thirdly, road traffic accident is an undesirable outcome of urban environment that costs more than 1 million lives, fifty million injuries and sum of more than 500 billion US$ across the globe every year (WHO, 2008). Further, it is estimated that more than 1 million vehicle crashes take place annually in the world (Krug *et al*., 2000).

RTAs result in death to more than 1000 youngster on daily basis. Furthermore, this problem is the leading cause of death among 15-19 years and second leading cause of death of the people to age group of 10-19 and 20-24 years in the world (WHO, 2007). Road designs that trigger speedy movement of vehicles are responsible for greater proportion of fatalities and serious injuries in road accidents (Blincoe *et al*., 2002).This might be due to the fact that in most of the countries roads are designed from the perspective of vehicle user rather than the road user i.e. pedestrian and cyclists (OECD, 1998). In Karachi more than 30% road crashes are evidently due to structural design road (Zubair, 2013).

The major objectives of this study were as follows: 1) to assess the area and percentage of population under the risk to different severity of Noise pollution, 2) to ascertain the level of Air pollution (CO levels), 3) to assess Road Traffic Accidents (RTA) to which the population is subjected, and 4) to expose the spatial patterns of these three environmental hazards.

The Study area

Geographical extent of Karachi is 24° 45’ N to 25° 37’ North and 66° 42’ E to 67° 34’ East. North and North eastern part is bordered by Dadu District (Sindh), in the east lies the Thatta district (Sindh) and in the North West it is bordered by Lasbela District (Balochistan).The core area of the city experiences the highest influx of traffic due to hub of economic activity in the central part of the city.

Karachi was selected as study area because it has diversified traffic conditions. Moreover, the city is ranked fourth in the world for highest road accident conceiving cities of the world (Zubair, 2013). Lastly, this city was within easy access to the authors for conducting the field survey and the collection of data feasible.

Estimated population of the city is more than 18 million (ECIL, 2007). The population is still increasing at a rapid rate due to recent infrastructure development within the city, accelerating the rural urban migration. Better socio-economic opportunities of life have attracted the mass inflow of migrants to the city. This has raised the demand of vehicles. Important industrial zones, sea port, stock exchange have made the city an economic hub of the country. Karachi being a coastal city is equipped with all four modes of transportation: airways, seaways, railways and roadways, which are prominent features of traffic in the city. Notably, central part of the city has high road density, whereas, peripheral parts of the city experience lower road density.

Demography and Urban Sprawl

Karachi along with its suburbs spreads over nearly 3,600 sq.km having an estimated population of 18 million, (ECIL, 2007). According to year 2005 statistics the number of households were about 2.1 million and by 2020, they would increase to 3.9 million. The city has grown nearly 25 times since 1947 and is growing at the rate of about 5.4% per annum (Afsar, 2001) and (KDA, 1991) turning it to be one of the fastest growing cities of the world (Anonymous, 2007). Due to its spatial limits the vertical growth has been increased sharply during the last two decades, hence increasing the population density of the city, leading to an increase in RTAs in the city. Development within the city has so far been carried out without sufficient coordination, proper planning and design exercises (Kazmi. *et al*., 2013) that results in disarray, and traffic related predicament is one of the many dilemmas the people of this city face, that is costing the people in terms of life, health and property losses.

Transportation

Karachi holds a very dense road network with total road length of over 250,000 km, accommodating more than 3.6 million vehicles (Jooma, 2013). In 2015, total number of registered vehicles has climbed to 3,610,890 with an annual increase of 335,598 (Khan, 2008, Amir *et al*., 2015).This has increased the need to change road environment which include expanding of road width, reducing the radius of roundabouts, converting the roundabout to signals, establishment of flyovers, construction of underpasses and intrusion of a new term of signal free corridor. Despite these facilities, serious problems have been created by triggering greater traffic related complications in the city.

Accelerating rate of Motorization

Karachi has been facing mass increase of vehicles due to the soft loan policies provided by the banks that results in eruption of huge influx of vehicles on the arteries of Karachi. Getting new model vehicles has never been experienced, this easily, before. This makes the traffic conditions worrisome, increasing the incidents of accidents, causing noise and air pollution as well. Fig. 1 shows the enormous increase of vehicles in Karachi in the past few years, particularly from 2012 to 2015 there is increase of more than three hundred thousand vehicles, making it nearly one thousand vehicles per day. This made the traffic condition very alarming for the road users. Fig. **2** depicts that the highest proportion of vehicles running on the roads of Karachi comprises of private vehicles. In Karachi about 75% of the inhabitants depend on public transport that holds the share of only 2.7% of total number of running vehicles in the city. This has pushed up the traffic related issues within the city.

MATERIAL AND METHODS

Following steps were taken into consideration to execute this study.

Data Collection and Representation

Pakistan owns neither macro nor micro scale mechanism to monitor the noise level and the concentrations of hazardous gases in the atmosphere. To cope up with this problem, 300 sites were selected on major road junctions, to collect noise level through Noise Dosimeter and concentration of CO (carbon monoxide) in the atmosphere. The variation in values of different noise levels and concentration of CO was shown through a GIS technique called IDW (***inverse distance weighted)*** that generated a surface with town boundaries. Road Traffic accident data was obtained from RTIPC and NEDUET. Coordinate data of each accident event was attempted to display spatially, based on victim related information with the help of Google Earth. Out of 28,761 accident cases, 19,509 cases had sufficient information of their spatial dynamics that enabled the author to generate point data of accident locations. Different spatial analysis tools were used to count the number of accidents falling under each town. A risk grid was utilized to show the possible percentage area and population under threat due to these problems in different towns of Karachi based on the possible influence to respective towns.

GIS Technique

Although noise pollution and air pollution are continuous phenomena that are not restricted by any administrative boundary but for the sake of convenience these areas are treated town-wise when taking into consideration the two issues aforementioned. This was done so that the actual percentage area and percentage population under threat at various levels can be identified. To achieve these goals overlay analysis was performed by using different thematic layers of Karachi affected due to noise and air pollution in Administrative-units of Town. However, RTA affected areas were easy to show through thematic maps because the specific values of number of road accidents events for every town of the city were available.

Spatial Autocorrelation

The joint count statistics earlier used by (Ebdon, 1991) was employed to assess autocorrelation as a measure of aggregation of values of variable in the same range. This statistics, popularly employed in geography, is used in this study for the first time in Pakistan, to conserve the spatial information content at town level of each sample point (Sokhal and Oden, 1978). Data on each variable was divided by the median into two subsets; the lower subset was arbitrarily named as Black, while the upper subset as White. Joint count statistics was then applied and the significance was tested using a z-statistics, as follow:

$$Z = (Obs - Exp) / Sbw \qquad \text{Equation 1}$$

Where Obs equals the observed number of white-to-black (or vice versa) and Exp equals the expected number of white- to- black joint counts and Sbw is the standard deviation of white- to- black joints (Ebdon, 1991).

Cluster analysis Technique

A cluster analysis of the overall data set was performed using Ward’s clustering strategy and the Euclidean distance as the resemblance method (Everitt *et al*., 2011).

RESULTS AND DISCUSSION

RTA Pattern

Towns having smooth roads with speedy movement of vehicular traffic experience highest number of road accident as seen in

Fig. 4. Whereas, a greater number of towns experience medium number of road accidents. Marginal towns of the city with less road density experience least number of road accidents.

Noise Pollution

Fig. 6 clearly shows that the considerable part of the city is under high risk to noise pollution with approximate value of 102dB due to high road density as well as frequent movement of heavy traffic. Whereas, southern and eastern part of the city mostly suffer from medium noise pollution with nearly 65dB value. Lastly, peripheral parts of the city experience low noise pollution with less than50dB due to low density of road so as the low traffic volume.

Table 1. Risk Grid Showing different Levels of Traffic borne menaces in different Towns of Karachi.

S.No	Town	Noise Pollution			Air Pollution			RTA_2012		
		H	M	L	H	M	L	H	M	L
1	Jamshed	[red]				[yellow]		[red]		
2	Orangi			[grey]			[grey]		[yellow]	
3	New Karachi	[red]				[yellow]		[red]		
4	Landhi	[red]					[grey]		[yellow]	
5	Liaqatabad	[red]			[red]			[red]		
6	Gulshan-e-Iqbal	[red]				[yellow]			[yellow]	
7	Saddar	[red]			[red]			[red]		
8	Lyari	[red]			[red]				[yellow]	
9	Korangi	[red]					[grey]		[yellow]	
10	North Nazimabad		[yellow]		[red]			[red]		
11	S.I.T.E	[red]			[red]				[yellow]	
12	Gulberg	[red]			[red]				[yellow]	
13	Baldia		[yellow]				[grey]			[grey]
14	Malir		[yellow]			[yellow]			[yellow]	
15	Kemari			[grey]			[grey]			[grey]
16	Shah Faisal		[yellow]				[grey]		[yellow]	
17	Gadap			[grey]			[grey]			[grey]
18	D.H.A		[yellow]				[grey]		[yellow]	
19	Bin Qasim		[yellow]			[yellow]				[grey]
20	Faisal Cantonment	[red]				[yellow]			[yellow]	
21	Karachi Cantonment	[red]			[red]			[red]		
22	Malir Cantonment	[red]					[grey]			[grey]
	Level of severity	[red]	High		[yellow]	Medium		[grey]	Low	

Table 2. Percentage Population at risk to different traffic borne issues of Karachi.

Percentage Population at risk to different Hazards in Karachi				
Level of Risk	**Noise Pollution**	**Air Pollution**	**RTA Risk**	**Overall Population at Risk**
High	65%	40%	33%	**44%**
Medium	21%	22%	53%	**34%**
Low	14%	38%	14%	**22%**

Table 3. Percentage area at risk to different traffic borne issues in Karachi.

Percentage Area at risk to different Hazards in Karachi				
	Noise Pollution	Air Pollution	RTA Risk	Overall Area at Risk
High	9%	5%	3%	5%
Medium	19%	17%	8%	15%
Low	72%	78%	89%	80%

Table 4. Results of spatial autocorrelation test of the variables using joint count statistics.

Variables	Total Joints (L)	Black to white or White to black	Z score	P Value	Expected	Observed
Population	113	25	-18.5	<0.05	54	25
Population Density	113	8	-1.11	N.S.	19	08
Road Density	113	22	-6.41	<0.01	36	14
RTA Minor	113	17	-1.75	N.S.	35.2	17
RTA Severe	113	25	-4.84	<0.001	51.3	25
RTA Fatal	113	28	-16.68	<0.001	54.78	28
RTA Total	113	18	-1.65	N.S.	36.22	18
Cost Minor	113	30	-2.20	<0.05	47	30
Cost Severe	113	25	-12.32	<0.001	54	35
Cost Fatal	113	29	-4.93	<0.001	59	29
Cost Total RTA	113	21	-21.04	<0.001	54	21

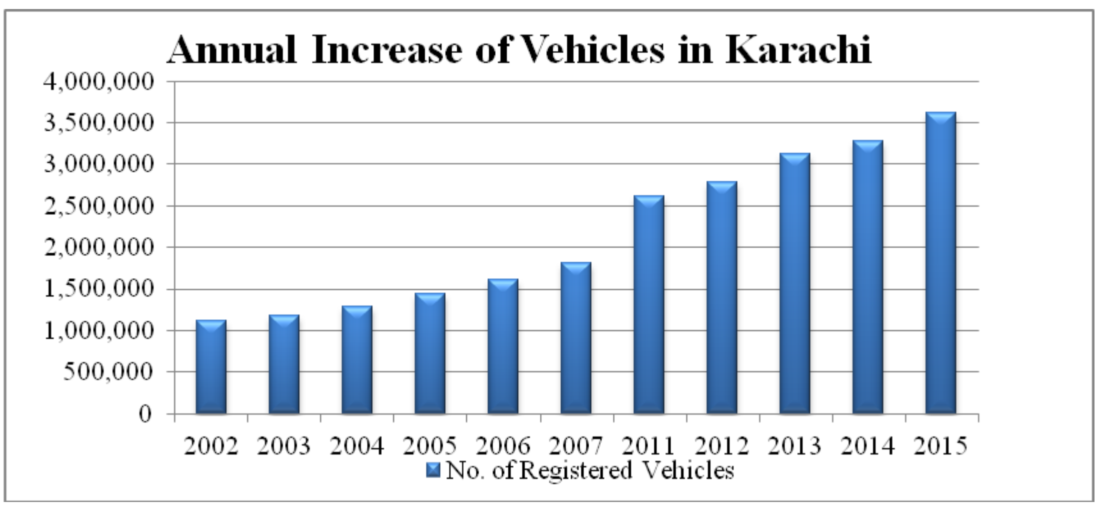

Fig. 1. Annual increase of Vehicles in Karachi (Khan, 2008, Amir et al., 2015).

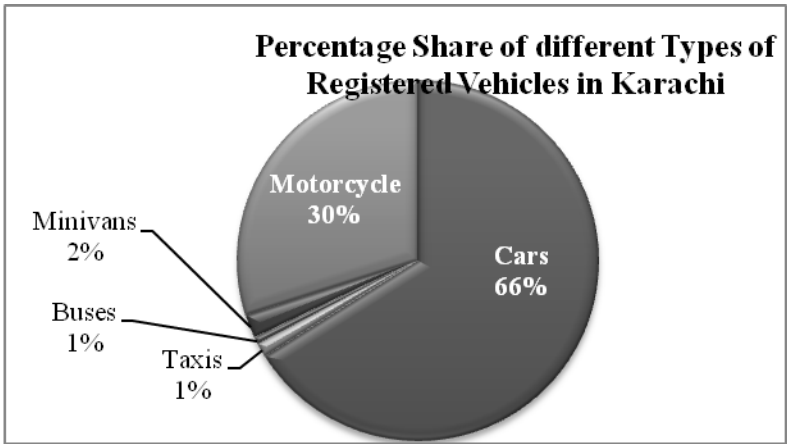

Fig. 2. Different types of vehicles in Karachi (Amir *et al.*, 2015).

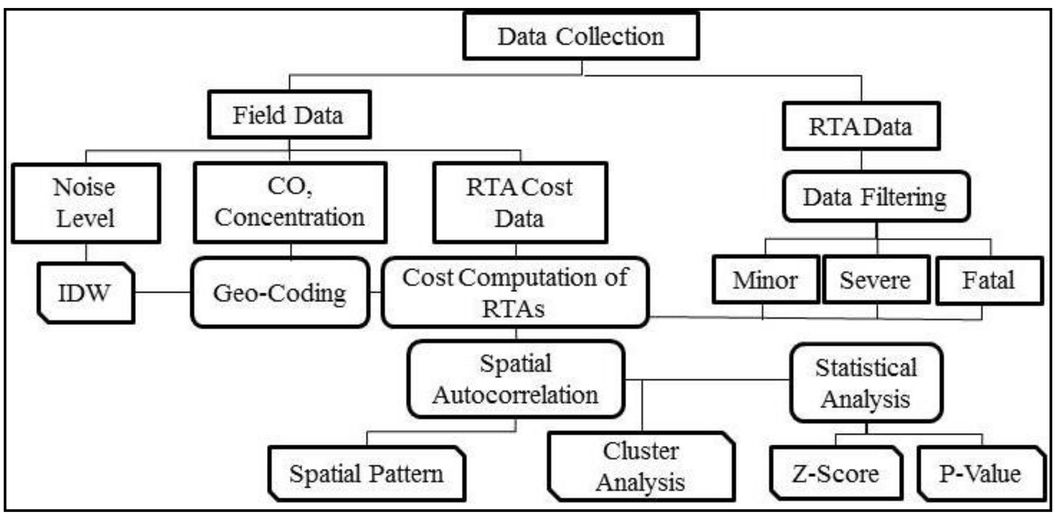

Fig. 3. The frame work of this study.

Air Pollution

The traffic pollution studies by (Mehdi, 2002, Arsalan, 2002, Akhter, 2010) suggested that core areas and the central business district are most exposed to air pollution due to highest inflow of traffic. The spatial distribution of Carbon monoxide (CO) concentration shows that the presence of highest amount of CO (i.e. 50-200ppm) is observed within the towns having high road density, Fig. 5. The spatial pattern of CO concentration shows that constant traffic jams and concentration of commercial activities brought about by heavy inflow of vehicles and their high fuel combustion result in high concentration of toxic gases. Medium concentration of CO gas (i.e. 10-49 ppm) is observed in eastern part of the city where road density is low. These areas are away from Central business district so that they experience less traffic jam. The farthest towns from the city center are under lowest threat to CO concentration (i.e. 0-9 ppm). These towns come under the category of least road density as well.

Cluster Analysis

The first group on the left comprising of 12 towns is characterized by high noise, medium level of air pollution (CO level) and low RTA. The towns in this group are located either in the core areas or adjacent towns. The road density of these towns is generally high therefore, the average noise level is high. The second group consisting of 7 towns are mostly located in the centre of the city where both population density as well as road density is high. This cluster displays high values while the third group having only two towns shows low levels of noise and air pollution as well as RTAs. These towns have low road density and human population and are located at the periphery of the city. The fourth group consisting of a single town (Gadap) that has the highest areal extent and least road density. Therefore, it displays least levels of noise, air pollution (CO level) and RTAs.

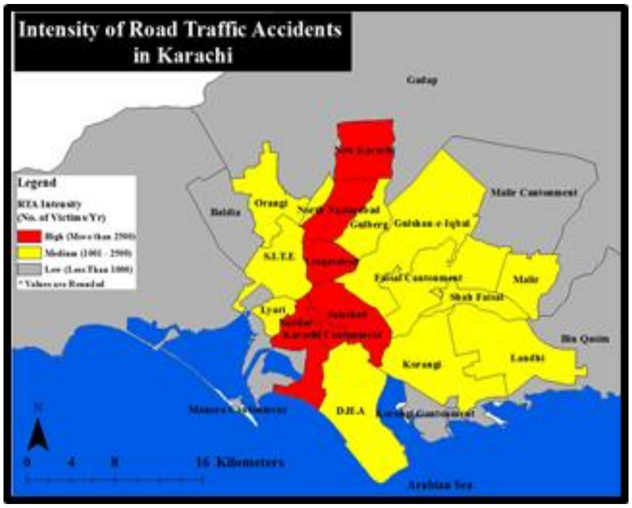

Fig. 4. Spatial Distribution of RTAs in Karachi.

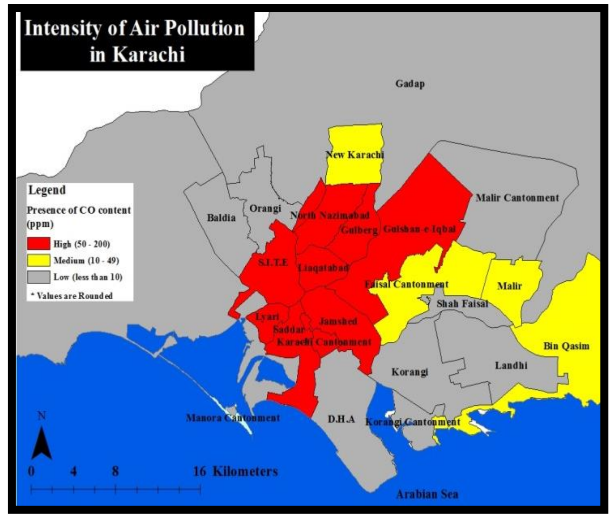

Fig. 5. Spatial distribution of Air Pollution in Karachi.

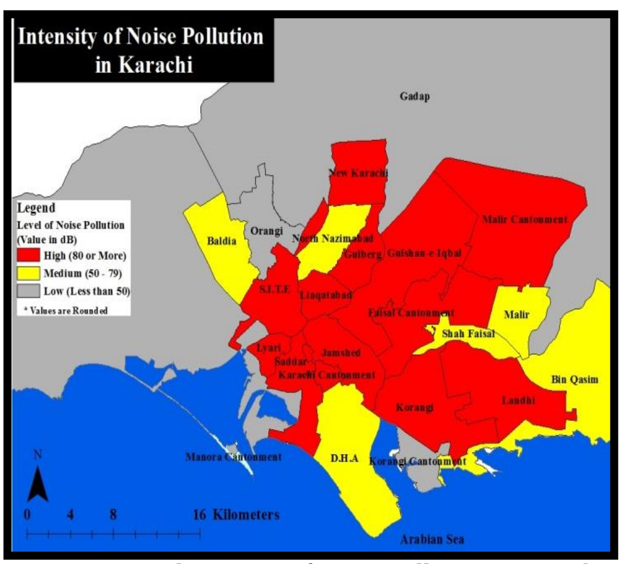

Fig. 6. Spatial Intensity of Noise Pollution in Karachi.

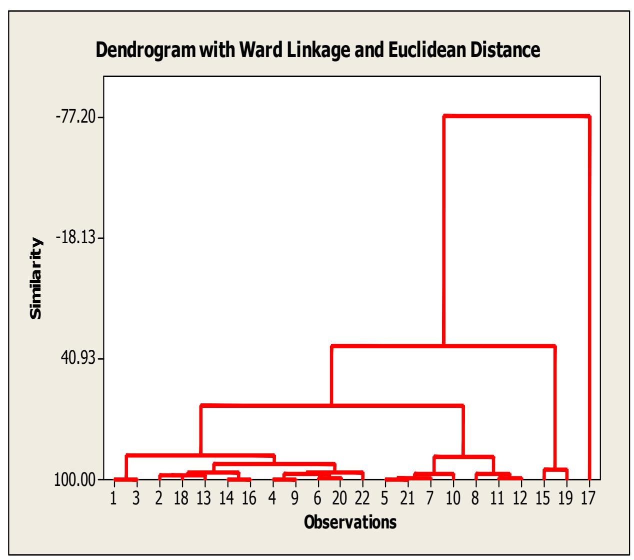

Fig. 7. Dendrogram derived from Ward's cluster analysis of RTA , noise and carbon monoxide.

Table 1 shows the risk grid of different severity of traffic related problems, based on this it is estimated that higher number of centrally located towns of Karachi is under greater threat to said problems and vice versa.

Following is the percentage of area along with the percentage of residents affected due to traffic related problems in Karachi.

Based on risk grid, it is evident that a very high percentage (65%) of people of Karachi is living at high risk to noise polluted areas (Table 2). Whereas, 21% of population is at medium risk and only 14% of population of the city is exposed low risk to noise pollution. Forty percent of the residents of the city are at high risk to air pollution mostly caused due to vehicular traffic. A low percentage (22%) is at medium level threat and Considerable proportion (38%) of population is at low risk to air pollution. The table makes it easier to comprehend that 33% population of the city is at high risk to Road Traffic Accidents. Fifty Three percent population lives with medium risk to their lives due to RTA's and only 14% of the population of the city is at low risk. In total, 44% population of the city is at high risk to all three mentioned traffic borne hazards. A substantial proportion (34%) of population is at medium risk while 22% population is at low risk to these menaces.

In Karachi most of the population is concentrated in the central part of the city as mentioned earlier. As far as noise pollution is concerned, 9% area of the city is at high risk, 19% of the area is at medium risk and 72% area is found to be at low risk (Table 3). Five percent area of Karachi is at high risk to air pollution. Moreover, 17% and 78% areas of the city are at medium and low threat to air pollution, respectively. Road traffic accidents dominate with high severity to only 3% area of the city. Likewise, 8% and 89% area of the city is under medium and low threat to road accidents, respectively. On a cumulative basis, 5% area of Karachi is under high threat to the mentioned traffic borne problems of the city. Fifteen percent and 80% area of the city is found to be at medium and low risk to these hazards, respectively.

Above mentioned variables were tested for spatial pattern using spatial autocorrelation (Table 4). It was found that variables including RTA Minor Cost, Severe RTA Cost, RTA Fatal and Total RTA Cost show aggregated distribution pattern which is more pronounced around the periphery of Karachi, suggesting that most of the heavy vehicles are involved in road accidents from these parts and the cost of such accidents is considerably high. Most of the central parts of the city predominated by small vehicles especially motorbikes that are involved in RTAs that cost low in monitory terms. Z value of these variables is high rendering them statistically significant (P at the most 0.05).

Additionally, variables including population, Road density, RTA severe and RTA fatal show aggregated patterns of respective phenomena in central part of the city. The Z values of these variables are high and their respective probabilities suggested significant spatial autocorrelation. (P at the most 0.05)

Conclusion

It was revealed that all the traffic generated problems are strongly associated with areas having high road density i.e. old city area which is considered as the hub of economic activities of the city. Considerable proportions (65%) of the people are under high exposure to noise pollution. These people dwell in towns, having high road density but small spatial extent of only 9%, suggesting that most of the vehicular traffic of privately owned cars and public transport are confined to such towns of the city. Moreover, some marginal towns of Karachi come under high noise pollution because of industrial land use and the presence of heavy vehicle movement. Likewise, considerable proportions of population are under high threat to air pollution, found in almost same number of towns. Area intensely affected due to air pollution is just 5% of total area of Karachi. These areas which tend to be the central part of the city show high road density as well as high population density. Significant proportion of people (33%) is at high threat from RTAs, mostly found in Towns having speedy traffic. Surprisingly, a very low proportion of area is at high risk due to RTAs, which indicates that very few towns possesses fast moving traffic and long roads in the city. Towns affected with medium intensity of the three interrelated problems under discussion are situated adjacent to the preceding category towns with lesser intensity of roads and population. Peripheral towns are least affected due to these problems. Though such towns comprise a gigantic share of the area i.e. 80% but the percentage of population affected with noise pollution, air pollution and RTAs are 14%, 38% and 14% respectively, which is evidently due to the fact that these towns are not equipped with intense road network and population density.

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