Environmental & Socio-Economic Impacts of Mass Rapid Transit Using GIS

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Abstract

The present study is to monitor the Environmental and Socio-economic status of mass rapid transit of metropolitan city using GIS techniques. The data generated is used to estimate the present trend in comparison with emission standards. Comparison is based on four parameters namely CO level, NO2 level, Land Price and RSPM. Effect of metro at a certain radius from the alignment is getting affected is observed in terms of environment and socio-economic impacts. A case study is considered for Metropolitan city, Delhi, India.

Keywords: Mass rapid transit; Environment, Socio-Economic, GIS

INTRODUCTION

The need of Metro system in a city is generally considered necessary when the population of the city exceeds one million. Delhi crossed this milestone in early 1990'sand by early 1950's; it was observed that the city's population was doubled which drastically increased the vehicular traffic. By 1990's, Delhi has registered more number of vehicles than Mumbai, Chennai and Kolkata put together. These increased automobiles contributed to more than two third of the city's atmospheric pollution, Delhi turned to become one of the most polluted cities in the World .Due to the above mentioned there aroused an urgent need to analyse and improve the quality and availability of mass transport services.

In 1957, Central Road Research Institute (CRRI) carried out the first ever traffic study of Delhi, followed by, more than 50 studies conducted by various agencies. Most of these studies recommended the MRTS as one of the effective means to solve the city's traffic problems.

In addition to the above, there was a detailed study on the traffic and travel studies in 1969 which mentioned the MRTS of Delhi. Since then, there had been many official reports and discussions among the government authorities to explore the issues related to technology (like underground rail, surface rail, light rail, bus based, etc.) already being adopted in foreign

countries. In 1984, Delhi Development Authority (DDA) and Urban Arts Commission (UAC) proposed developing a multi-modal transport system consisting of three underground mass rapid transit corridors, as well as augmenting the city's existing suburban and road transport networks (Sreedharan, 2001). Based on the emphatic ideas proposed by DDA, the Government of National Capital Territory of Delhi (GNCTD) commissioned Rail India Technical and Economic Service (RITES) Limited, , to study the feasibility and impact of introducing an Integrated Multi-Modal Mass Rapid Transit System for Delhi. The study was conducted for two years by RITES and in 1991, RITES recommended a 198.5 km predominantly rail based network. After getting approval from Central Cabinet in 1994, RITES finalised (May 1995) the DPR for a 55.30 km MRTS comprising rail and metro corridors, for completion by March 2005. The Union Cabinet sanctioned the Delhi MRTS Phase I (Project) of 55.30 km in September 1996, at a total cost of USD 971 million. For implementation and operation of the project, the Delhi Metro Rail Corporation Limited was registered in May 1995 as a joint venture between the Ministry of Urban Affairs and the GNCTD. It started its operation in December 2002 with an 8 km line (CAG, 2008). The construction of the Delhi Metro has been carried out in phases. With the completion of Phase I and II of the Delhi Metro Rail project, the Delhi Metro currently has an operational network of 190 km^2 consisting of elevated, at-grade and underground lines. The 22.7 km long – 16 km underground and 7 km elevated – airport line, or the orange line, under the Delhi Metro network is officially called the Delhi Airport Express Line.

There are numerous benefits of metro. Some of them are: Time saving for commuters, reliable and safe journey, and reduction in atmospheric pollution, accidents, fuel consumption, vehicle operating cost and also increase in the average speed of road vehicles. The other benefit of the metro is reduced congestion, due to users' shifting from road-based motorized modes to metro systems. This kind of shift naturally results in reduced air pollution and road accidents as well. However, the experience of metro rails in low and middle income counties around the World shows a different scenario (Mohan, 2008). Due to the induced demand, the available road space fills up with motorized vehicles, and the modal shift to metro does not result in the reduction of congestion or air pollution. A study done by the Centre for Science and Environment (CSE) on pollution levels in Delhi illustrate that in 2001 (Delhi Metro started in 2002) the annual average level RSPM, in residential areas was 149 microgram per cubic metre. After registering a drop in 2005, the level rose to 209 microgram per cubic metre in 2008. The concentration is approximately three times higher

than safe levels. Similarly, the eight-hourly maximum current level of carbon monoxide (CO) is touching 6,000 microgram per cubic metre, it is way above the safe level of 2,000 microgram per cubic metre, though the annual levels have registered a drop. Overall, these figures illustrate that the operation of the Delhi Metro has not led to a reduction in pollution levels in the city (Randhawa, 2012). It is been observed that much of this pollution is caused due to the electricity that is being used by Delhi-metro. It has electricity consumption from traction, running of trains and for non-traction purposes such as lifts, air-conditioning of underground stations, lighting of stations, etc. According to 2007 estimate, electricity generation in India contributes 37.8% of CO_2 emissions (MOEF, 2010). The increase is mainly because India's production of electricity is coal-based thermal power plants. In 2009, 69% of electricity in the country came from coal (IEA, 2011). Since the coal in India has higher fly ash content (30–40%), electricity generation leads to the formation of particulate matter (PM_{10} /$PM_{2.5}$), a source of air pollution in the form of fly ash (Senapati, 2011). Therefore, the Delhi Metro has no direct emissions from its operation, but it contributes significantly to carbon emissions. Therefore, there is an urgent need to carry out an impact study of the Delhi metro on the quality of air. Air pollution effects human health adversely and research gives considerable scientific evidence. Block et al. (2012) provide a review of epidemiological research that shows how air pollution can lead to damage of central nervous system and may result in decreased cognitive function, low test scores in children, increased risk of autism and neurodegenerative diseases such as Parkinson's and Alzheimer's. Air pollution also leads to cardiovascular disease (Brook et al., 2010), and worsens asthma (Auerbach and Hernandez, 2012). Recent research by Ghosh and Mukherji (2014) examines the effect of ambient air quality on children's respiratory system in urban India and found that a rise in particulate matter significantly increases the risk of respiratory ailments. Currie and Walker (2011) found that exposure to vehicular emissions around toll plazas in North-eastern United States increased the likelihood of pre-mature births, and low birth weight. Much of these dangerous health problems are caused due to pollutants generated from transport sources. The primary pollutants are CO, NO_2 and RSPM. Hence the present study focuses on the impact of these parameters on the environment.

With the alignment of the Delhi Metro being guided by locations that can be most profitably developed for high-end business parks, the DMRC has become a major property developer with plans to develop the plots of land it has acquired along the route (Siemiatycki, 2006). This is further confirmed by reviewing the funding pattern of the Delhi Metro project (3–7%

from property development) as well as the revenue streams, according to which revenue from real estate contributed as much as half of the total operating revenue (see Table 3) during its initial years of operation. The arrival of metros at different locations in Delhi has led to an increase in the real estate prices of areas adjacent to the metro line. According to studies done in 2007–2008 (Swamy, 2008), for residential and commercial areas, on average, land value within 500 m of a metro line increased by 11.3% and 18.1%, respectively. Moreover, land value changes are more consistent and higher after a metro is operational, when compared to construction and planning stage, and increase by 2–4% every year. It was observed that the increase in land value is highly dependent on the income of people occupying the area, and whether the area has planned development or not. Another study, by Magicbricks.com in 2012, found that areas such as Model Town and Azadpur, in North Delhi, witnessed an average appreciation of 30% in capital values after the advent of metro rail services. Similarly, areas like Rajouri Garden, Punjabi Bagh, Vikaspuri and Janakpuri, in West Delhi, property values appreciated by 25–30% as a result of the metro rail services in the area. Additionally, a similar study by Swamy, observed that in the residential segment, houses within a radius of 500 m from a metro station fetched higher capital and rental values than those that are farther, at a radius of 1 km from the metro stations. The Delhi Government is proposing a policy on Transit Oriented Development (TOD) to capture the benefits of increase in land value around metro stations.

From the above mentioned, it can be inferred that before introducing any transport system, the goal the policy makers must be directed to achieve a sustainable transportation system. Sustainability is the capacity to endure, maintain itself or recover its potentialities. Long-term economic growth can only be achieved if it is in harmony with a responsible approach to society and the environment.

In the present study, an attempt has been made to examine two different scenarios of Pre metro and Post metro situation in Delhi between two selected stations namely: Huda City Center and Patel Chowk (Yellow line) to analyse the contribution of metro-rail towards the sustainability of environment. The comparison is based on four parameters CO, NO_2, Land Price and RSPM level with the help of Arc GIS software (version 10.1).

STUDY AREA

The study area that has been chosen is a portion of the yellow line of Delhi metro i.e. Huda City Center to Patel Chowk (Fig. 1). The length of the total route is about 28.161 km

consisting of 21 stations.CO level, NO_2 level, Land Price and RSPM has been observed in a radius of 3 km from the alignment of the metro rail line.

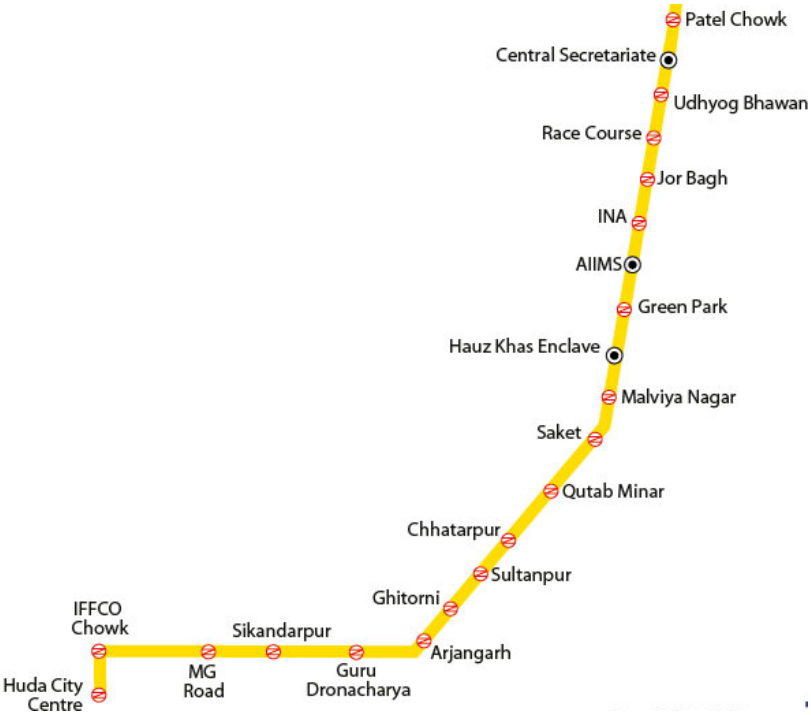

Fig. 1: Yellow line from Huda City Centre to Patel Chowk.

Source: http://delhimetrorail.info/delhi-metro-map

MATERIALS AND METHODS

In this section, Arc GIS software (version 10.1) has been used to examine two different scenarios Pre metro and Post metro situation in Delhi for the study area (Yellow line) for CO, NO_2, Land Price and RSPM level. The data has been collected from Central Pollution Control Board (CPCB, 2012). The methodology is as follows:

Step 1: Acquiring the Map

The map of Delhi metro rail study area has been acquired from open sources in internet. (http://www.bing.com/images/search?q=map+of+Delhi+metro+rail+&view=detailv2&&&id=77572A941579860D6CA6B1A4646B718B14071804&selectedIndex=201&ccid=55Ip9e6s&simid=608031872111411262&thid=JN.QJziRKcFH4VLzZ4B3lrlPA&ajaxhist=0)

Step 2: Geo-referencing

The map has been Geo-referenced in two ways: (i) Using Google Earth and (ii) using a rectified map of same place.

While using Google Earth for Geo-referencing, the latitude and longitude of three points in Google Earth have been taken.

For geo-referencing a rectified map, first three points on the non rectified map were taken and by going to the rectified map, same points are identified and selected. After selecting three such points, the map is geo-referenced and for check, it is observed whether newly geo-referenced map overlays on the map used for rectification. If it doesn't, then the same procedure is repeated. In the case study, Geo-referencing was done with the help of a rectified map. The geo-referenced map has been shown in the Fig. 2:

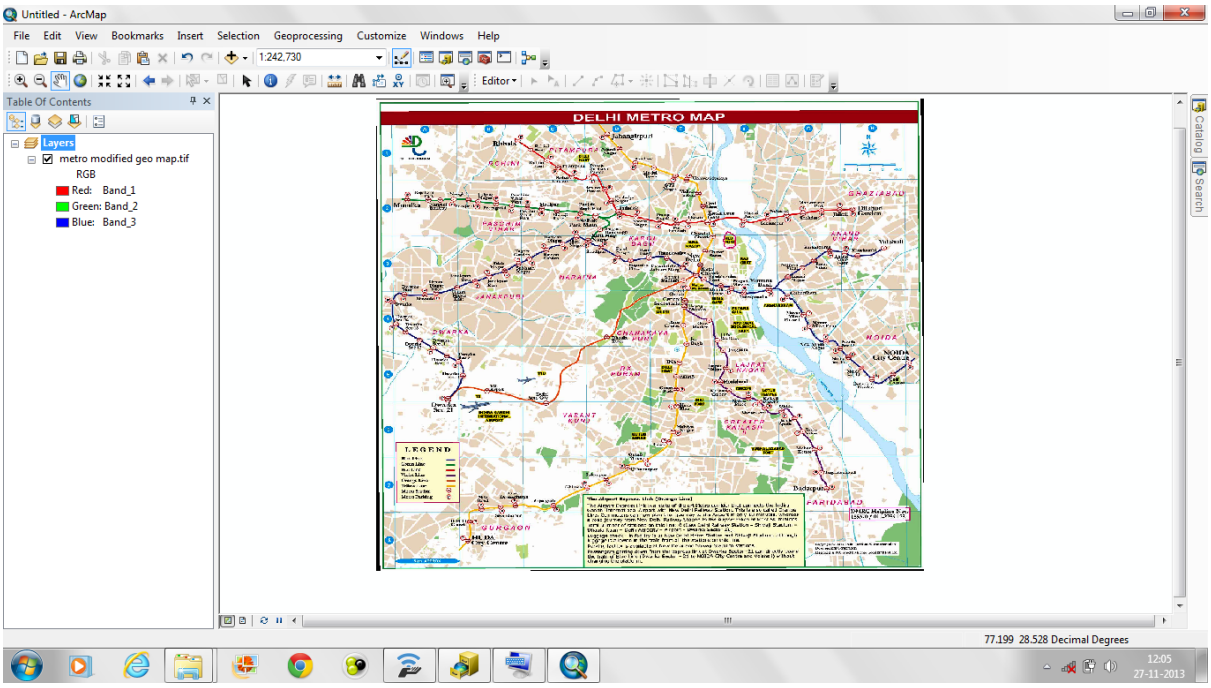

Fig. 2: Geo-referenced Map

Step 3: Digitization

The next step involves digitization of all the metro stations on the map along the metro path. This is done by creating a 'point' feature named metrostations.shp and 'polyline' feature named station path using Arc Toolbox and adding the feature in Arc View 10.1 . Digitizing of all stations and path is performed by selecting option 'Start Editing' in the toolbar. Once all the stations have been digitized, the editing is saved and stopped. The digitized image has been shown in the Fig. 3 below.

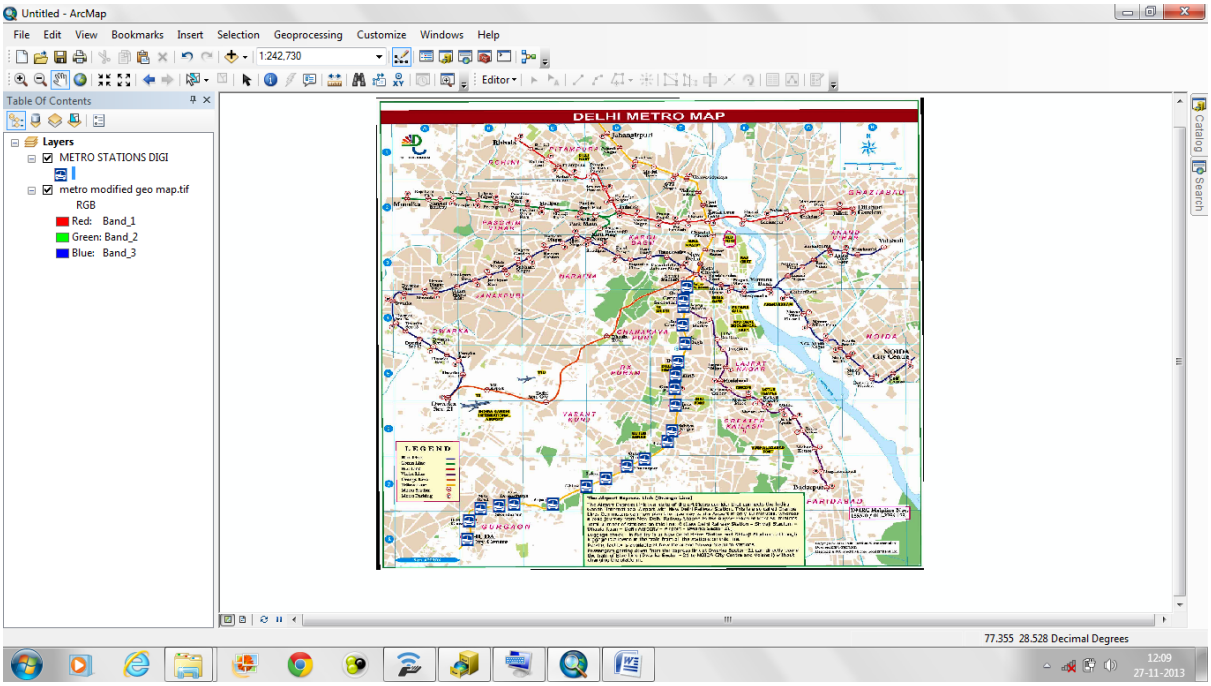

Fig. 3: Digitized Map

Step 4: Entering the values in Attribute Table

Two attribute tables are created for pre-metro and post-metro. The attribute tables has been prepared in the excel sheet. Post metro excel sheet contains 4 columns namely decrease in NO_2, decrease in CO, decrease in RSPM (µg/m^3), and increase in land price. Similarly the pre-metro consists of NO_2 level, CO level, RSPM (µg/m^3) and land price. The excel sheet has been imported in to the attribute table of the shape files by selecting the 'properties' of the shape file and using the command 'join' and 'relates', followed by the command 'join the table' where the excel sheet is selected and joined. The same procedure is followed for both the excel sheets (Fig. 4 and Fig. 5).

Table

Postmero

FID	Shape *	METRO_STAT	FID_1	Sr	METRO_ST_1	Xcord	Ycord	N2_LEVELS	CO_LEVELS	LAND_PRICE	Unit	RSP
0	Point	HUDA CITY CENTRE	0	1	HUDA CITY CENTRE	77.071935	28.459042	24	1300	8000	µg/m3	36
1	Point	IFFCO CHOWK	1	2	IFFCO CHOWK	77.073115	28.471231	32	1600	3200	µg/m3	48
2	Point	M.G.ROAD	0	0		0	0	34	1700	10000		51
3	Point	SIKANDARPUR	2	3	SIKANDARPUR	77.093254	28.481206	34	1800	8000	µg/m3	54
4	Point	GURU DRONACHARYA	3	4	GURU DRONACHARYA	77.103072	28.482053	36	1800	3000	µg/m3	54
5	Point	ARJANGARH	0	0		0	0	34	1700	3500		51
6	Point	GHITORNI	4	5	GHITORNI	77.150107	28.49372	36	1900	3000	µg/m3	57
7	Point	SULTANPUR	5	6	SULTANPUR	77.162621	28.498974	34	1900	15000	µg/m3	57
8	Point	CHHATTARPUR	6	7	CHHATTARPUR	77.176659	28.506933	38	1840	4000	µg/m3	55
9	Point	QUTUB MINAR	7	8	QUTUB MINAR	77.188337	28.511644	38	1600	6000	µg/m3	48
10	Point	SAKET	8	9	SAKET	77.203388	28.523489	36	1700	2500	µg/m3	51
11	Point	MALVIYA NAGAR	9	10	MALVIYA NAGAR	77.206261	28.530268	32	1800	10000	µg/m3	54
12	Point	HAUZ KHAS	10	11	HAUZ KHAS	77.208621	28.547011	34	1800	8000	µg/m3	54
13	Point	GREEN PARK	11	12	GREEN PARK	77.20812	28.557843	36	1800	15000	µg/m3	54
14	Point	AIIMS	12	13	AIIMS	77.208287	28.566471	28	1400	16000	µg/m3	42
15	Point	INA	13	14	INA	77.210491	28.575266	30	1500	5000	µg/m3	45
16	Point	JOR BAGH	14	15	JOR BAGH	77.215056	28.587434	36	1800	10000	µg/m3	54
17	Point	RACE COURSE	15	16	RACE COURSE	77.213029	28.599801	34	1700	6000	µg/m3	51
18	Point	UDYOG BHAWAN	16	17	UDYOG BHAWAN	77.213541	28.611813	30	1500	8000	µg/m3	45
19	Point	CENTRAL SECRETARIAT	17	18	CENTRAL SECRETARIAT	77.213719	28.615522	26	1300	15000	µg/m3	39
20	Point	PATEL CHOWK	18	19	PATEL CHOWK	77.216246	28.624139	36	1800	8000	µg/m3	54

1 (0 out of 21 Selected)

Postmero

Fig. 4: Attribute Table for Post Metro

Table

PreMero

FID	Shape *	METRO_STAT	Sr	METROSTA	RSPM_µg_m3	CO_µg_m3	LANDPRICE_	N02_µg_m3
0	Point	HUDA CITY CENTRE	1	HUDA CITY CENTRE	150	4847	4500	120
1	Point	IFFCO CHOWK	2	IFFCO CHOWK	120	3916	2200	90
2	Point	M.G.ROAD	0		100	3343	7000	120
3	Point	SIKANDARPUR	4	SIKANDARPUR	75	3259	6500	100
4	Point	GURU DRONACHARYA	5	GURU DRONACHARYA	80	2905	2500	130
5	Point	ARJANGARH	0		60	2500	3100	100
6	Point	GHITORNI	7	GHITORNI	60	2000	2700	90
7	Point	SULTANPUR	8	SULTANPUR	50	2688	10000	110
8	Point	CHHATTARPUR	9	CHHATTARPUR	50	2392	3800	90
9	Point	QUTUB MINAR	10	QUTUB MINAR	60	2500	4400	80
10	Point	SAKET	11	SAKET	75	2462	2200	70
11	Point	MALVIYA NAGAR	12	MALVIYA NAGAR	110	2850	9000	60
12	Point	HAUZ KHAS	13	HAUZ KHAS	90	2688	7000	70
13	Point	GREEN PARK	14	GREEN PARK	80	2905	11000	80
14	Point	AIIMS	15	AIIMS	110	3343	13000	100
15	Point	INA	16	INA	100	3259	4000	90
16	Point	JOR BAGH	17	JOR BAGH	90	3464	8000	110
17	Point	RACE COURSE	18	RACE COURSE	80	3200	4500	70
18	Point	UDYOG BHAWAN	19	UDYOG BHAWAN	100	3916	7000	90
19	Point	CENTRAL SECRETARIAT	20	CENTRAL SECRETARIAT	120	3800	9000	110
20	Point	PATEL CHOWK	21	PATEL CHOWK	150	4628	5500	130

1 (0 out of 21 Selected)

PreMero

Fig. 5: Attribute Table for Pre Metro

Step 5: Symbology

In this step, the factors/parameters are displayed on the map. By selecting the layer properties→ display → select field, desired field that should be shown on the map is selected. To display the field in terms of desired symbols, shapes, and classes; go to layer properties→

symbology→ quantities→ graduated symbols; here one can select the required number of classes and symbols. Three classes have been selected. Fig.5 and Fig.6 shows the NO_2 level being displayed using this tool.

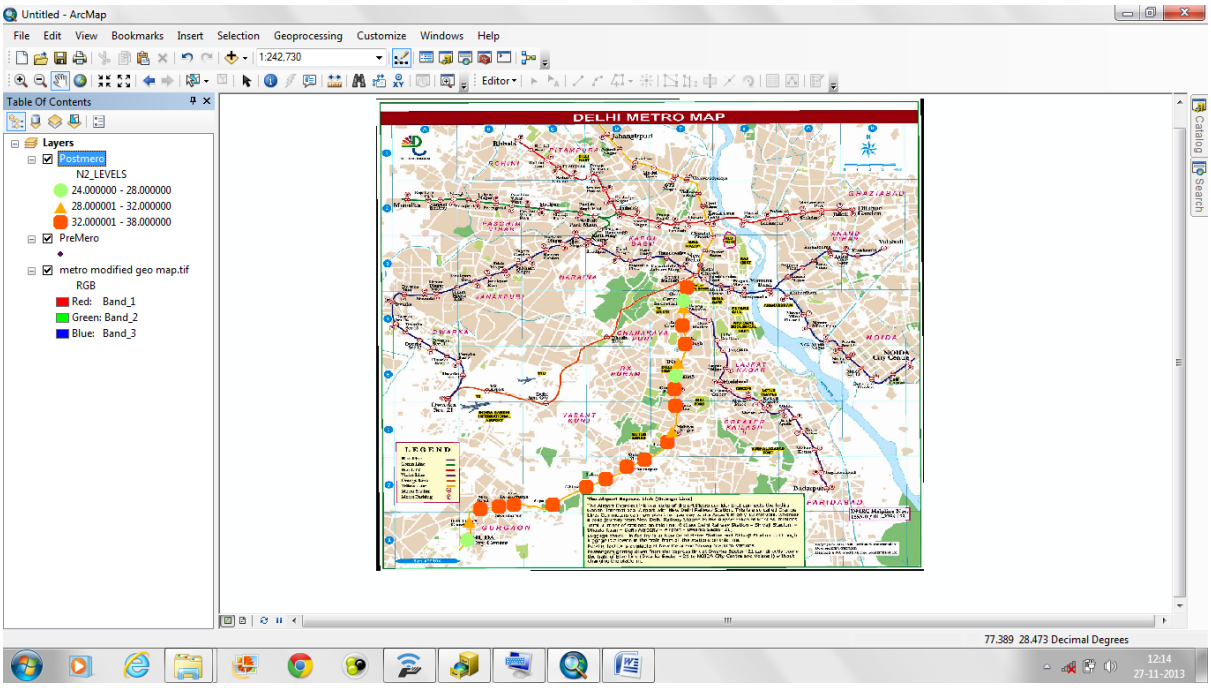

Fig 5: Post metro NO_2

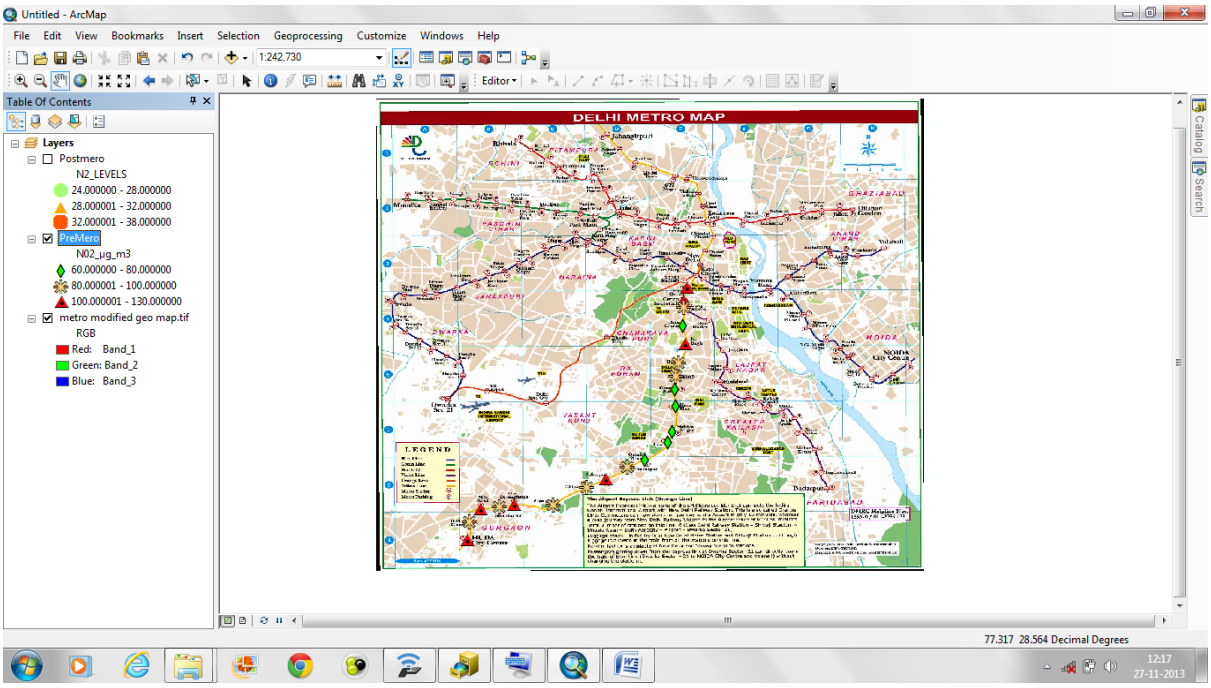

Fig 6: Pre metro NO_2

Step 6: Interpolation

The interpolation commands are as follows:

Select geo-processing→ geo statistical analysis→ interpolation→ IDW select the required field i.e. NO_2 levels, CO levels, land price and RSPM. As mentioned above, the features given in symbology are used for representation and classification of fields. Transparency option is used to clearly show the interpolation and the stations. Transparency of 40-50 % is applied. Fig. 7 and Fig. 8 show the interpolated results for CO.

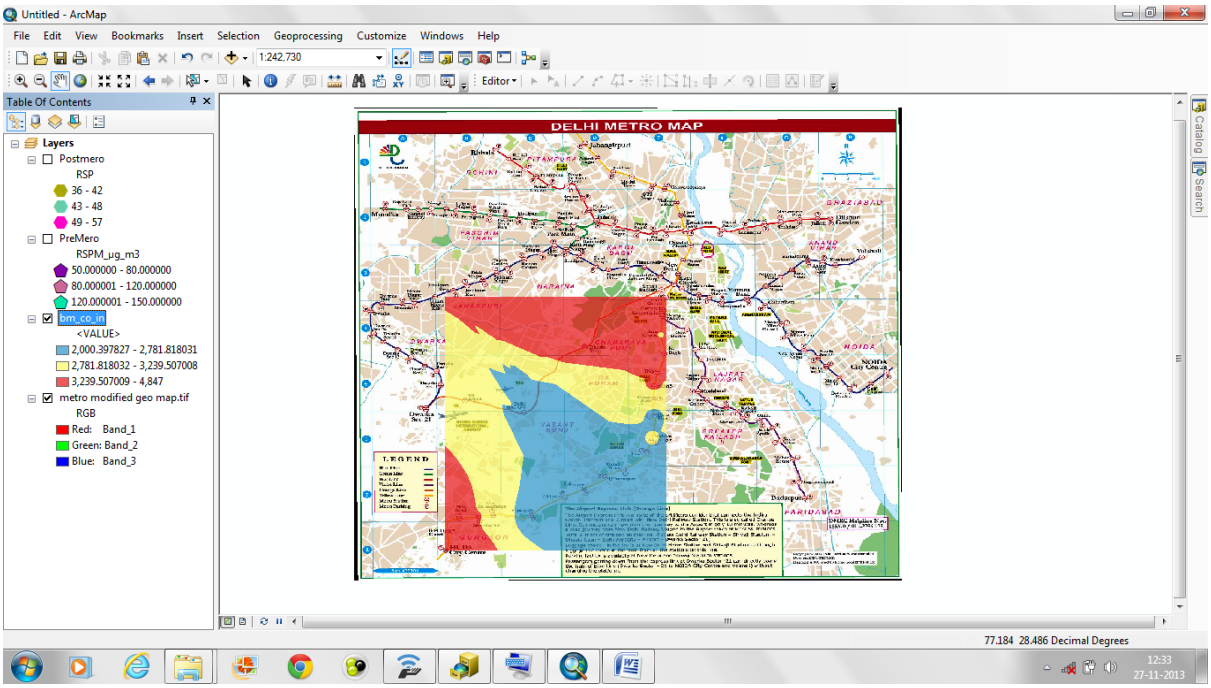

Fig 7: Pre metro CO

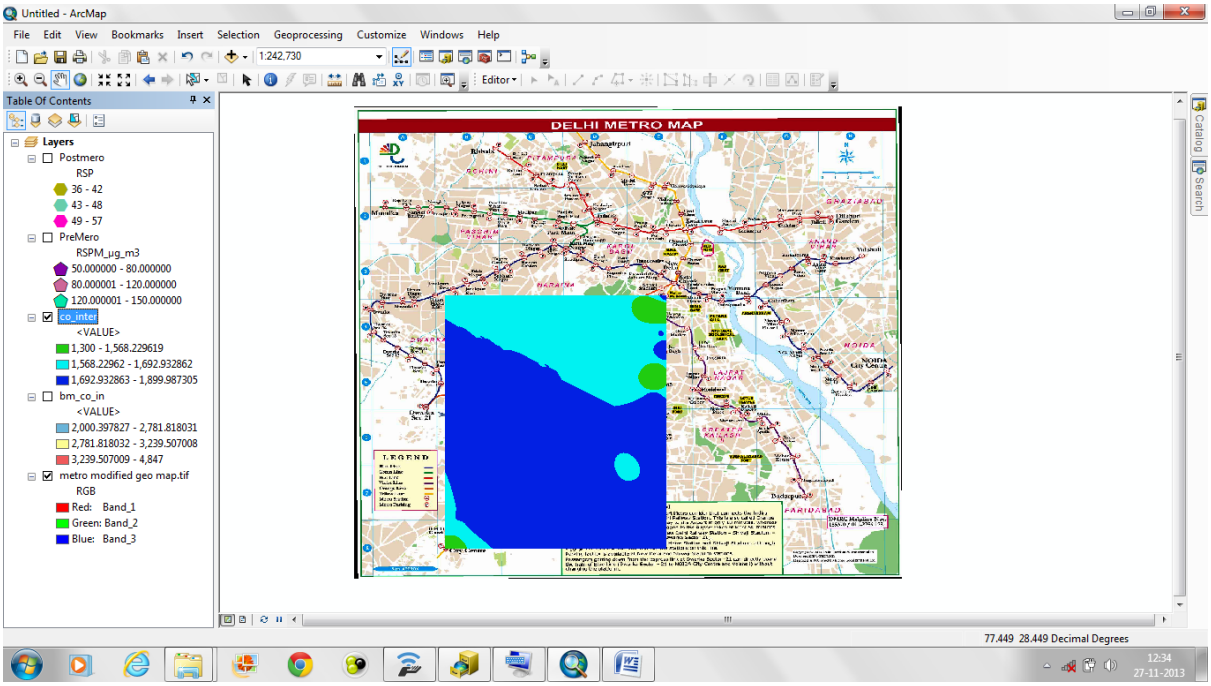

Fig 8: Post metro CO

Step 7: Clipping

To show the target area and fields more clearly, the area between the two target stations is clipped from the whole map. For this go to Arc Tool box → extract → Clip. In the clip give input features, here make a shape file of polygon feature and select the desired area to be clipped and apply. In this way the clipped image has been obtained. Here the clipping is done for Raster layer (Fig. 9)

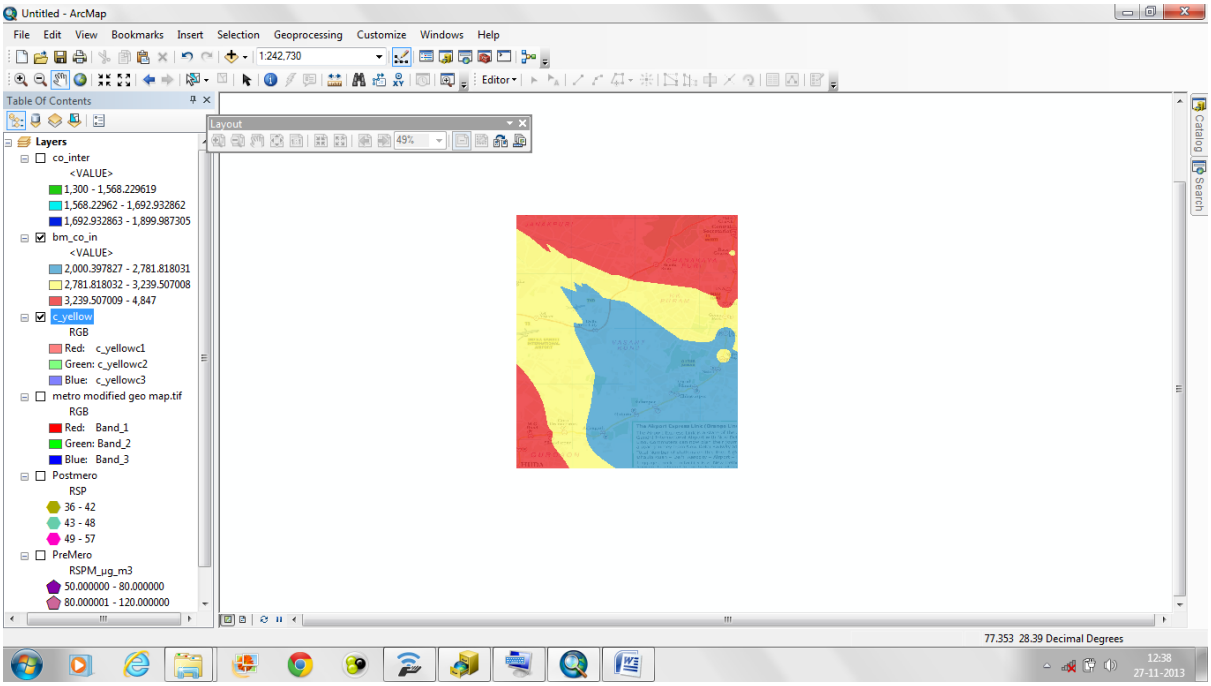

Fig 9: Clipping

Step 8: Comparison

To enable comparison between pre metro and post metro and for convenience, all the shape files of pre metro and post metro are imported to the menu box, due to which the desired field can be simultaneously shown in pre metro and post metro situation.

Step 9: Layout

To show the map with desired features in the layout view, one can go to view→ layout view; get the map in layout view. Then go to insert and insert the title and legend for the map. The legend will be changing according to the field selected whereas title remains the same. The layout has been shown in Fig. 10.

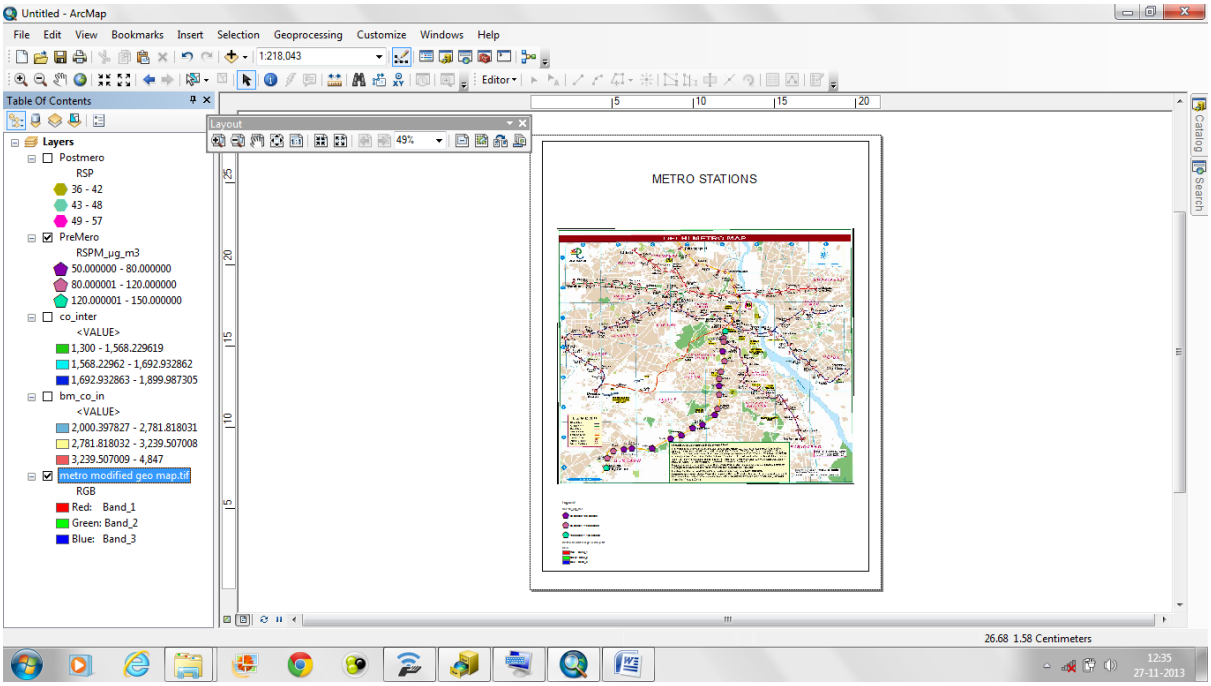

Fig 10: Layout

Results and Discussions

In this study, the effect of Delhi-metro rail at a certain radius from the alignment is observed in terms of environment and socio economic factors. A buffer area of 3 km is found to be appropriate for the analysis.

The present study analyzes the metro rail condition in a city and its effect on environment and socio factors. It is observed several operations of metros like maintenance of infrastructure, and construction of rail tracks significantly impacts the metro rail energy consumption and emissions. These emissions have adverse impact on the environment. It also appears that metro's overall negative impact on the environment is higher than the CNG-run bus systems, Delhi. Although there has been reduction in the values of CO, NO_2 and RSPM for the post-metro condition but these values are expected to rise owing to several operations of metros mentioned above. However there is a significant growth in the Land price at all places in the study area. It is relevant to note that the results emanated from the present paper are based on the chosen input parameters, which may vary for various locations. However, methodology and analysis remains same which is the main focus of the present study, which helps in proposing necessary mitigation strategies.

Conclusions

In the present study, ArC Geographical Information Systems (GIS) software has been used to perform the comparative analysis of Pre- MRTS (Mass Rapid Transit System) and Post-MRTS (Mass Rapid Transit System) with respect to Environmental and Socio-economic

factors in a metropolitan city. GIS provides very fast access to very large spatial databases for a large number of users, at the same time maintaining the spatial data using standard DBMS technology. The software also provides a framework for directly map, query, analyze, and edit data maintained in a geo-database.

The study area that has been chosen is a portion of the yellow line of Delhi metro i.e. Huda City Center to Patel Chowk having a total length of 28.161 km and consisting of 21 stations.CO level, NO_2 level, Land Price and RSPM has been observed in a radius of 3 km from the alignment of the metro rail line. . The analysis performed clearly demonstrates that several operations of metros like maintenance of infrastructure, and construction of rail tracks significantly impacts the metro rail energy consumption and emissions and thus contributing to environmental pollution. It also appears that metro's overall negative impact on the environment is higher than the CNG-run bus systems, Delhi. Although there has been drop in the values of CO, NO_2 and RSPM for the post-metro condition but these values are expected to rise owing to several operations of metros mentioned above. However there is a significant growth in the Land price at all places in the study area.

The study helps the planners to have the complete view of the pre-metro and post-metro status of the environment and thus environment planning and policies formulation can be done in a sustainable way. GIS representation helps in identifying the critical areas which requires immediate attention in terms of improving the quality of environment with respect to the selected parameters. The study serves as a model to analyze the environmental impact of Delhi metro within some given radius around the area where metro is operating. The study also provides as a tool for comparison of impact of metro at different areas in a particular state or a city simultaneously and thus allows different scenarios to be investigated quickly and efficiently.

To establish the model and methodology, study deals with few important environment and socio-economic factors which can be enhanced easily.

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http://delhimetrorail.info/delhi-metro-map

http://www.bing.com/images/search?q=map+of+Delhi+metro+rail+&view=detailv2&&&id=77572A941579860D6CA6B1A4646B718B14071804&selectedIndex=201&ccid=55Ip9e6s&simid=608031872111411262&thid=JN.QJziRKcFH4VLzZ4B3lrlPA&ajaxhist=0