Urban Development at the Expense of Environment: Assessment of Air Quality Following Deforestation for the Infrastructural Development of Red Line in Karachi

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Abstract

Urbanization and rapid population growth have increased the dependence on diverse modes of motorized transport across the globe. Further, due to densification of the inner cities, people are more compelled to live in the peripheral areas amplifying the need for commuting mostly through private vehicles. This ever-increasing dependence on automobiles has raised concerns about degradation of the environment, traffic congestion, excessive energy consumption, road accidents, and pollution of noise and air. Governments around the world are focusing more on sustainable and green modes of transport. The concept of Bus Rapid Transit (BRT) is relatively new but has become quite popular around the world especially in the developing countries due to its cost-effectiveness in contrast to rail systems and is promoted with an idea to reduce dependence on private vehicles which in turn is a benefit to the environment. However, in the context of Karachi, the development process of BRT is being carried out at the expense of environment whereby, trees present along the medians and traffic islands are brutally cut away to make way for BRT even in the situation where the hazards of climate change and global warming are much apparent.The trees and green belts are a source of ground water recharge, cutting of which leads to drying of water from the surface rather than getting absorbed in the sub-soil. The shortage of land in the city and quickly diminishing open spaces i.e., parks, playgrounds, medians, road islands, sidewalks, etc. are further aggravating the situation threatening the quality of life of the city. The study relies on IOT-AI based assessment of the air quality amid deforestation along 10 km approx. strip of main University Road. The study is carried out with an objective to highlight how green spaces act as lungs for the city and how cutting of them results in reduced air quality with recommendations guiding how the process of development can be carried out in a sustainable manner causing minimal threat to the natural assets.

Keywords: Urban degradation, Deforestation, Air-Quality, BRT, Environmental sustainability

I. INTRODUCTION

The need for transportation in the cities is ever increasing,especially in the cities because of increasing population and migrations as cities have an important role in economic development. Transportation is in fact an important part of urban infrastructure for the urban dwellers to attain goods and services with convenience. Motorized transportation helps families to access income opportunities contributing to other economic activities [1]. While transportation has made lives convenient there are certain issues surrounding it. The most common of which are travel delays which in turn lead to increased cost of travel [2]. This travel delay is mainly due to the imbalanced transportation distribution model and insufficient substructure of transportation [1]. Another important concern regarding the transportation systems is that of air pollution. This calls for sustainable modes of transportation in cities causing less destruction to the environment while addressing the crucial social concerns. Bus Rapid Transit is thus considered as a sustainable mode of transportation. A BRT system is an innovative, high capacity, and lower cost public transport solution that significantly improves urban mobility. It is a permanent, integrated system that uses buses running in dedicated lanes that quickly and efficiently transport passengers to their destinations. BRT systems are flexible and can easily be customized in response to community needs. They incorporate state-of-the-art, low-cost technologies that result in high passenger throughput and less congestion [3]. Other than this, the concerns for environmental pollution lay emphasis on making use of open spaces such as roads, medians, sidewalks, traffic islands or green belts more productive. While wider lanes for driving and dense road networks, on one hand, have improved traffic efficiency, on the

other, have degraded the environment quality of outdoor urban space resulting in limited use of social and commercial activities along the sidewalks. In advanced cities, more emphasis is being laid on replacing vehicle-oriented transportation by the human oriented transportation by way of promoting public transportation, connected sidewalks and lanes for bikes [4]. Roads are an important element of an urban outdoor space which not only functions as an element of transportation but also act as a space to hold social and commercial activities[5]. Also, besides pollution and rising concerns for global warming and related urban heat island effect, the concerns for urban outdoor thermal environment have also increased. For many years the dimension of outdoor human thermal comfort seeking solutions to create comfortable urban environments has been a crucial topic for discussion in urban design [6,7,and 8].

II. THE CONTEXT OF KARACHI

The city of Karachi, even being a metropolis sprawling towards the periphery of the city even to this date lacks an established and efficient mass transit system. Talking of different modes of traffic in the city, it is mostly the private buses, rickshaws and ride-hailing services which remain the most popular and easily accessible among the people. According to the estimates, [9]. Besides this, the public bus system in the city is also considered to be unreliable, unstable and causes discomfort. People thus rely more on motorcycles, rickshaws and taxis or other ride-hailing services. Recently as per the study on Karachi's transportation requirement by JICA, the proposition of a circular railway (consisting of 2 railway systems) and 6 Bus Rapid Transit corridors came forward. After the master plan, 2 BRT corridors i.e., Green Line and Red Line were selected by JICA for development after feasibility study which was conducted between July 2011 and June 2012. As a result of this, two dedicated lanes for buses replacing the median strips connecting M.A Jinnah Road, Gurmandir, Lasbela, A.O. Clock and Surjani in case of Green Line while Regal Chowk, People's Roundabout, University Road, and Model Colony median strips connected for Red Line [10].

III. IOT-AI BASED SYSTEMS FOR AIR QUALITY ASSESSMENT

Air quality analysis is become an important area of study in major cities of Pakistan due to many reasons such as high levels of pollution, increase in vehicular traffic, increasing rate of population growth with mixed land use, as well as excessive urban deforestation. Air Quality is an identification or measure of how pure or toxic the air is for consumption. Since air supports life, it is thus important to continuously monitor the air quality. However the scale to assess air quality is called as 'Air Quality Index' (AQI)[11].Air quality index (AQI) is developed by the US Environmental Protection Agency (US EPA) for the purpose of determining air quality. The index focuses on the impact on health after inhaling unhealthy air. The measurements of each pollutant found in the ambient air are thus converted into an AQI value using a set of formulas [13]. AQI employs different colors for demonstrating the intensity of pollutants present in the air such that the color scheme ranges from green i.e. the best level of air to maroon showing the least healthy. The AQI values are measured on a scale of 0-500. The more is the AQI value, greater is the level of air pollution, raising the health concerns.*At first,* When AQI values are above 100, air quality is stated to be unhealthy for vulnerable groups of people, and however, as it increases more than 100, it becomes a health risk for everyone [11].The pollutants present in the ambient air are measured as PM2.5 and PM10, where PM stands for 'particulate matter' i.e., particles preset in the air. These particulate pollutants can be anything like dust particles, airborne bacteria, dust from construction projects or coal particles or fumes from factories. The Air Quality Index (AQI) can be determined by taking the highest value for each contaminant as follows[16]:

Step-I: Determine which monitor has the highest concentration within each reporting area, then truncate it as follows.

Ozone (ppm) – truncate to 3 decimal places

PM2.5 (µg/m3) – truncate to 1 decimal place

PM10 (µg/m3) – truncate to integer

CO (ppm) – truncate to 1 decimal place

SO2 (ppb) – truncate to integer

NO2 (ppb) – truncate to integer

Step-II: Identify the two breakpoints where the concentration is contained (as given below).

Table 1: Breakpoints of Air Pollutant Concentration Levels [16]

These Breakpoints…							…equal this AQI	…and this category
O_3 (ppm) 8-hour	O_3 (ppm) 1-hour[1]	$PM_{2.5}$ (µg/m³) 24-hour	PM_{10} (µg/m³) 24-hour	CO (ppm) 8-hour	SO_2 (ppb) 1-hour	NO_2 (ppb) 1-hour	AQI	
0.000 - 0.054	-	0.0 – 12.0	0 - 54	0.0 - 4.4	0 - 35	0 - 53	0 - 50	Good
0.055 - 0.070	-	12.1 – 35.4	55 - 154	4.5 - 9.4	36 - 75	54 - 100	51 - 100	Moderate
0.071 - 0.085	0.125 - 0.164	35.5 – 55.4	155 - 254	9.5 - 12.4	76 - 185	101 - 360	101 - 150	Unhealthy for Sensitive Groups
0.086 - 0.105	0.165 - 0.204	(55.5 - 150.4)[3]	255 - 354	12.5 - 15.4	(186 - 304)[4]	361 - 649	151 - 200	Unhealthy
0.106 - 0.200	0.205 - 0.404	(150.5 - (250.4)[3]	355 - 424	15.5 - 30.4	(305 - 604)[4]	650 - 1249	201 - 300	Very unhealthy
([2])	0.405 - 0.504	(250.5 - (350.4)[3]	425 - 504	30.5 - 40.4	(605 - 804)[4]	1250 - 1649	301 - 400	Hazardous
([2])	0.505 - 0.604	(350.5 - 500.4)[3]	505 - 604	40.5 - 50.4	(805 - 1004)[4]	1650 - 2049	401 - 500	Hazardous

Step-III: Calculate the index using the equation.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}.$$

Where, I_p = the index for pollutant p

C_p = the truncated concentration of pollutant p

BP_{Hi} = the concentration breakpoint that is greater than or equal to C_p

BP_{Lo} = the concentration breakpoint that is less than or equal to C_p

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

Step-IV: The index is rounded off to the nearest integer.

IV. METHODOLOGY OF STUDY

In order to highlight how development when carried out at the expense of the environment causes nothing but a threat to the whole ecosystem, we live in. However, much of the importance is laid on the transportation development projects. In this regard, one such transportation development project i.e., Red Line from Karachi is highlighted for discussion. The study involves mapping of the number of trees that had existed on the median of approximately 10kilometers strip of main University Road starting from Secretariatintersection (*Chowrangi*)culminating at Karachi University. This empirical study highlights the importance of vegetation along roads and their contribution to the improvement of overall environmental quality such that IOT-AI based assessment is carried out to calculate the environmental quality on three different days and timings in order to note variations of the readings during the times when the area is excessively active in comparison to when the area becomes inactive.

For the purpose of assessing air quality, an IOT-AI based device is used. The device measures air pollutants where particulate matter with an aerodynamic diameter<1.0 µm ($PM_{1.0}$), aerodynamic diameter<2.5 µm ($PM_{2.5}$), and aerodynamic diameter<10µm (PM_{10}), nitrogen dioxide (NO_2), carbon dioxide (CO_2), and carbon monoxide (CO), ammonia (NH_3) and LPG besides smoke, humidity and temperature. Particulate matter is diverse due to which they are measured in terms of diameter i.e.

PM_1 refers to size of particles less than 1.0 microns which are very fine in size;

$PM_{2.5}$ also considered as fine particles with particle size less than 2.5 microns while,

PM_{10} means particles smaller than 10 microns [14]

To calculate the air quality index (AQI) US EPA's method was employed such that the highest average concentration of each pollutant was detected among all. The equation to calculate AQI i.e. I_p was used [15];

$$I_p = \frac{IHi - ILo}{BPHi - BPLo}(Cp - BPLo) + I_{Lo}$$

Where;

BP_{Hi} and BP_{Lo} denote the greater and lower concentrations of the air pollutant,

I_{Hi} and I_{Lo} are the AQI values corresponded to those breakpoints concentrations,

I_p is the Index for Pollutant 'p'

C_p is the truncated concentration of pollutant 'p'

BP_{Hi} is the concentration breakpoint can be ≥ Cp

BP_{Lo} is the concentration breakpoint can be ≤ Cp

I_{Hi} is the AQI value corresponding to BP_{Hi}, while

I_{Lo} is the AQI value corresponding to BP_{Lo}

The readings calculated are then compared to standard quality of environment that is healthy for living beings i.e. on an Air Quality Index scale of 0-500.

V. FINDINGS

The study was carried out such that the number of trees along the 10 kilometers (approx.) strip of the main university road starting from Secretariat Chowrangi and culminating in front of Karachi University gate was mapped giving detail of the total number of trees, the number of trees cut down as of date 27thOctober, 2022 and the remaining trees. The extensive activity was carried out over a period of one week.

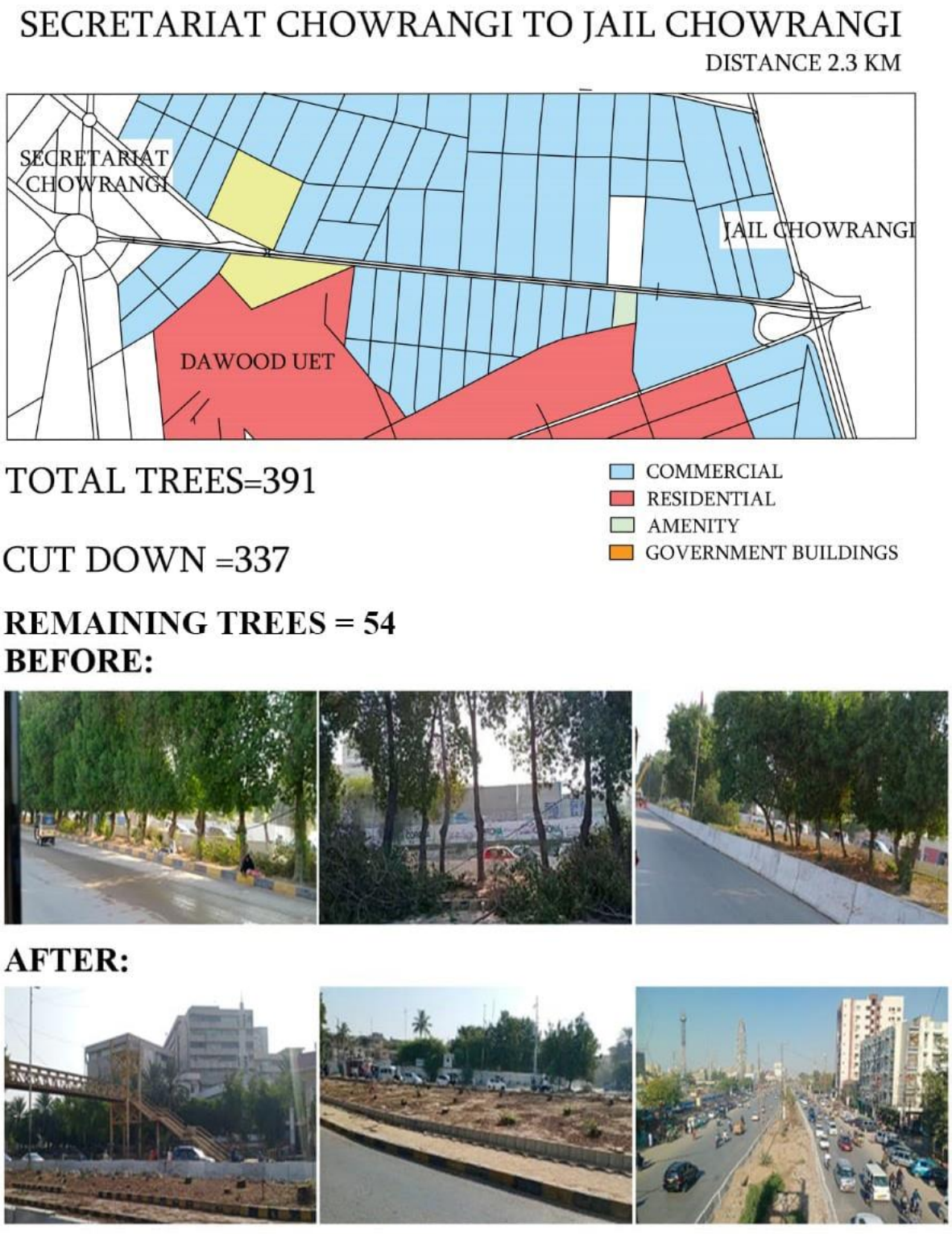


Fig. 1. Details of the total number of trees in relation to the number of trees cut down between Secretariat Chowrangi and Jail Chowrangi as of date 27thOctober, 2022.

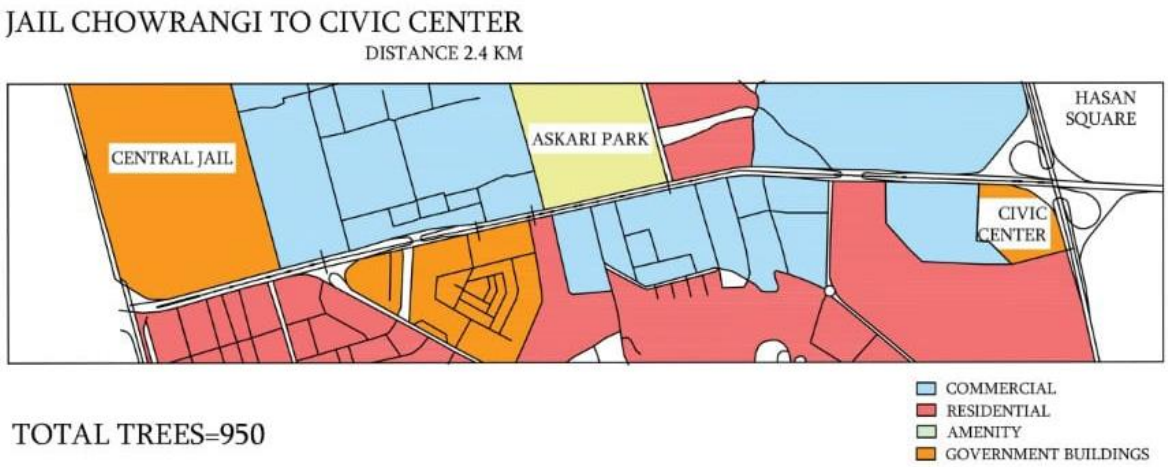
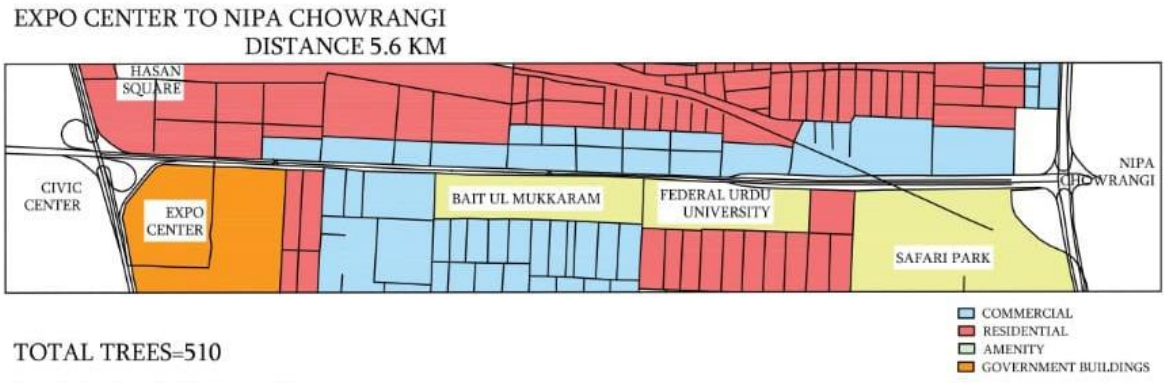


Fig. 2. Details of the total number of trees in relation to the number of trees cut down between Jail Chowrangi and Civic Center as of date 27thOctober, 2022.



TOTAL TREES=510

CUT DOWN/ SHORT =300

REMAINING TREES = 210

BEFORE:

AFTER:

Fig. 3. Details of the total number of trees in relation to the number of trees cut down between Expo Center and NIPA Chowrangi as of date 27thOctober, 2022.

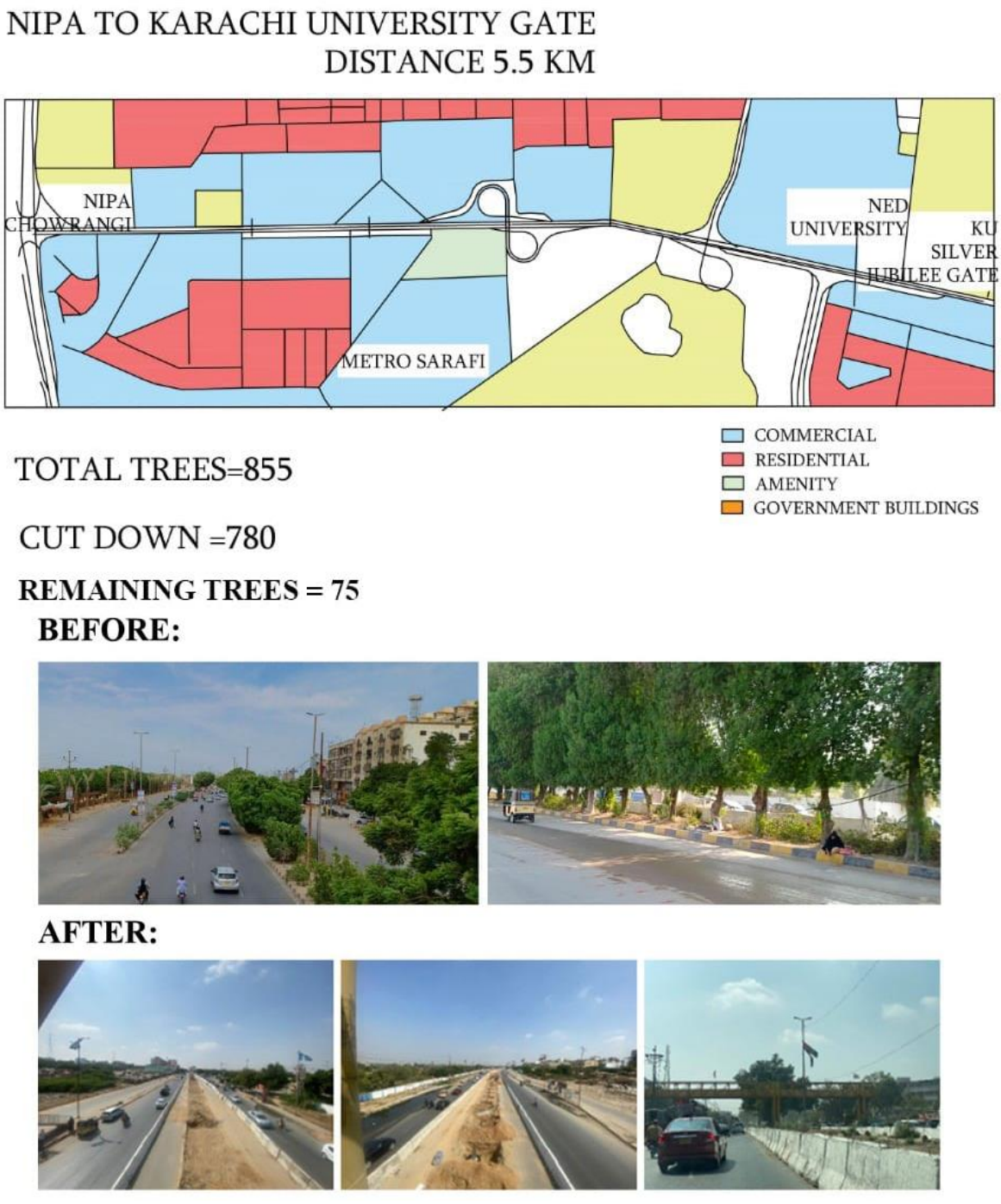


Fig. 4. Details of the total number of trees in relation to the number of trees cut down between NIPA Chowrangi and Karachi University gate as of date 27thOctober, 2022.

As a second part of the study,Air Quality was measured using an IOT-AI based electronics device developed byDawood University of Engineering and Technology on different locations of the main University Road on three different times of the day i.e., morning (8:00-9:00 a.m, afternoon (4:00-5:00 p.m and night-time 8:00-9:00 p.m). The selected points were: Secretariat Chowrangi, Jail Chowrangi, Hasan Square, Federal Urdu University, NIPA and Karachi University. It was found out that in general, the air quality index was found to be more than 100 during most time of the day at all the points which lies in the low range of air quality. However, in instances of traffic jam the air quality index excelled 200 making the atmosphere unhealthy for those who get exposed (Table 2 & Table 3).

Table 2: Measure of Ambient Air Quality measured using IOT-AI device showing details of particulate matter. Readings were taken in the month of January 2023.

LOCATION ON UNIVERSITY ROAD	CO (ppm)	CO2 (ppm)	NO2 (ppm)	NH3 (ppm)	LPG (ppm)	PM 1.0 (µg/m3)	PM 2.5 (µg/m3)	PM 10 (µg/m3)	AQI (2.5)	REFERENCE IMAGES
SECRETARIAT CHOWRANGI	0.0029	250.1	0.15	0.62	0.0057	82	138	154	193	
JAIL CHORANGI	0.0039	414.2	0.15	0.68	0.0067	65	106	123	177	
HASAN SQUARE	0.0016	468	0.15	0.68	0.0033	71	113	125	180	
NIPA	0.0000	990.5	0.15	0.75	0.0001	77	120	144	184	
KARACHI UNIVERSITY	0.0027	555.3	0.15	0.62	0.0053	67	108	121	178	

Table 3: Air Quality Index (AQI) measured using IOT-AI device on three (03) different timings on three different days (03) in the month of January 2023.

S.NO	LOCATION	AT MORNING (8:00 AM -9:00AM)	AT AFTERNOON (4:00 PM -5:00 PM)	AT NIGHT (8:00 PM -9:00PM)
1	SECRETARIAT CHOWRANGI	92,101,95 AVG=96	92,104,105 AVG=100.3	90,95,105 AVG=96.66
2	JAIL CHOWRANGI	105,115,124 AVG=114.6	99,110,137 AVG=115.3	110,87,95 AVG=97.33
3	HASAN SQUARE	150,177,216 AVG= 181	103,104,106 AVG=104.3	117,120,133 AVG=123.33
4	FEDERAL URDU UNIVERSITY	178,233,170 AVG=194	71,86,75 AVG=77.3	123,102,113 AVG=112.6
5	NIPA	122,137,139 AVG=132.6	112,103,115 AVG=110	130,147,127 AVG=134.6
6	KARACHI UNIVERSITY	125,114,140 AVG=143	90,105,99 AVG=98	115,108,126 AVG=116.3
7	IN TRAFFIC	274>	282>	288>

GOOD (1-50) LOW (101-200)
MODERATE (51-100) UNHEALTHY (201>)

VI. DISCUSSIONS

The data collected shows the use of an IOT-AI based device for determining air quality of a primary road stretching up to 10 kilometers where deforestation had taken place to accommodate infrastructure for Bus Rapid Transit. The whole stretch was divided into 6 parts to study and take readings at different times of the day. The collected data revealed that in general, the air quality along most of the points on the main University Road was found to be low, ranging from 101 to 200. However, during the peak traffic hours, the air quality index was

found to exceed 200 making the overall air quality unhealthy to sustain life. The mapping along different points on the university road shows the tree count before and after deforestation revealing a major tree cut down declining the overall air quality thereby, also making the whole stretch exposed to harsh sunlight making it difficult for the passerby.

VII. CONCLUSIONS AND RECOMMENDATIONS

This paper made an attempt to highlight how transportation development projects when carried out without weighing the negative impacts to the atmosphere are nothing but nuisance to the people associated with it. It also aims to highlight that use of technology, i.e., IOT-AI based systems can be made use of in urban design and planning in order to strive to attain a healthy environment for the city dwellers. Air Quality assessment amid deforestation along main University Road for the development of Red Line is an example of assessing the situation. However, in order to promote healthy urban outdoor environments, the study makes the following recommendations;

1. The potential of technology should be explored in terms of projects related to urban planning for prompt decision making.
2. IOT-AI can prove to be a useful tool in the assessment of air quality both indoors and for outdoors guiding interventions to improve the quality.
3. Concerning deforestation, especially in the case of urban scale intervention, alternative solutions be worked out to avoid compromising urban open spaces i.e., medians, sidewalks, etc.
4. When removal of trees is necessary, stem cutting should be avoided and hence the whole tree should be relocated with roots intact.
5. Awareness and teaching at all levels must be carried out concerning pollution and transportation [12]. Regarding this, the importance of urban open spaces i.e., medians, green spaces, roads, etc. be explored as active cultural and social space rather than components of transportation.

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REFERENCES

[1] Hamid Mohammad-Beigi, Jafar Nouri1 & Humman Liaghati. 2015. Strategic Analysis of Bus Rapid Transit System in Improvement of Public Transportation: Case of Tehran, Iran. Modern Applied Science; Vol. 9, No. 9; 2015

[2] Gwillian, K., Kojima, M., & Johnson, T. (2010). Reducing Air Pollution from urban transport Washington: The World Bank.

[3] K. Kim. 2013. Lanzhou BRT: Solution for Sustainable Urban Transport. Lecture presented at Insight Thursday. Manila. 4 April.

[4] Parizi, S.M., Kazeminiya, A., 2015. Evaluation of human-oriented transport in city hall transportation projects approach to sustainable case study of the Kerman City Hall. J. Build. Constr. Plan. Res. 3, 149–161.

[5] Lillebye, E., 1996. Architectural and functional relationships in street planning: ahistorical view. Landscape and Urban Planning. 35, 85–105.

[6] Mayer, H., 1993. Urban bioclimatology. Experientia 49, 957–963.

[7] Mayer, H., Hoppe, ¨ P., 1987. Thermal comfort of man in different urban environments. Theor. Appl. Climatol. 38, 43–49. https://doi.org/10.1007/BF00866252.

[8] Mayer, H., Holst, J., Dostal, P., Imbery, F., Schindler, D., 2008. Human thermal comfort in summer within an urban street canyon in Central Europe. Meteorologische Zeitschrift. 17, 241–250. https://doi.org/10.1127/0941-2948/2008/0285.

[9] H. Tunio, "City Finally gets Urban Transport," *Express Tribune* , 28 June 2022.

[10] "The Transportation Improvment Project," C40 , December 2019. [Online]. Available: www.c40.org/case-studies/the-karachi-transportation-improvement-project/. [Accessed 28 December 2022].

[11] An Analysis of the Annual and Seasonal Trends of Air Quality Index of Delhi, Manju Mohan & Anurag Kandya, 23 January 2007. Environ Monit Assess (2007) 131:267–277 DOI 10.1007/s10661-006-9474-4.

[12] Yuksel, I., & Leviren, M. D. (2007). Using the analytic network process (ANP) in AWOT analysis- a Case study for textile firm, Information Sciences, no. 177.

[13] EPA. Air Quality Index a Guide to Air Quality and Your Health. 2014

[14] T. Talhelm, "PM2.5 vs. PM10: The Difference in Particle Air Pollution," Smart Air , 26 April 2019. [Online]. Available: https://smartairfilters.com/en/blog/pm10-pm2-5-difference-particle-air-pollution/. [Accessed 15 Jan 2023].

[15] Somayeh Yousefi, Abbas Shahsavani, Mostafa Hadei, "Applying EPA's instruction to calculate air quality index (AQI) in Tehran," *Journal of Air Pollution and Health*, vol. 4, no. 2, pp. 81-86, 2019.

[16] U. E. P. Agency, "Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI)," Office of Air Quality Planning and Standards, U.S. EPA, North Carolina, 2018.

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