

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452

NAAS Rating (2026): 4.49

Maths 2026; 11(6): 234-238

© 2026 Stats & Maths

<https://www.mathsjournal.com>

Received: 11-04-2026

Accepted: 13-05-2026

Bhaskar Chatterjee

Department of Physical Science,
Rabindranath Tagore
University, Bhopal, Madhya
Pradesh, India

Bhawna Agrawal

Department of Physical Science,
Rabindranath Tagore
University, Bhopal, Madhya
Pradesh, India

Gaurav Sharma

Department of Applied Sciences,
Sagar Institute of Research and
Technology, Bhopal, Madhya
Pradesh, India

Corresponding Author:

Bhaskar Chatterjee

Department of Physical Science,
Rabindranath Tagore
University, Bhopal, Madhya
Pradesh, India

Quantitative analysis of green open space allocation in response of freight transportation to carbon emissions in Indian metropolitan area

Bhaskar Chatterjee, Bhawna Agrawal and Gaurav Sharma

DOI: <https://www.doi.org/10.22271/math.2026.v11.i6c.2577>

Abstract

In metropolitan regions we introducing a transportation method in operation method to perform of emission of carbon in India. Including Mumbai, Delhi, Bhopal, Kolkata, Chennai, Hyderabad, Ahmadabad, Pune, Jaipur, Bhubaneswar, Indore and Ranchi, the intensity of Green Freight transportation activities significantly contributes to the escalation of carbon emissions. We have to calculate the Green Open Space (GOS) respect to the distance covered by Truck (Diesel) through road freight Transportation in different cities in India. Introducing Vogel Approximation Method to calculate Carbon emission in reference of fuel consumption of the truck. The augmentation of carbon emissions necessitates a recalibration of green open spaces to mitigate air pollution. This study aims to quantify the requisite green open spaces in Indian metropolitan areas, predicated on the carbon emissions generated. The findings reveal that a total distance of 20% can be allocated that is of 936 km of green open space is essential to offset the emissions amounting to 3,294.72 kg CO₂ by VAM Method.

Keywords: Operation research, carbon emission, green open space, transportation

1. Introduction

India has a unique culture and is one of the oldest and greatest civilizations of the world. India has achieved all-round socio-economic progress since its Independence. India covers an area of 32, 87,263 sq. km, extending from the snow-covered Himalayan heights to the tropical rain forests of the south. As the 7th largest country in the world, India stands apart from the rest of Asia, marked off as it is by mountains and the sea, which give the country a distinct geographical entity. Bounded by the Great Himalayas in the north, it stretches southwards and at the Tropic of Cancer, tapers off into the Indian Ocean between the Bay of Bengal on the east and the Arabian Sea on the west. Lying entirely in the northern hemisphere, the mainland extends between latitudes 8° 4' and 37° 6' north, longitudes 68° 7' and 97° 25' east and measures about 3,214 km from north to south between the extreme latitudes and about 2,933 km from east to west between the extreme longitudes. It has a land frontier of about 15,200 km. The total length of the coastline of the mainland, Lakshadweep Islands and Andaman & Nicobar Islands is 7,516.6 km.

An open space is a piece of land that is undeveloped and is accessible to the public. Green space that is land which is partially or completely covered by grass, trees or other vegetation, due to rapid urbanization and unplanned construction our green space was converted to concrete which has disbalance our environment. The restoration strategies can be employed to restore our rapidly vanishing green space^[3].

A third of India's population currently lives in cities. It is projected that by 2030, the urban population will increase by 590 million and its economic contribution will surge to 75 per cent of GDP from the current 65 per cent. With a growing population and as centers of economic growth, Indian cities face complex infrastructural challenges and environmental degradation due to rapid urbanization and climate change. Consequently, cities must undertake sustained actions to prepare for and develop their ability to thrive in the changing environment.

In accordance with the need for sustainable urban planning and climate-informed development actions across Indian cities, the Climate Smart Cities Assessment Framework (CSCAF) was developed and rolled out by the Ministry of Housing and Urban Affairs (MoHUA). It is a first-of-its-kind self-assessment framework on climate-relevant parameters with intent to provide a roadmap to Indian cities towards mainstreaming climate actions within current and future policies, programs and projects. Emissions that give a great impact is the CO₂ emissions of the pollutants that have a large contribution toward global warming and climate change [5].

Green open space is function to suppress the negative effects of the built environment in urban areas, such as increased air temperatures, a decrease in the level of water infiltration and humidity, pollution and others [6]. Green Open Space has a necessary environmental role especially in urban areas where the demand for build up land increases persistently. It is also integrated government office complex [2].

With a vision to be more aspirational and progressive, the current CSCAF assesses the climate performance of cities, encompassing national and international initiatives including but not limited to National Mission on Sustainable Habitat, Nationally Determined Contributions, Sustainable Development Goals and Sendai Framework for Disaster Management. In 2020, under CSCAF 2.0, 126 cities including 100 Smart Cities, capital cities and other cities were assessed on these parameters. This study will assess the comprehensive determination of green open space that is required for each area in Indian different cities as a public green open space of CO₂ emissions that is generated by each respective area / region of the transportation sector. The study used to method collecting of the data emission CO₂ from transportation sector based on types of the road transportation in Indians cities. Apart of the data emission CO₂ in each area, the large area of data in India to get the large of green open space in different city in India from the 20% total distance of these cities including Mumbai, Delhi, Bhopal, Kolkata, Chennai, Hyderabad, Ahmadabad, Pune, Jaipur, Bhubaneswar, Indore and Ranchi. The goal of this study is to calculating the large of green open space in India cities from data of the large each area and data emission of CO₂ in each area in India from transportation sector.

2. Preliminaries

2.1 Transportation Model

Suppose a company has m origins (**factory, warehouses etc**) and n destinations (**warehouses, stores etc**). A single product is to be shipped from origins to the destinations. Each level of supply and each origin have a given level of demand. We are also given the transportation cost between every pair of origins and destinations and these costs are assumed to be linear.

So mathematically notation of the transportation problem can be stated as

$$\text{Minimize } Z_1 = \sum_{i=1}^m \sum_{j=1}^n d_{ij} \cdot x_{ij} \quad (2.1)$$

$$\text{Subject to } \sum_{j=1}^n x_{ij} \geq a_i, i = 1, 2, \dots, m$$

$$\sum_{i=1}^m x_{ij} \leq b_j, j = 1, 2, \dots, n$$

$$x_{ij} \geq 0 \forall i, j$$

2.2 Fuel Consumption: Fuel consumption is the amount of fuel used by a vehicle to travel a certain distance between cities. It helps measure vehicle efficiency and transportation cost during travel.

$$\text{Fuel Consumption } (\eta) = \frac{\text{Distance } (d)}{\text{Vehicle Mileage}} \quad (2.3)$$

Here we are going to considered the mode of transportation is truck and mileage of truck is found that 3.75 km/litter, i.e.

$$\text{Fuel Consumption } (\eta) = \frac{\text{Distance } (d)}{3.75 \text{ km/litter}} \quad (2.4)$$

2.3 Carbon Emission: Carbon emission is the release of carbon dioxide (CO₂) into the atmosphere from burning fuels such as petrol, diesel, coal, and natural gas, contributing significantly to global warming and climate change.

$$\text{Carbon Emission } (\xi) = \text{fuel consumption} * \text{Emission} \quad (2.5)$$

Here we found that the carbon emission is released by 2.64 kg CO₂/litter a truck, then we get formula for carbon emission is as follows

$$\text{Carbon Emission } (\xi) = \text{fuel consumption} * 2.64 \text{ kg CO}_2/\text{litter} \quad (2.6)$$

2.4 Green Open Space

Green Open Space (GOS) is an area of land covered with grass, trees, plants, or other natural vegetation that is kept open for public use, recreation, and environmental protection. It helps improve air quality, reduces pollution, provides a habitat for wildlife, and offers people a place to relax, exercise, and enjoy nature. Examples include parks, gardens, playgrounds, green belts, and community forests.

2.5 Working Method

- **Step 1:** Firstly, we check the given transportation model is balanced or unbalanced. If problem is unbalanced then add a dummy row or dummy column with zero transportation cost to balance the table.
- **Step 2:** Apply any suitable method to find feasible solution of given transportation model.
- **Step 3:** Implemented optimality test with help of MODI Method or Stepping Stone Method to get optimal solution.
- **Step 4:** Find fuel consumption and carbon emission between two cities with the help of equation (2.4) and (2.6)
- **Step 5:** Calculation of percentage of CO₂

$$\kappa = \frac{\text{CO}_2 \text{ emission between two cities}}{\text{Total CO}_2 \text{ emission during shipment of Product}}$$

Also we assumption $\tau\%$ of total distance to calculate Green open space (GOS) area covering for the city $\tau\%$ of the total distance of the cities covered by shipment of products

$$d_\tau = \text{Total distance} \times \tau\% \quad (2.2)$$

Percentage of the Green Open Space (GOS)

$$\xi_\tau = \tau\% \text{ of the Percentage of CO}_2$$

Step 6: $GREEN\ OPEN\ SPACE\ (GOS) = \frac{d_{\tau} * \xi_{\tau}}{\tau}$

Numerical Problem: Computation of CO_2 equivalent of the non CO_2 using their respective global potential. The method in this study is used to collect the CO_2 emissions data of each area of the respective transportation sector to calculate total area required for green open space in the metropolitan cities in India. Consists of area of the seven cities comprising

Mumbai, Delhi, Bhopal, Kolkata, Chennai, Hyderabad, Ahmadabad, Pune, Jaipur, Bhubaneswar, Indore and Ranchi. Each city in India belongs to large area for based to calculate total emission of CO_2 in each area in India. Emissions in each area from the transportation sector based on Road. Sector wise quantification of GHG emission. Computation of CO_2 equivalent of the non- CO_2 using their respective global potential.

Table 1: Distance between two cities

	Ahmadabad	Pune	Jaipur	Bhubaneswar	Indore	Supply
Mumbai	521	151	1172	1592	587	500
Delhi	977	1364	296	1857	761	700
Bhopal	589	787	577	1171	193	350
Kolkata	2056	1878	1514	443	1617	250
Chennai	1771	1199	2052	1226	1444	500
Hyderabad	1132	460	1425	1050	805	900
Demand	500	800	250	650	300	

Table 2: Supply Capacity

Name of City	Supply Capacity
Mumbai (M)	500
Delhi (D)	700
Bhopal (B)	350
Kolkata (K)	250
Chennai (C)	500
Hyderabad (H)	900
Total	2500

Table 3: Demand of Cities

Name of City	Supply Capacity
Ahmadabad (A)	500
Pune (P)	800
Jaipur (J)	250
Bhubaneswar (Bh)	650
Indore (I)	300
Total	3200

Step 1: Here, Total demand (= 2500) is less than to Total Supply (= 3200). So we add a dummy demand constraint with 0-unit cost and with allocation 700. Now the modified table is got as follows

Table 4: Transportation Cost Matrix and Demand-Supply Distribution

	A	P	J	Bh	I	D	Supply
M	521	151	1172	1592	587	0	500
D	977	1364	296	1857	761	0	700
B	589	787	577	1171	193	0	350
K	2056	1878	1514	443	1617	0	250
C	1771	1199	2052	1226	1444	0	500
H	1132	460	1425	1050	805	0	900
Demand	500	800	250	650	300	700	

Step 2: Now apply Vogel Approximation Method to find allocation of products to get basic feasible solution,

Table 5: Optimal Transportation Allocation Solution

	A	P	J	Bh	I	D	Supply
M	400 521	100 151	1172	1592	587	0	500
D	100 977	1364	250 296	350 1857	761	0	700
B	589	787	577	50 1171	300 193	0	350
K	2056	1878	1514	250 443	1617	0	250
C	1771	1199	2052	1226	1444	500 0	500
H	1132	700 460	1425	1050	805	200 0	900
Demand	500	800	250	650	300	700	

We get the allocation between cities as follows

$$x_{11} = 400, x_{12} = 100, x_{21} = 100, x_{23} = 250, x_{24} = 350$$

$$x_{34} = 50, x_{35} = 300, x_{44} = 250, x_{52} = 700$$

Here, the number of allocated cells

$$= 11 \text{ is equal to } m + n - 1 = 6 + 6 - 1 = 11$$

This solution is non-degenerate

Step 3: Now, apply optimality test to get optimal solution is as follows

Table 6: Optimal Transportation Plan and Allocation

	A	P	J	Bh	I	D	Supply
M	200 521	300 151	1172	1592	587	0	500
D	250 977	1364	250 296	1857	761	200 0	700
B	50 589	787	577	1171	300 193	0	350
K	2056	1878	1514	250 443	1617	0	250
C	1771	1199	2052	1226	1444	500 0	500
H	1132	500 460	1425	1050	400 805	0	900
Demand	500	800	250	650	300	700	

We get the allocation between cities as follows

$$x_{11} = 200, x_{12} = 300, x_{21} = 250, x_{23} = 250, x_{44} = 250$$

$$x_{31} = 50, x_{35} = 300, x_{52} = 500, x_{54} = 400$$

Step 4

Here found that fuel consumption and carbon emission between two cities that have allocation of products with the help of equation (2.4) and (2.6)

Table 7: Distance, Fuel Consumption and Emissions

Distance b/w Cities	Distance (d)	Fuel Consumption (η)	Carbon Emission (ξ)
Mumbai-Ahmadabad	521	138.93	366.78
Mumbai-Pune	151	40.27	106.31
Delhi-Ahmadabad	977	260.53	687.80
Delhi-Jaipur	296	78.93	208.38
Bhopal to Ahmadabad	589	157.07	414.66
Bhopal to Indore	193	51.47	135.88
Kolkata to Bhubaneshwar	443	118.13	311.86
Hyderabad to Pune	460	122.67	323.85
Hyderabad to Bhubaneshwar	1050	280	739.20
Total	4680	1248	3,294.72

Step 5: Calculation of percentage of CO_2 =

$$\frac{CO_2 \text{ emission between two cities}}{\text{Total } CO_2 \text{ emission during shipment of Product}}$$

- Also, we assumption 20% of total distance to calculate Green open space (GOS) area covering for the city

- Total Distance of all the metropolitan cities covered by shipment of products = 4680 km
- 20% of the total distance of the cities covered by shipment of products = $4680 \times 20\% = 936 \text{ km}$
- Percentage of the Green Open Space (GOS) $\xi_r = 20\% \text{ of the Percentage of } CO_2$

Table 8: Green Open Space Requirement Analysis

Distance b/w Cities	Distance (d)	% of CO_2 (κ)	20% of the total distance of the cities covered by during shipment of product (d_r)	Percentage (%) of Green Open Space (GOS) (ξ_r)
Mumbai-Ahmadabad	521	11.13	936	2.23
Mumbai-Pune	151	3.23	936	0.65
Delhi-Ahmadabad	977	20.88	936	4.18
Delhi-Jaipur	296	6.32	936	1.26
Bhopal to Ahmadabad	589	12.59	936	2.52
Bhopal to Indore	193	4.12	936	0.82
Kolkata to Bhubaneshwar	443	9.47	936	1.89
Hyderabad to Pune	460	9.83	936	1.97
Hyderabad to Bhubaneshwar	1050	22.44	936	4.49

Step 6: Calculation of the area of GREEN OPEN SPACE (GOS) in the Indian metropolitan cities = Multiply 20% of the total area of the city with percentage of GOS is divided by 20.

Table 9: Green Open Space Area Estimation

Distance b/w Cities	20% of the total distance of the cities covered by during shipment of product	Percentage (%) of Green Open Space (GOS)	Area of Green open space (GOS)
Mumbai-Ahmadabad	936	2.23	104.20
Mumbai-Pune	936	0.65	30.20
Delhi-Ahmadabad	936	4.18	195.40
Delhi-Jaipur	936	1.26	59.20
Bhopal to Ahmadabad	936	2.52	117.80
Bhopal to Indore	936	0.82	38.60
Kolkata to Bhubaneswar	936	1.89	88.60
Hyderabad to Pune	936	1.97	92.00
Hyderabad to Bhubaneswar	936	4.49	210.00

Result and Discussion

The study of calculating method of Green Open Space (GOS) based on Carbon emission from transportation sector used to data large of each cities and emission of CO₂ in each cities in India by the VAM transportation method. In this paper first we take Metropolitan Cities of India like Mumbai, Delhi, Bhopal, Kolkata, Chennai, Hyderabad, Ahmadabad, Pune, Jaipur, Bhubaneswar, Indore and Ranchi.

Conclusion

India, currently classified as a developing nation, has embarked on the Smart Cities Mission, an initiative by the Government of India aimed at propelling economic growth and enhancing the quality of life for its citizens. This is achieved through fostering local area development and leveraging technology to yield smart outcomes for the populace. In terms of carbon emissions, the transportation sector's contribution in each city has led to a total CO₂ emission of 3,294.72 kg CO₂. The strategy for green open spaces in India assumes a target of 20% of the total area, which amounts to 936 km. The distribution of these green spaces across various Route is Covered by VAM Method as follows: Mumbai to Ahmadabad at 104.20 km, Mumbai to Pune at 30.20 km, Delhi to Ahmadabad at 195.40 km, Delhi to Jaipur at 59.20 km, Bhopal to Ahmadabad at 117.80 km, Bhopal to Indore at 38.30 km, Kolkata to Bhubaneswar at 88.60 km, Hyderabad to Pune at 92.00 km, Hyderabad to Bhubaneswar at 210.00 km.

References

- Nastiti FN, Giyarsih SR. Green open space in urban areas: a case in the government office of Boyolali, Indonesia. *Regional Science Inquiry*. 2019;11(1):19-28.
- Ahirrao P, Khan S. Assessing public open space: a case of Nagpur city, India. *Sustainability*. 2021;13(9):4997.
- Malik KT, Gupta A. Open green spaces in urban Indian cities: its importance, rapid decline and restoration strategies. *International Journal of Scientific Research and Review*. 2018;7(4):178-186.
- Santoso B, Hidayah R, Sumardjito. Green open space use patterns in the township area of Plemburan Tegal, Ngaglik, Sleman. *Inersia*. 2012;8(1):1-14.
- Gusnita D, Suaydhi. Emission estimation of fuel consumption and CO₂ absorption by green open space in Jakarta. *Proceedings of the IConSSE FSM SWCU*. 2015:21-29.
- Pratiwi SR. Adequacy analysis of private residence green space in absorbing CO₂ emissions and fulfilling human oxygen needs in North Surabaya (case study: Kenjeran District). *Scientific Conference of Environmental Technology IX*. 2012:1-6.
- Widyanadiari SR. Adequacy analysis of green open space as a CO₂ emission absorber in urban areas using the STELLA program (case study: Central and South Surabaya). *Paper of Institute Technology of Sepuluh Nopember*. 2011:1-27.
- Santoso B, Hidayah R, Sumardjito. Green open space use patterns in the township area of Plemburan Tegal, Ngaglik, Sleman. *Inersia*. 2012;8(1):1-14.
- Olaosebikan TE. Application of the Euler-Lagrange method for solving optimal control problems. *Munich: GRIN Verlag*; 2019.
- Salami AO. Application of transportation linear programming algorithms to cost reduction in the Nigerian soft drinks industry. *International Journal of Social Behavioral, Educational, Economic, Business and Industrial Engineering*. 2014;8(2):416-422.
- Turkensteen M. The accuracy of carbon emission and fuel consumption computations in green vehicle routing. *European Journal of Operational Research*. 2017;262(2):647-659.
- Zhang J, Zhao Y, Xue W, Li J. Vehicle routing problem with fuel consumption and carbon emission. *International Journal of Production Economics*. 2015;170:234-242.
- Li H, Yuan J, Lv T, Chang X. The two-echelon time-constrained vehicle routing problem in line haul-delivery systems considering carbon dioxide emissions. *Transportation Research Part D: Transport and Environment*. 2016;49:231-245.
- Lin Q, Zhu Q, Huang P, Chen J, Ming Z, Yu J. A novel hybrid multi-objective immune algorithm with adaptive differential evolution. *Computers and Operations Research*. 2015;62:95-111.
- Shang R, Du B, Ma H, Jiao L, Xue Y, Stolkin R. Immune clonal algorithm based on directed evolution for multi-objective capacitated arc routing problem. *Applied Soft Computing*. 2016;49:748-758.
- Liang Z, Song R, Lin Q, *et al*. A double-module immune algorithm for multi-objective optimization problems. *Applied Soft Computing*. 2015;35:161-174.
- Sicilia JA, Royo B, Quemada C, Oliveros MJ, Larrodé E. A decision support system for long-haul freight transportation using ant colony optimization. *DYNA Ingeniería e Industria*. 2015;90(1):105-113.
- Trucks Tractor Junction.
- Maps of India.