ISSN NO.2395-0692
International Journal of
Arts, Humanities and Management Studies

Investigating the Link between Urbanization and CO_2 Emissions in India (2000–2023)

Dr. Ashutosh Chandra Dwivedi* & Abhishek Kumar**

**Professor, Department of Applied Economics, Shri Jai Narain Misra P.G College (K.K.C) Lucknow*

***ResearchScholar, Department of Applied Economics, University of Lucknow*

ABSTRACT

This study investigates the impact of urbanization on CO_2 emissions in India from 2000 to 2023 using secondary data sourced from the World Development Indicators. The analysis employs descriptive statistics, trend analysis, correlation, and regression techniques to assess the relationship between the percentage of the population living in urban areas and per capita CO_2 emissions. Findings indicate a positive correlation between higher urban population density and increased CO_2 emissions. Regression results show that a 1% rise in the urban population leads to a corresponding increase in CO_2 emissions. The study highlights several environmental consequences of urbanization, including greater energy consumption, transportation-related emissions, and industrial growth. To address these challenges, the study recommends policies such as integrated urban development, investment in sustainable transport systems, the creation of green urban spaces, promotion of renewable energy, and effective waste management. These strategies, inspired by global best practices, aim to support sustainable urban development and reduce CO_2 emissions in India.

KEYWORDS: *Urbanization, CO_2emissions, sustainable development, Sustainable urbanization, urban population growth, urban planning, environmental impact.*

INTRODUCTION

Global climate change poses a significant threat to natural life, prosperity, and security. Human activities such as fossil fuel usage have increased greenhouse gasses, particularly carbon dioxide, which is one of the primary causes of global warming and climate change. The atmospheric concentration of carbon dioxide is higher than ever, and it is causing devastating effects such as floods, droughts, violent storms, rising sea levels, and melting glaciers. UNFCCC (2017).

Over the Last few years, it has been observed that, urbanization has been emerged as one of the most important megatrends on the 21st century, as over half of the population of the planet living in cities. Such demographic change has been rather more dramatic in developing nations for which economic development is intrinsically tied to the growth of urban infrastructure.Currently, people who live in urban areas are more than 50% of the global population, and it is forecasted that the rate will increase and reach 66% of inhabitants by 2050. This implies that global populations in urban areas will increase about 2.5 billion people due to the ongoing growth particularly in Africa and

Asia.The number of mega-city (urban areas with over ten million persons) has stemmed greatly.This implies that global populations in urban areas will increase about 2.5 billion people due to the ongoing growth particularly in Africa and Asia.The number of mega-city (urban areas with over ten million persons) has stemmed greatly. While in 1970 there were just three such cities by 2000 the number increased to 17 and is expected to touch 41 in the year 2030("Global Trends of Urbanization - MORPHOCODE," 2014). Cities are key players in the growth of the economy and producers of ideas. Energy consumption and greenhouse emissions of the developed countries take 70% of the global rates despite representing less than 5% of the global land use. The standard human density is found in cities, which create economic interaction but elevate the level of pressures applied to the environment.

India's urban population is expected to reach 600 million by 2031, representing a significant rise above current levels. This development is mostly driven by rural-urban migration, as individuals seek greater economic possibilities, social mobility, and superior living conditions in cities (Punyamurthy & Bheenaveni, 2023)As of 2023, about one-third of India's total population resides in urban areas, marking an increase of over 4% in the last decade. This trend indicates a shift away from agriculture towards urban employment, particularly in the services sector (O'Neill, 2023).The growth of the service and industrial sectors has drawn a huge number of migrants to urban areas. Economic expansion has improved living conditions and increased access to key services Significant efforts are being made in developing urban infrastructure, ranging from residential complexes to social, transportation, and smart city projects. Initiatives such as Delhi-Mumbai Industrial Connected Corridor are meant to develop infrastructure and also support the development of sustainable cities. Due to urbanization, there is pressure on resources resulting in degradation of the environment and competition for resources. To reduce these impacts, sustainable urban planning has to be adopted and implemented more so as the country seeks to continue driving economic growth.

Rapid urbanization has resulted in large increases in air pollution, particularly from industrial activity, traffic emissions, and construction. Major cities such as Delhi have serious air quality challenges, with automotive emissions accounting for more than 60% of greenhouse gas emissions in metropolitan areas. The use of diesel automobiles worsens this issue, resulting in significant quantities of harmful gasses being emitted into the environment. (Jena, 2019)Urban expansion frequently results in the conversion of agricultural land and forests into urban areas. This transition leads to habitat loss and a reduction in biodiversity. The fast rate of development has converted natural landscapes into concrete jungles, severely damaging ecosystems. (Nagendra et al. (2013).Urbanization causes considerable climate change by increasing greenhouse gas emissions. According to studies, warming in metropolitan areas has increased by 60%, especially in eastern Tier II cities. This problem gets worse by the urban heat island effect, which occurs when cities become much warmer than their rural environs due to human activity and changing land surfaces.(Sethi & Vinoj, 2024).

In 2023, India's total carbon dioxide (CO_2) emissions reached around 2.8 billion metric tons, up over 7% from the previous year. This increase exceeded the country's GDP growth, which was roughly 6.7% during the same period.(IEA, 2023).The per capita CO_2 emissions are projected to reach 2.07 metric tons, up from 0.4 metric tons in 1970. This is a 6.7% increase from the 2022 levels (Tiseo, 2024). However, India has increased its per capita emission, which as of now is below the global average of 4.6 metric tons of CO_2 equivalent per capita.The energy industry is the single largest contributor to greenhouse gas emissions, accounting for over 75% of total emissions, with CO_2 emissions from coal exceeding 1.8 billion metric tons in 2022, a fivefold increase since 1990(Tiseo, 2024).India's strong reliance on fossil fuels, especially coal for electricity generation, continues to increase emissions. In 2023, fossil-based power plants accounted for around 57% of India's total installed electricity capacity. The carbon dioxide remains the leading greenhouse gas emitted in India, accounting for around 79% of total greenhouse gas emissions in 2019. (Zaidi & Raheja, 2024). Another factor that raises the levels of greenhouse gases in the atmosphere is methane emitted from animal production systems in the agriculture sector.

The Indian government has designed several programs and policies to the task of managing the effects of urbanization. All these endeavors are primarily designed to develop the infrastructure within cities, increase the quality of human life, as well as advance sustainable cities. The Smart Cities Mission, initiated in 2015, is aimed at making 100 cities sustainable by improving the operational efficiency through smart technology and minimization of carbon footprints for better provision of basic infrastructure. Similarly, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is another central government venture that is designed to work towards a sustainable use of natural resources in a long run by promoting clean water supply, efficient sewerage systems and other infrastructure for green cities. The Green Cities Mission extends the concept of sustainable cities through encouraging energy efficient structures, increasing green spaces, and encouraging eco-friendly urban planning. The National Clean Air Program targets cities with measures to reduce pollution and identifying renewable energy as an antidote. All these initiatives of Indian government collectively aim to balance urban growth with environmental sustainability and carbon reduction.

This study is highly relevant since India is already one of the fastest urbanizing countries, expected to reach 600 million people in urban areas by 2030; the rise in energy use, industrialization, and transportation associated with CO_2 emissions are thus significant in cities. It is for this reason that the relationship has to be well understood to inform the strategies of minimizing emission and fostering sustainable urbanization. Further, the journey towards achieving net-zero emission targets by 2070 also calls for frequent evaluations on how the factor of urbanization affects India's emissions baseline, in light of national plans and international commitments such as the Paris Agreement.

LITERATURE REVIEW

Soheila Khoshnevis Yazdi and Anahita Golestani Dariani(2019}This paper examines the relationship between CO_2 emissions, energy, economic growth, trade openness and urbanization in Asian countries from 1980 to 2014. Applying P.M.G. and Granger causality tests the study established that there was a long-run co-movement of all the variables. The insights reveal that CO_2emissions – implying that as cities expand, the environment turns increasingly unhealthy. Also, the study established that economic growth has a bidirectional relationship with urbanization, and both have a causal effect on CO_2emissions. From this it can be inferred that economic development is also augmented by emissions and also in the same way emissions promote urbanization. These findings are useful to the policymakers and planner in the future making of sustainable cities in the Asian region.

Perry Sadorsky (2014): This paper examines the impact of urbanization on CO_2emissions in emerging nation-states by adopting state-of-the-art econometric techniques that permit cross-country comparisons. As a result, the study established that energy use and affluence variables were both positively related to CO_2 emissions. But regarding to the effect of emissions, it is not very clear with reference to urbanization, the effect differs with the techniques used, and overall, lacks significant impact in most occasions. These results reveal that urbanization influences emissions in a nonlinear way, and thus it is not very easy to predict. From the study of the impact of policies on sustainable development, the government needs to ensure that any policy that it implements it does so strategically.

Zahoor Ahmed & Zhaohua Wang & Sajid Ali (2019): This paper analyses the effect that urbanization has on CO_2emissions in Indonesia over the period 1971-2014. The results show an inverted U-shaped pattern: By comparing the above two graphs, we can see that as urbanization grows up, CO_2emissions go up too, while as urbanization goes up further, urbanization decreases emissions. Our findings also indicate that economic growth and energy consumption enhance the level of CO_2emissions, but trade openness do not affect the emission level. It alsoaffirms the findings by estimating the environmental impact through the ecological carbon footprint. This research concluded that economic growth leads to emissions and energy intensity and that, in turn, urbanization affects emissions. In all the guidelines offered by the study, prospects for enhancing the environmental base while avoiding a slowdown in urbanization are given.

Maxwell Kongkuah, Hongxing Yao&Veli Yilanci (2021):The Environmental Kuznets Curve (EKC) hypothesis for China is examined in this study and future trend of CO_2emission is modelled. Based on this, it concludes that China does not fit into the EKC by predicting continuing emissions in the country. A relationship is that, economic growth stimulates the use of energy, energy use and trade expand emissions while urbanization reduces emissions through increasing efficiency of resources. To reduce the emission of CO_2it suggested power generation from clean electricity through the utilization of hydropower, wind and, solar as well as the enhancement of urbanization.

Usama Al-mulali et.al (2013): This paper focuses on analyzing the co-integration of urbanization, energy consumption, and CO_2emissions analysis of the selected MENA countries for the period 1980 to 2009. These forms of transport concluded that some of them are inseparable with the result that the overall global rate of urbanization and proportional energy consumption leads to increased emissions. The study established that these variables are interactive and that the interaction has a differential effect depending on a country's income and development status. The study highlights that downwards moderation of the urbanization rate, enhancement of energy efficiency, and implementation of energy conservation measures can be useful for pollution and energy minimization in the MENA cluster of nations.

Selçuk Gürçama(2023): Sustainable urbanization for climate change mitigation and socio-economic development is the main theme of this research work. It explores how such cities as Copenhagen; Curitiba; Singapore; Stockholm; Melbourne; handle problematic aspects like pollution, public health via Eco - friendly transport, renewable powers, waste disposal, and green areas. Thus, the research highlights that there should be a concern with advanced collaboration to develop resilient, inclusive and sustainable urban settlements, which are a vital tool in the battle against climate change and overall attainment of the sustainable development goals.

RESEARCH GAP

The literature review shows that there is a lacking of research focusing on the details of the relationship between the fluctuation of the urban population and the CO_2emissions in Indian between the year 2000-2023.Many current studies focus on data from individual cities or regions, with little attention to the overall national perspective. However, the use of correlation and regression analysis, as well as other statistical procedures, in exploring these relationships remains limited. Moreover, investigations across the past give little or no consideration to the effects on CO_2emission of policy changes introduced in recent years to support sustainable development of cities. This research therefore seeks to fill these CO_2emissions at the national level in India.

OBJECTIVES

1. To observe and assess the trends in urban population growth and CO_2 emissions in India from 2000 to 2023.
2. To analyze the relationship between urban population percentage and CO_2emissions in India over the study period.
3. To apply correlation and regression analysis to investigate the relationship and impact of urbanization on CO_2emissions in India**.**

RESEARCH QUESTIONS:

1. What are the trends in urban population growth and CO_2emissions in India from 2000 to 2023?
2. How does the urban population percentage relate to CO_2emissions in India during the study period?
3. What is the impact of urbanization on CO_2 emissions in India as determined by correlation and regression analysis?

HYPOTHESIS

Null Hypothesis (H0): There is no statistically significant relationship between the percentage of the urban population and CO_2emissions (measured in metric tons per capita) in India.
Alternative Hypothesis (H1): There is a statistically significant positive relationship between the percentage of the urban population and CO_2 emissions (measured in metric tons per capita) in India.

METHODOLGY

This study depends on secondary data sourced from the World Development Indicators database of the World Bank. The data spans from 2000 to 2023 and focuses on two key variables: urban population percentage means the extent of population that lives in the urban area this then is followed by the CO_2emissions per capita which is in metric tons. Here statistical analysis is performed where the percentage of the urban population is assumed as the independent variable and the CO_2 emissions as dependent variable.
The study employs three primary statistical techniques: these include descriptive statistics, trend analysis, and correlation and regression analyses. To analyze the relationship between urban population percentage and CO_2 emissions, descriptive statistics are adopted to present the overall

statistics of the two variables. These summaries consist of the mean, median, and standard deviation of the levels to give an outlook of the distribution, midpoint and Spread of the data within the given period of study. After this, a trend analysis is undertaken in order to compare the variations in both the urban population and CO_2 emission on the same year basis from 2000 to 2030. These trends are illustrated in line graphs and the annual growth rate of the urban population is examined to identify any significant change in the rate of urbanization.

Using Pearson correlation coefficient, the strength and direction of relationship between the two variables such as urban population percentage and CO_2emission is established. This correlation analysis is very important in establishing the fact as to whether or not there is correlation between urbanization and CO_2 emissions in India. Also, in order to measure the contribution of urbanization towards CO_2 emission a basic model of linear regression is performed. The regression equation takes the form:

$$\text{Ln}CO_2\ \text{Emissions}=\beta0+\beta1\text{Ln(Urban Population Percentage)}+\epsilon$$

where β0 is the intercept,β1 is the coefficient representing the rate of change in CO_2 emissions for each percentage increase in urban population, and ϵ\epsilonϵ is the error term. The results from the regression analysis will provide insights into the magnitude and significance of the impact of urbanization on CO_2 emissions in India.For analysis, the variables such as the percentage of the urban population and CO_2 emissions have been normalized by applying the natural logarithm (LN) so as to linearly relate the variables.

All statistical computations employed in the process of data analysis, such as calculation of means, standard deviations, and correlation coefficients, or application of regression equations, are made with the help of Microsoft Excel. Furthermore, Excel is also applied in preparing charts and graphics to display the discoveries made during the analysis.

DATA ANALYSIS

DATA

TABLENO.1 URBAN POPULATION(in millions) AND % OF URBAN TO TOTAL POPULATION WITH ITS ANNUAL GROWTH(%)

YEARS	Urban Population (millions)	Percentage of Urban to total Population (%)	Annual Growth(%)
2000	293.2	27.7	2.6
2001	301.2	27.9	2.7
2002	310.2	28.2	2.9
2003	319.3	28.6	2.9
2004	328.4	28.9	2.8
2005	337.6	29.2	2.7
2006	346.7	29.6	2.7
2007	355.8	29.9	2.6
2008	365.0	30.2	2.6
2009	374.3	30.6	2.5
2010	383.7	30.9	2.5
2011	393.3	31.3	2.5

2012	403.2	31.6	2.5
2013	413.2	32.0	2.5
2014	423.3	32.4	2.4
2015	433.6	32.8	2.4
2016	444.2	33.2	2.4
2017	455.0	33.6	2.4
2018	465.9	34.0	2.4
2019	476.8	34.5	2.3
2020	487.7	34.9	2.3
2021	498.2	35.4	2.1
2022	508.4	35.9	2.0
2023	519.5	36.4	2.2

Source: world bank

TABLE NO. 2 CO_2 EMISSIONS(in metrics tons per capita) FROM 2000-2023

YEARS	CO_2 Emissions (metric tons per capita)
2000	0.89
2001	0.89
2002	0.90
2003	0.91
2004	0.96
2005	0.99
2006	1.04
2007	1.13
2008	1.19
2009	1.29
2010	1.34
2011	1.41
2012	1.51
2013	1.54
2014	1.66
2015	1.65
2016	1.66
2017	1.73
2018	1.81
2019	1.80
2020	1.98
2021	2.09
2022	2.22
2023	2.35

Source: world bank
Note: the values of CO_2 emissions for the year 2020,2021,2022,2023 are extrapolated

ISSN NO.2395-0692
International Journal of
Arts, Humanities and Management Studies

TABLE NO.3 URBAN POPULATION PERCENTAGE (% of total population) AND CO_2 EMISSIONS(metrics tons per capita) ALONG WITH THEIR LOGARITHMIC VALUES

YEARS	Urban Population (% of total population)	Urban Population Percentage(LN)	CO_2 emissions (metric tons per capita)	CO_2 emissions (LN)
2000	27.7	3.3	0.9	-0.12
2001	27.9	3.3	0.9	-0.12
2002	28.2	3.3	0.9	-0.10
2003	28.6	3.4	0.9	-0.09
2004	28.9	3.4	1.0	-0.04
2005	29.2	3.4	1.0	-0.01
2006	29.6	3.4	1.0	0.04
2007	29.9	3.4	1.1	0.12
2008	30.2	3.4	1.2	0.17
2009	30.6	3.4	1.3	0.25
2010	30.9	3.4	1.3	0.30
2011	31.3	3.4	1.4	0.34
2012	31.6	3.5	1.5	0.41
2013	32.0	3.5	1.5	0.43
2014	32.4	3.5	1.7	0.51
2015	32.8	3.5	1.6	0.50
2016	33.2	3.5	1.7	0.51
2017	33.6	3.5	1.7	0.55
2018	34.0	3.5	1.8	0.59
2019	34.5	3.5	1.8	0.59
2020	34.9	3.6	2.0	0.68
2021	35.4	3.6	2.1	0.74
2022	35.9	3.6	2.2	0.80
2023	36.4	3.6	2.3	0.85

Source: world bank

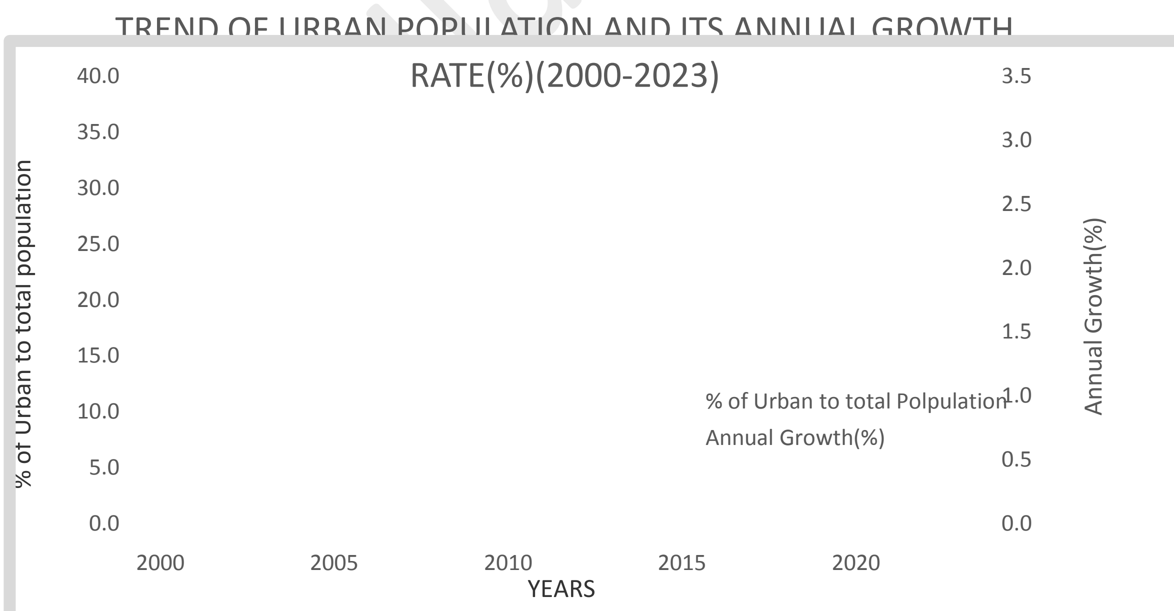
The Urban Population (% of total population) and CO_2 Emissions (metric tons per capita) measures are quite informative from a descriptive analysis perspective. Mean urban population, for the countries in the study, is estimated at 31.65% while mean CO_2 emissions stand at 1.46 metric tons of CO_2 per capita; coefficients of variation are low, suggesting accurate estimates. The distribution of both variables is not far from symmetric as denoted by the medians: the value of 31.45% for urban population and 1.46 for CO_2 emissions is fairly close to the corresponded means. The coefficients of variation (2.65% for the urban population and 0.45 for CO_2 emissions) show moderate fluctuations.The results have shown that urban population data has a negative kurtosis (-1.12) while the CO_2 emissions data has a slightly negative kurtosis (-0.91), which mean both distributions contain less outliers. The variations are seen in the ranges (8.70% for urban population and 1.46 metric tons for CO_2 emissions) as well. Margin of Error (± 1.12% for urban population and ± 0.19 Metric tons for CO_2emission) supports precise estimates.

ANALYSIS

<u>Descriptive Statistics</u>

Urban Population(% of total population)		***CO_2 emissions(metric tons per capita)***	
Mean	31.65375	Mean	1.455006245
Standard Error	0.541530892	Standard Error	0.091367541
Median	31.455	Median	1.456788292
Mode	#N/A	Mode	#N/A
Standard Deviation	2.652948733	Standard Deviation	0.447607707
Sample Variance	7.038136978	Sample Variance	0.20035266
Kurtosis	- 1.116922747	Kurtosis	- 0.908367828
Skewness	0.196261301	Skewness	0.338389098
Range	8.697	Range	1.462279303
Minimum	27.667	Minimum	0.887013876
Maximum	36.364	Maximum	2.349293179
Sum	759.69	Sum	34.92014988
Count	24	Count	24
Confidence Level(95.0%)	1.120242002	Confidence Level(95.0%)	0.189008158

Figure



1

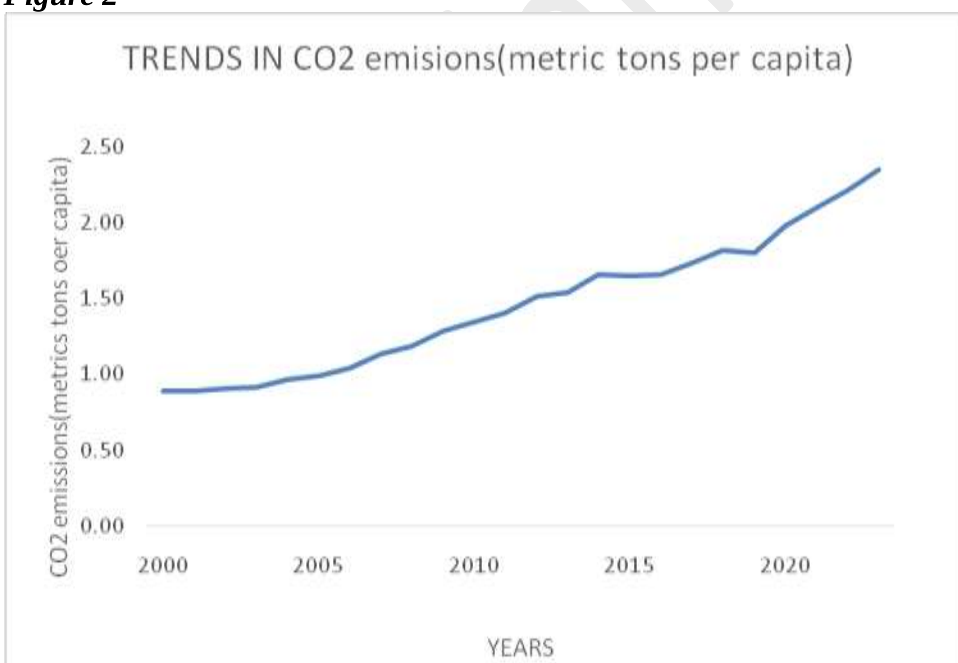
Note: Data from table no. 1

Above figure illustrates the trend of urbanization in India from 2000 to 2023, focusing on two key aspects: percentage of the total population residing in the urban areas and the annual growth rate of this population. The proportion of the people living in Urban areas has been rising gradually for this period. The urban population out of the total population in 2000 was 27.7% and it increased gradually every year to 36.4% in 2023. This uptrend further indicates degree of urbanization by showing that there is a transfer of people from rural areas to urban ones due to factors like industrialization, better economic opportunities in the urban area and development of better infrastructure in urban areas.

Nonetheless, while the numbers of people living in cities has gone up over the years, the rate of this urbanization has been slowing down annually. The growth rate was 2.6% in 2000 and 2.9% in 2002- 2003 showing that the urban expansion increased after the year 2000. After that, the growth rate slightly reduced to range between 2.4% and 2.5% per capita within the year 2004 up to year 2015. After 2015 the growth rate increase was slowed more considerably and by 2022 it reached a pace of 2.0%. This reflects a deceleration in the pace of urban migration as the urban population matured. There was a fairly positive outlook in the year 2023 with the growth rate which was 2.2% showing that the rate of urbanization may gradually rise though not to the levels observed in earlier decades.

In general, the chart shows that urbanization in India is exhibiting a gradual upward trend, and the percentage of people in urban areas is continuously rising from year to year. However, we see that the rate of this growth is diminishing, which indicates a natural process when an initial rapid increase in the speed of urbanization is followed by a stabilization of the urban population.

Figure 2



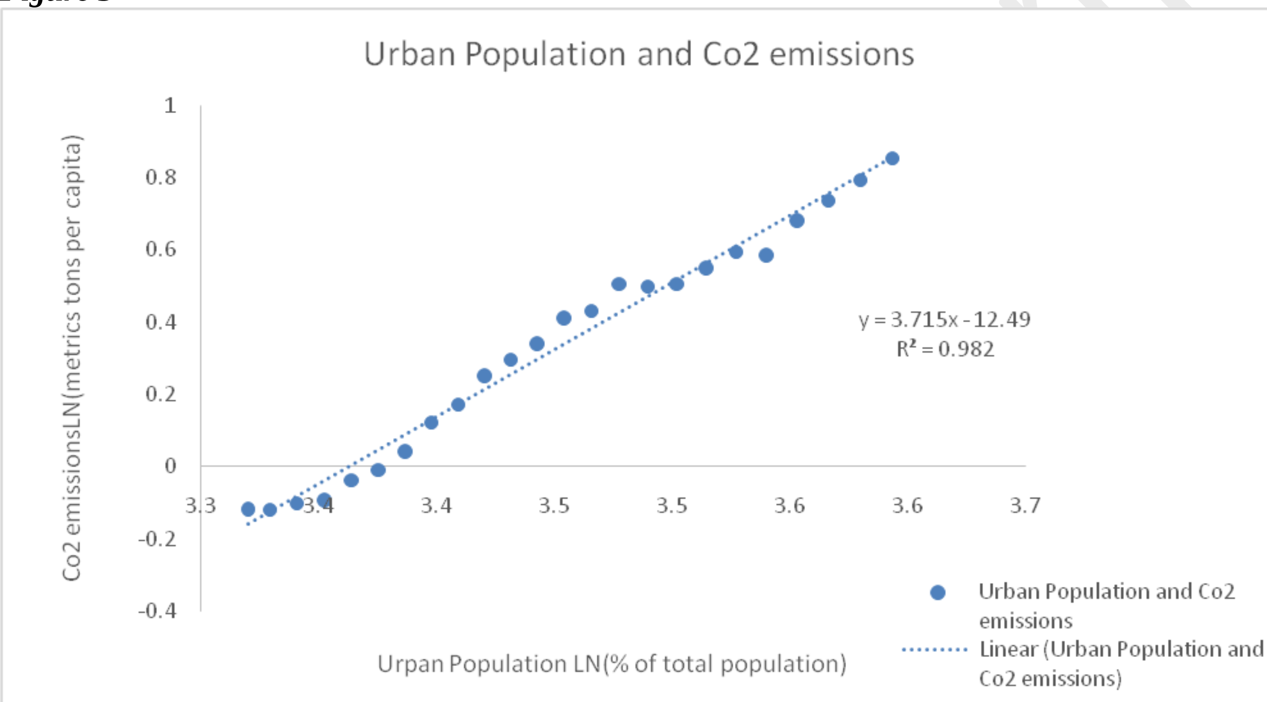
NOTE: Data from table no. 2

The line chart above shows the data of CO_2 emissions per capita in India and the data is from the year 2000 to 2023. From the graph, it is evident that emission has been on the rise over the years.

ISSN NO.2395-0692
IJAHMS International Journal of Arts, Humanities and Management Studies

The emissions stood at 0.89 metric ton per capita in 2000 and were more or less stagnant in the early years of the new millennium, but increased progressively from 2006. It peaked between 2006 and 2014, after which there was relative stability between 2015 and 2019. Emissions started to increase after 2020, and they went up to 2.35 metric tons per capita in 2023.The upward slopping line is proof of a growing Industrialization in the country, and amplified use of energy resources resulting in enhanced CO_2 emissions. The very slight decrease from 2015 and 2019 may reflect a period of stabilization on account of policy measures and energy efficiency, whereas the post-2020 rise might result from more economic activity post-COVID-19.

Figure 3



NOTE: Data from table no.3

The above scatter plot clearly shows a positive relationship between the percentage of the urban population and CO_2 emissions.Therefore, we see that the linear trendline is quite accurate to the data points, although distortion appears in the initial years. While the urbanization is increasing, emissions of CO_2 also increasing and at a faster phase from the year 2010 onwards. This pattern incurred for the support of hypothesis that suggest that there is a positive relation between urbanization and increased emission of CO_2 implying the menace that expanding urban centers pose to the environment. This analysis focuses on the process of urbanization and increases in emissions, drawing attention to sustainable urbanization.

RESULTS

DescriptiveStatistics

The descriptive statistics for the two variables—Urban Population (% of total population) and CO_2 Emissions (metric tons per capita)—provided an understanding of the behavior of the two variables over the period under consideration. The mean value is further 31.65 for the urban population which implies that on mean basis, approximately 31.65% population of India was living in the urban area throughout the period under study. For CO_2 emissions, the mean is at 1.46 metric tons per capita which gives an insight into the average amount of carbon dioxide emission per person in India during the given period of time.The standard error, which gives an indication of how accurate these estimates are, is actually not very large and is equal to 0.54% for the variable 'urban population' and 0.091 metric tons of CO_2 emissions, which suggests that in reality, the true mean value is not very different from these mean values calculated from the given data set.

While the distance between the median and mean for both variables is negligible, demonstrating that the distribution of values is nearly symmetric for both the urban population and CO_2 emissions, the above table shows that the standard deviations for each set of data are significantly different. The lack of a mode mean that there are no duplicate values in data set A or data set B. Uncertainty level expressed with percent value is 2.65% for urban population and 0.45 metric tons for CO_2 emissions and Standard deviation, that reflects variance of data from mean, is also presented.This degree of variability seems somewhat moderate for both the variables, marked by the fact that the variable of urbanization may vary by about 2.65% and the variable of CO_2 emissions may vary by about 0.45 metric ton per capita. The variance again exaggerates the variability within the data set, the urban population having a sample variance of 7.04 and CO_2 emissions variance 0.20.

We find that both kurtosis values are negative; a value of -1.12 for the population of urban areas and a value of -0.91 for CO_2 emissions suggest that both variables have platykurtic distribution, which is light-tailed and lacks outliers as compared to a normal distribution. The skewness values are slightly positive—0.20 for urban population (which means that the data is slightly right-skewed with few observations higher than the mean urban population) and 0.34 for CO_2 emissions. Using the range, the variability can be defined as; For the part of the population living in urban areas, the variability from year to year is at 8.70%, with variations ranging from 27.67% to 36.36%. For the CO_2 emissions, the variability from year to year was at 1.46 metric tons with the ranges from 0.89 to 2.35 metric tons.

The 95% confidence intervals – 1.12% for the urban population, 0.19 metric tons per capita for CO_2 emissions – indicate that in 95% of the cases, the true population means will not exceed the ranges of the corresponding sample means.

Correlation Results

A correlation of **0.9914** suggests a very strong positive linear relationship between Urban Population and CO_2 emissions.This indicates that, as the urban population (log scale) grows, so do CO_2 emissions.

Regression Results

Variable	**Coefficient**	**Standard Error**	**P- value**	**Lower 95%**	**Upper 95%**
CO_2emissions(intercept)	-12.495	0.361	1.11E-20	-13.243	-11.746
Ln Urban Population	3.715	0.105	6.29E-21	3.499	3.932

Additional Statistics:

STATISTIC	VALUE
DEPENDENT VARIABLE	Ln CO_2 Emissions (metric tons per capita)
INDEPENDENT VARIABLE	Ln Urban Population (% of total population)
MULTIPLE R	0.9914
R SQUARE	0.9829
ADJUSTED R SQUARE	0.9821
STANDARD ERROR	0.0419
OBSERVATIONS	24

The model equation is

$LnCO_2\ \beta0+\beta1\times Ln(\text{Urban Population Percentage}) + \epsilon$

Where, β0 is the intercept andβ1 is the slope, which indicates the relationship between the independent variable (urban population) and the dependent variable (CO_2 emissions).ϵ is the error term, representing the difference between the actual y-values and the values predicted by the regression model.

Referring to figure 3,scatter plot depicts the comparison of the log urban population and the log of CO_2 emissions from the year 2000 to 2023. A simple linear trendline has been added to the plot, with the equation where y is the dependent variable (CO_2 emissions) x is the independent variable (Urban Population Percentage).The equation is as follows:

Y=3.7153x-12.495

Y is the dependent variable, which is the CO_2 emissions per capita in metric tons and x is the independent variable which is in this case the level of urbanization, which has been logarithmically transformed as is appropriate within this context. The slope**3.7153**indicates that for every 1% increase in the urban population as a proportion of the total population, CO_2 emissions per capita rise by about 3.7153 metric tons.This implies a significant beneficial relationship between urbanization and CO_2 emissions, meaning that as more people live in cities, their per capita CO_2 emissions increase significantly. This could be attributed to increased energy use, transportation emissions, and industrial activities concentrated in metropolitan areas.The y-intercept indicates that if the urban population accounts for 0% of the total population, the model forecasts CO_2 emissions per capita of around **-12.495** metric tons.While a negative emission number may not make sense in practice, it does show that at very low levels of urbanization, other variables contribute to emissions. It is important to note that the model may fail to appropriately anticipate CO_2 emissions outside of the known urban population percentages.The **R^2**value **0.9829** shows that about **98.29%** variation in the of CO_2 emissions is dependent on the urban population. This is a clear relationship, which implies that while the urban population rises, so does the emission of CO_2 in a linear manner.This high value demonstrates a significant connection between urbanization and CO_2 emissions, implying that urban population expansion is a major factor influencing emissions levels in the study area. It suggests that the model fits the data well and can be used to create accurate predictions about how changes in urbanization may affectCO_2 emissions.The regression model has an **Adjusted R** Square of **0.9821**, which implies that **98.21%** of the CO_2 emissions variances is attributable to urban population percentage in its logged form. This comparatively high value which

ISSN NO.2395-0692

IJAHMS International Journal of Arts, Humanities and Management Studies

is more than 0.5 shows good fit and thus corroborates the hypothesis adopted in this paper that urbanization is a critical variable responsible for emission of CO_2 in India.The**P value** is**6.28848E-21**, for log (percentage of the urban population) in relation to emissions of CO_2 is statistically significant ($p < 0.05$). This means that according to the statistical model used, urbanization is a statistically significant determinant of CO_2 emissions in India. The regression analysis shows a strong and statistically significant association between urban population (logarithmic) and CO_2 emissions per capita. The model explains a significant percentage of the variability in emissions and is supported by the statistical tests conducted.

The regression result shows that coefficient of the log of urban population is positive with a value of **3.715** which implies that increase in the percentage of population living in the urban area is associated with increase in the CO_2 emissions. The p-value for the log of urban population which is **6.29E-21** is much lower than alpha of 0.05 and indicates that one should reject the null hypothesis. Further, to confirm the fitness of the model, the Adjusted R Square value **0.9821** indicates that **98.21** percent of variation in CO_2 emissions can be explicated by the percentage of urban population. Hence, the null hypothesis **(H0)** is **rejected** and the alternative hypothesis **(H1)** is **accepted:** there is a statically significant positive relationship between the percentage of urban population and CO_2 emission in India showing that urbanization leads to increase in CO_2 emission.

CONCLUSION

The study of urbanization and CO_2 emissions for the period of 2000-2023 defines numerous facts of the growth of urbanization and its impact on the environment of India. The findings presented in this research Increase our understanding of the correlation between urbanization and CO_2 emissions in India in 2000-2023. The descriptive statistics results show slightly above average variability of around **31.65%** of the population living in the urban areas with a mean value of the CO_2 emission of 1.46 metric ton per head. The results obtained indicate that the frequency distribution of both variables is almost normal, although a very mild positive skewness indicates an increase in the level of urbanization and CO_2 emissions across time.

Thus, the correlation analysis shows that the growth of the urban population has a strong positive linear relationship with CO_2emission, correlation coefficient = **0.9914**. The regression results provide a proof to this correlation too Further, the value of R^2 is **0.9829** indicating that the variation in percentage of urban population has an influence of **98.29%** on the variations in the CO_2 emissions. Similarly, this study concurs with the hypothesis proposing urbanization as central factor influencing CO_2 emission in India through reaffirming statistically analyzed p-value of **6.29E-21.**

The model shows that if the percentage of the urban population increases by **1%,** the CO_2' emissions per capita increase by **3.715** metric ton, this showing the effect of rapid urbanization on the environment. This strong relationship can be explained by the fact that there is a great need to have integrated urban planning with strategies aimed at reducing emissions and addressing the continued expansion of urban areas.

Therefore, based on the analysis of the results of this study, it is possible to conclude that there is a need to consider the patterns of urbanization and CO_2 emissions alongside the implementation of sustainability factors in India. It is especially important to achieve sustainable urban and economic development in order to create a balance between economic growth and the relation with the natural environment.

POLICY RECOMMENDATIONS

To effectively execute sustainable urbanization, we have to learn from the global leaders who adopted the best strategies to incorporate sustainable urbanization.The cities like Copenhagen, Curitiba, Singapore, Stockholm, and Melbourne gives the much-needed pointers on how sustainable urbanization can be achieved in India. The policy recommendations include encouraging integrated urban planning through mixed-use buildings and zoning reforms that allow for more density while preserving green spaces Supporting well-organized and environmentally friendly transport systems including, for example Curitiba bus rapid transit system; augmenting of non-motorized transport systems for example Amsterdam's cycling paths. Moreover, improving green spaces in cities like Melbourne or incorporating green roofs for stormwater management, as in Stockholm, can be beneficial for both biodiverse and urban resiliency. Promoting the use of renewable resources by use of solar programs and efficient technologies is crucial as exemplified by investments in wind energy in Copenhagen and Sweden high standards on energy consumption. Additionally, expanding the concepts of waste management innovations which include Singapore's compulsory waste collection and sorting and Stockholm Limited's waste recycling technologies can greatly minimize landfill use. Including climate resilience planning as executed in climate action plans and infrastructure in case of the Netherlands and Melbourne will enhance major cities' resilience to climate related catastrophes. In the last place, promoting community participation in planning together with raising people's awareness of sustainable solutions will guarantee that urban development addresses community demands. With these practices and strategies, India can fight with environmental issues, improve the social aspects and economic productivity to produce sustainable cities during the course of rapid urbanization.

REFERENCES

i. Ahmed, Z., Wang, Z., & Ali, S. (2019). Investigating the non-linear relationship between urbanization and CO_2 emissions: An empirical analysis. *Air Quality, Atmosphere & Health*, *12*(8), 945–953. https://doi.org/10.1007/s11869-019-00711-x

ii. Al-mulali, U., Fereidouni, H. G., Lee, J. Y. M., & Sab, C. N. B. C. (2013). Exploring the relationship between urbanization, energy consumption, and CO_2 emission in MENA countries. *Renewable and Sustainable Energy Reviews*, *23*, 107–112. https://doi.org/10.1016/j.rser.2013.02.041

iii. Chandaneshwari Punyamurthy, & Ram Shepherd Bheenaveni. (2023). URBANIZATION IN INDIA: AN OVERVIEW OF TRENDS, CAUSES, AND CHALLENGES. *International Journal of Asian Economic Light*, *11*, 9–20. https://doi.org/10.36713/epra12473

iv. Global Trends of Urbanization - MORPHOCODE. (2014, November 3). Retrieved from MORPHOCODE website: https://morphocode.com/global-trends-urbanisation/

v. GÜRÇAM, S. (2024). Paving the Way for Climate Resilience through Sustainable Urbanization: A Comparative Study. *Lectio Socialis*, *8*(1), 17–34. https://doi.org/10.47478/lectio.1396483

vi. IEA. (2023). Energy-intensive economic growth, compounded by unfavourable weather, pushed emissions up in China and India – CO_2 Emissions in 2023 – Analysis. Retrieved from IEA website: https://www.iea.org/reports/CO_2emissions-in-2023/energy-intensive-economic-growth-compounded-by-unfavourable-weather-pushed-emissions-up-in-china-and-india

vii. Jena, R. J., Abhinash. (2019, November 20). Impact of rapid urbanization on the environment of India. Retrieved from Knowledge Tank website: https://www.projectguru.in/rapid-urbanization-impact-on-the-environment-of-india/

viii. Khoshnevis Yazdi, S., & Dariani, A. G. (2019). CO_2 emissions, urbanization and economic growth: evidence from Asian countries. *Economic Research-Ekonomska Istraživanja*, *32*(1), 510–530. https://doi.org/10.1080/1331677x.2018.1556107

ix. Kongkuah, M., Yao, H., & Yilanci, V. (2021). The relationship between energy consumption, economic growth, and CO_2 emissions in China: the role of urbanisation and international trade. *Environment, Development and Sustainability*, *24*(4), 4684–4708. https://doi.org/10.1007/s10668-021-01628-1

x. Nagendra, H., Sudhira, H. S., Katti, M., & Schewenius, M. (2013). Sub-regional assessment of India: Effects of urbanization on land use, biodiversity and ecosystem services. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, 65-74. doi:10.1007/978-94-007-7088-1_6

xi. O'Neill, A. (2023). India - Urbanization 2017 | Statistic. Retrieved from Statista website: https://www.statista.com/statistics/271312/urbanization-in-india/

xii. Sadorsky, P. (2014). The effect of urbanization on CO_2 emissions in emerging economies. *Energy Economics*, *41*, 147–153. https://doi.org/10.1016/j.eneco.2013.11.007

xiii. Sethi, S. S., & Vinoj, V. (2024). Urbanization and regional climate change-linked warming of Indian cities. *Nature Cities*, 1–4. https://doi.org/10.1038/s44284-024-00074-0

xiv. Tiseo, I. (2024, September 5). Per capita carbon dioxide (CO_2)emissions from fossil fuels in India from 1970 to 2023(in metric tons). Retrieved from Statista website: https://www.statista.com/statistics/606019/CO_2emissions-India/

xv. UNFCCC (2017) UN climate change ANNUAL REPORT 2017. United Nations Framework Convention on Climate Change. Bonn, Germany. https://unfccc.int/resource/annualreport/

xvi. Zaidi, F., & Raheja, S. (2024, January 24). 5% rise in India's GHG emissions since 2016, driven by energy & industrial sectors. Retrieved August 29, 2024, from Down To Earth website: https://www.downtoearth.org.in/pollution/5-rise-in-india-s-ghg-emissions-since-2016-driven-by-energy-industrial-sectors-94076