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Analysing Trends in temperature and forecasting further change using quantitative techniques

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ABSTRACT: This project seeks to analyse changes in the average temperature of Delhi over a certain time period and explore potential correlations with various factors, including an increase in carbon emissions. The project will explore historical temperature records in Delhi using extensive data collection and statistical analysis to determine any identifiable trends or patterns. Additionally, it will look into the impact of human activities, like industrialization and urbanization, on carbon emissions and their potential contribution to rising temperatures in the region. By explaining these links, the research aims to enhance our understanding of climate change dynamics in urban areas and direct sustainable policy interventions for mitigating its negative effects.

KEYWORDS: Moving Average, time series, index numbers, descriptive statistics.

I. INTRODUCTION

This study aims to conduct a detailed analysis of the overall temperature change from 1990 to 2021 in Delhi, India, a city known for large temperature changes throughout the year due to its geographical location, urbanization, and environmental factors. Understanding the long-term temperature trends in Delhi is crucial for assessing the impact of climate change, informing urban planning decisions, and implementing effective mitigation strategies. To achieve this goal, the study will utilize various statistical techniques, including moving averages, time series using regression, and index numbers, to comprehensively understand the region's temperature changes over time. Understanding Delhi's long-term temperature patterns is crucial for evaluating the implications of the changing climate, formulating informed urban planning decisions, and implementing effective mitigation strategies. To achieve the aforementioned objective, the research will use a variety of statistical techniques, including moving averages, time series regression, and index numbers, to provide a comprehensive understanding of temperature variations in the region across time.

1. Moving Averages: Moving averages will be used to smooth out short-term variations in temperatures and detect underlying trends over time. By calculating moving averages for various time intervals (e.g., monthly, quarterly, yearly), the study will identify long-term temperature patterns and determine if average temperatures in Delhi have increased or decreased significantly. This research will help in determining the cause of temperature data trends and anomalies, as well as provide insights into regional climatic variability.

2. Time Series Analysis with Regression: To investigate the link between temperature and several explanatory variables, including seasonal changes, rates of urbanization, and greenhouse gas emissions, time series analysis with regression techniques will be used. To measure the influence of these factors on temperature variations and find any statistically significant correlations, regression models will be fitted to the temperature data. This analysis will make it feasible to evaluate the variables impacting Delhi's temperature variability and elucidate the variables influencing long-term temperature trends.

3. Index Numbers: To create composite indicators that depict temperature variations in relation to a base period, index numbers will be utilized. The study will evaluate the relative size and directionality of temperature changes by computing temperature indices for various time periods. Index numbers will make it easier to compare data and give a succinct overview of general temperature trends over time, facilitating interested parties to monitor temperature changes and evaluate the extent to which climate mitigation strategies are working. The analysis will entail gathering historical temperature readings for Delhi from credible sources such as meteorological agencies or climate research organizations. MS Excel will be used to organize, clean, and analyse the data. The research

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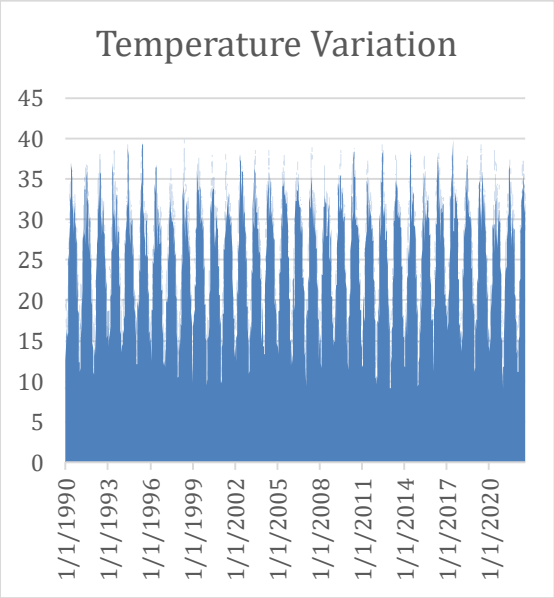
seeks to offer substantial insights into Delhi's longterm temperature changes and their determinants through this comprehensive examination.

Data:



https://1drv.ms/x/c/b0f932ad1bffab60/EVqLRpr2KvdMl4N4Bc8CTZEBfSl7AZTsXeZoWZcxle0gWg?e=J1ScqS

Here attached is the link and chart of the data that was found.
The dataset comprises daily temperature measurements spanning several decades to capture long-term temperature trends in Delhi accurately.

Temperature cyclical trends, such as seasonal variations or longer-term climate cycles, are periodic patterns or changes in temperature data across particular time spans. There are cyclical patterns in Delhi, where temperatures fluctuate regularly due to a variety of factors like solar radiation and atmospheric conditions.

The research will additionally take a look at how Delhi's average temperature has increased over time, exhibiting a long-term warming pattern that is consistent with global climate change. Moving averages and time series regression analysis are two statistical methods that will be used in this research to quantify and evaluate the rate of temperature increase. This study will gain a significant understanding of how Delhi's temperature trends are affected by climate change and assist in creating mitigation and adaptation strategies for this region.

Interpretation of Data Analysis:

I) Descriptive statistics

Descriptive stats	
Mean	24.99641525
Standard Error	0.067442364
Median	27
Mode	30.7
Standard Deviation	7.326115987
Sample Variance	53.67197545
Kurtosis	-1.028236116
Skewness	-0.367783049
Range	33.2
Minimum	6.6
Maximum	39.8
Sum	294957.7
Count	11800

The average temperature in Delhi is 24.99°C, indicating a moderately warm climate overall. The middle temperature, or median, stands at 27°C, slightly higher than the mean, hinting at a potential skew in the temperature distribution. The mode temperature, occurring most frequently, is 30.7°C, suggesting that hot temperatures are common in Delhi. Dispersion: With a standard deviation of 7.32°C, temperatures in Delhi vary considerably throughout the year. The temperature range spans 33.2°C, from a low of 6.6°C to a high of 39.8°C, indicating significant temperature differences. Distribution: A kurtosis value of -1.028 indicates a somewhat flattened distribution compared to a normal curve, with lighter tails. A skewness value of -0.367 suggests a slight negative skew, indicating more occurrences of higher temperatures. Variability: The coefficient of variation, at 29.31%, highlights substantial variability in Delhi's temperatures. In summary, these statistics portray Delhi as having a warm climate with significant temperature fluctuations. While hot temperatures are frequent, occasional cold spells are also observed, as evidenced by the low minimum temperature.
CV=29.30876

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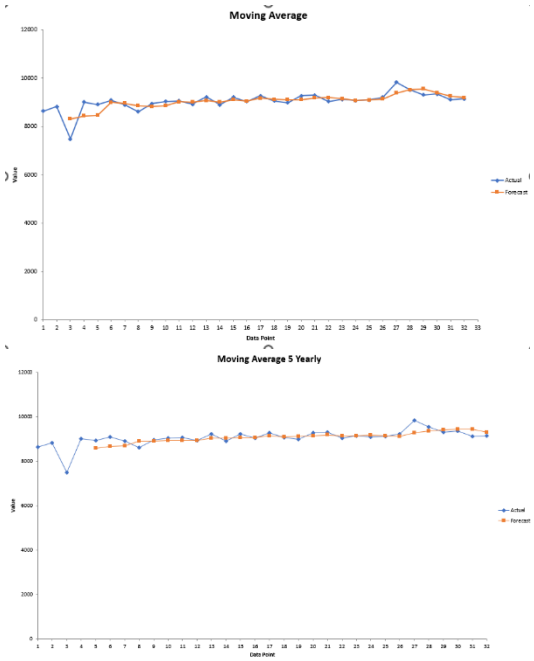
The coefficient of variation (CV) measures the relative variability of a dataset compared to its mean. A CV of 29% in daily temperature suggests that the daily temperature varies by approximately 29% of the mean temperature. And that the data is strongly consistent with steady increase in temperature.

II) Moving Averages



3-yearly and 5-yearly moving averages

The small but steady increase in these averages and its trend show us that the temperature in Delhi is consistent with the overall general trends of climate changes over a period of time. This pattern shows us that the average temperature is increasing and is probably due to issues like increasing carbon emissions and increased greenhouse gases trapped in the atmosphere cause a depletion of the ozone layer.

Here, while short term daily fluctuations are cause by factors such as directions of wind, clouds and general humidity levels, the long term changes remain consistent because of increased industrialization and increase in harmful gases such as CO2, Methane and many more.

This has implications for various aspects of the region's environment, economy, and society, including changes in weather patterns, impacts on agriculture and water resources, and potential risks to public health and infrastructure.

Further, the consistent rise in temperature tells us that we need to do something immediately to mitigate the effects of climate change and greenhouse gases. Suitable action at the local, national, and global level is necessary to avoid the same and the world governments should come together to do the same.

III) Time Series Using Regression

Here by taking the sum of average temperatures, we have used time series analysis through the least square or regression method.

Using excel we calculated the respective intercept and variables of x to end up at the equation:

Y=a+bX (a=9048.05, b=24.2878)….

The following equation helps us forecast and draw the average yearly temperatures by simply getting Y and dividing it by total number of days. This helps understand with a decent amount of accuracy that how the temperatures will look for the future years considering the same trend will be followed and no major changes will be made.

2021	9150.9	15.5	25.0709589
2022	9448.797984	16.5	25.88711776
2023	9473.08574	17.5	25.95365956
2024	9497.373497	18.5	26.02020136
2025	9521.661254	19.5	26.08674316
2026	9545.94901	20.5	26.15328496
2027	9570.236767	21.5	26.21982676
2028	9594.524523	22.5	26.28636856
2029	9618.81228	23.5	26.35291036
2030	9643.100037	24.5	26.41945216
2031	9667.387793	25.5	26.48599395
2032	9691.67555	26.5	26.55253575
2033	9715.963306	27.5	26.61907755
2034	9740.251063	28.5	26.68561935
2035	9764.53882	29.5	26.75216115
2036	9788.826576	30.5	26.81870295
2037	9813.114333	31.5	26.88524475
2038	9837.402089	32.5	26.95178655
2039	9861.689846	33.5	27.01832835
2040	9885.977603	34.5	27.08487014
2041	9910.265359	35.5	27.15141194
2042	9934.553116	36.5	27.21795374
2043	9958.840872	37.5	27.28449554
2044	9983.128629	38.5	27.35103734
2045	10007.41639	39.5	27.41757914
2046	10031.70414	40.5	27.48412094
2047	10055.9919	41.5	27.55066274
2048	10080.27966	42.5	27.61720454
2049	10104.56741	43.5	27.68374633
2050	10128.85517	44.5	27.75028813

Average temperature data till 2050

The data shows the average temperature to be steadily increasing through these predictions, showing an increase of a very high 2.7 degrees Celsius.
This goes with the general upward trend of rising temperatures across the globe, by the end of the century the average temperature of Delhi can go as

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high as by 5 degrees Celsius says a Times of India article. This is an alarming increase and should be addressed as soon as possible or it could be followed up by severe consequences.

IV) Index Numbers

Here, firstly we analyze monthly changes throughout the years using a chain base index numbers method. This method involves measuring relative change over a period of time.

By using chain base index numbers, we see certain changes from month to month in every year. This analysis helps to identify patterns, anomalies, and potential impacts of climate change on monthly temperature variations in the region.
Further, we used multiple different measures of finding an index number and getting one standards answer from all the methods used i.e:

…Index Number = 105.8815039…

The index number in the project above comes out to be approx. 105, which indicates that the temperature has increase by about 5% from the relative base value taken first. In simple words, the temperature in 2021 was approximately 5% higher than the one we measured in 1990.

This shows us that there is indeed a positive trend something that we determined in our previous analysis, but this tells us exactly by how much. A 5% increase in temperature may have various this 5% change has various implications, it shows us that there is a strong upward trend, which when measured in percentage may not sound a lot but is a change of about 1.3 degrees Celsius which is a lot for the temperature to change.

Overall, the index number of 105 provides a standard measure of relative change over time which helps us accurately compare data.

A 5% increase in temperature, as shown by the index number of 105 in the project, signifies a major shift with impacts in areas such as economic, social, humanitarian, and many more. This rise in temperature hampers eco-systems leads to health risks and damages a lot of the environment. Ecologically, it can impact bio-diversity, the working of systems, and vegetation, while economically, it can impact sectors of tourism, agriculture, and infrastructure. Public health concerns arise form an increase in health problems such as heat strokes and heart attacks due to increased temperature. Further, urban areas might experience more damage due to the urban island effect, which can worsen conditions considering the majority of the population abides in the same. Addressing the same requires collective efforts climate infrastructure, shift in energy sources, and finding sustainable ways to keep the world system going, only then we can avoid many risks and build resilience.

Limitations

One of the biggest limitations regarding data in the projects was to understand what will used as “quantity” while calculating index numbers, so for simplicity quantity is assumed to be number of days which remains constant through both the years but differs a little in every leap year produced. Also, due to other multiple factors playing a huge role in changes of weather, we can’t really pinpoint what changes are cause by what factors overtime and specially in the short-term, while we know there lies a correlation of increasing carbon emission and greenhouse gases in the atmosphere leading to increase in temperature but due to lack of accurate data present on the same we couldn’t calculate a correlation equation which the team was trying hard to do.

With the time series regression equation, we can calculate changes in temperature for the future too, but this is based on one major assumption that the trend or equation is set to be constant, it doesn’t factor into the changes that might take place in the future which is unpredictable to a large extent. The temperature can massively deviate from the predictions if there is strong climate action taken by the world governments or if climate condition worsens due to increase in carbon emission and greenhouse gasses to further power innovation and capitalistic growth.

II. Conclusion

Based on the analysis conducted, it is clear that there is a consistent rise of long-term temperature of Delhi with a 5% increase in the same from 1990 to 2021. This trend aligns with increased temperatures globally having impacts economically, environmentally, and socially.

Further ahead the temperature seems to be increasing by 2.7 degrees Celsius by 2050, further increasing the challenges faced. This expected increase in temperature highlights the necessity for change, including sustainable management of resources, climate-efficient infrastructure, and adaptations to protect potentially exposed ecosystems and communities.

Addressing these issues will require a local, national, and global push, to build strong resilience, avoid further damage, and decrease carbon emissions and exposure of greenhouse gases in the climate.

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