Analyzing Traffic Speed Variability During Peak and Off-Peak Hours in New York

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Abstract

Urban traffic congestion impacts daily life and economic productivity. This study analyzes traffic speeds in New York City during August and November, using skewness and kurtosis to assess variability and asymmetry. The findings provide insights for improving traffic management and urban mobility.

Keywords: Traffic Congestion, New York City, Peak Hours, Off-Peak Hours, Skewness, Kurtosis

Introduction

Urban traffic congestion is a pressing issue faced by cities around the world, significantly impacting both daily life and economic productivity. In order to address this challenge effectively, cities need not only to invest in infrastructural improvements but also to adopt sophisticated analytical tools to better understand and manage traffic dynamics. New York City, with its high population density and diverse commuting patterns, offers a unique opportunity to study the fluctuations in traffic conditions across different months and times of day.

This study focuses on comparing traffic patterns in two distinct months: August and November. These months reflect different aspects of city life, with August experiencing lighter traffic due to vacations and tourism, while November sees a return to regular work commutes. By analyzing the variations in traffic during these periods, the study aims to provide a detailed understanding of how different factors, such as tourism and regular commuting, influence traffic conditions.

Analysis of Traffic Speed Distribution in the City of New York

Understanding traffic speed distribution patterns and their differences under different conditions is one of the vital challenges for urban traffic management. With high and diverse traffic volumes and commuting patterns, New York City is an excellent place to study this phenomenon. This paper investigates the speed distribution of two different traffic periods, peak and off-peak hours, from two months, August and November. Some of the data collected were random samples of vehicle speeds, which were analyzed via different statistical approaches.

The fact that the distributions of the speeds of vehicles are typically asymmetric is relevant in terms of management since it has a direct influence on decisions in traffic control. Besides the Mean, Median, and Mode as primary parameters, two additional key indicators that are applied were Skewness and Kurtosis for examining distribution patterns more comprehensively in this study.

Skewness and Kurtosis Calculation

To gain a deeper understanding of traffic behavior, we analyze the distribution of traffic speeds using statistical metrics like Skewness and Kurtosis. Skewness measures the asymmetry of the traffic speed distribution, indicating whether traffic tends to be faster or slower than the average. Kurtosis assesses the "peakedness" of the distribution, highlighting the variability and presence of extreme values in traffic speeds. These metrics provide valuable insights beyond simple averages, helping us to better understand the traffic patterns during peak and off-peak hours."

Skewness is determined to examine the asymmetry of the distribution; it was calculated as follows:

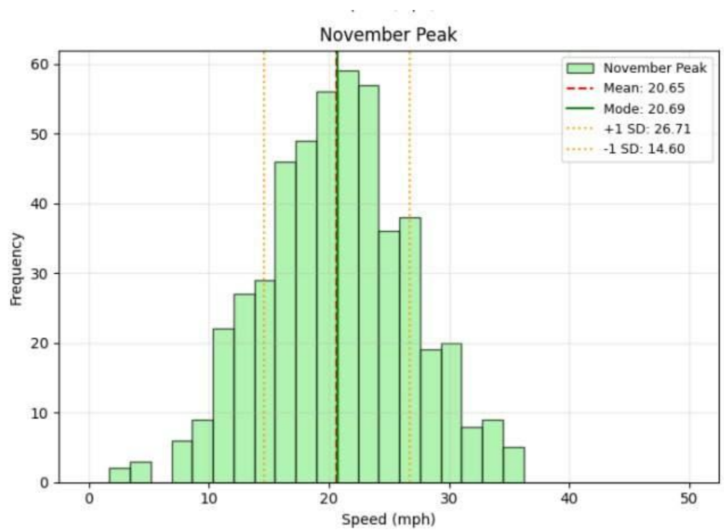
Karl Pearson's Coefficient of Skewness(1)

$$\mathbf{SK_p = \frac{Mean - Mode}{\sigma}}$$

SK_P = Karl Pearson's Coefficient of skewness

σ = standard deviation.

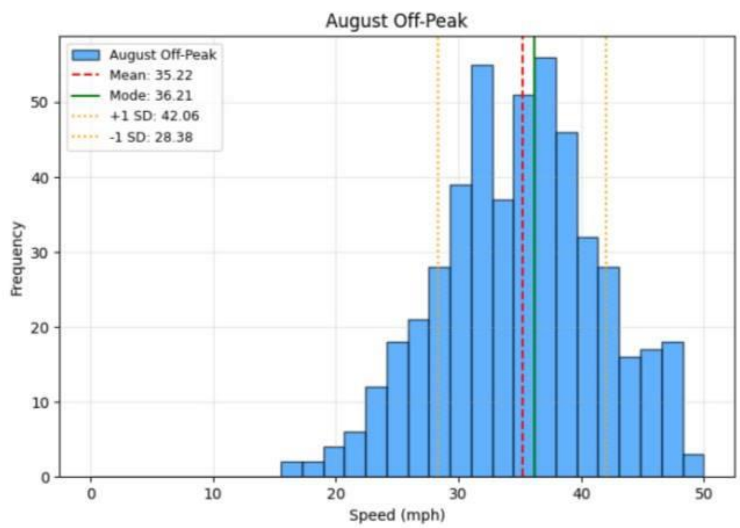
It helps to evaluate the skewness of data around the mean using the relationship between the mean median and mode.



- Mean (μ) = 20.65
- Mode = 20.69
- Standard Deviation(σ)= 26.71

$$\mathbf{SK_p = \frac{20.65 - 20.69}{26.71} = -0.0015}$$

Thus, the Skewness is -0.0015, which is negative, indicating a slightly left-skewed distribution.



- Mean = 35.22
- Mode = 36.21
- Standard Deviation(σ)= 42.06

$$\mathbf{SK_p = \frac{35.22 - 36.21}{42.06} = -0.0235}$$

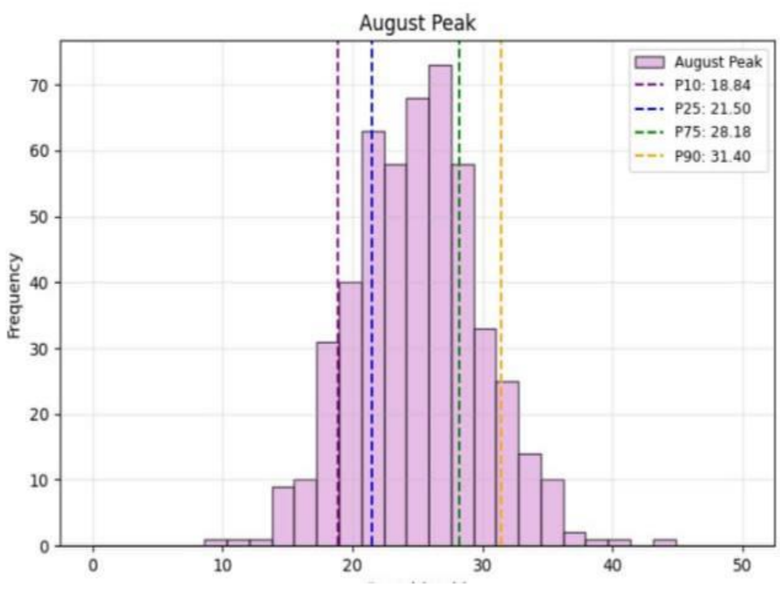
Thus, the Skewness is approximately -0.0235. This negative value indicates that the distribution is slightly left-skewed, although the value is very close to zero, suggesting the distribution is nearly symmetric.

For the Kurtosis, this formula was used:

Kelly's Measure of Kurtosis

$$\boldsymbol{\beta_2 = \frac{P_{75} - P_{25}}{P_{90} - P_{10}}}$$

Kelly has given a measure of Kurtosis based on percentiles

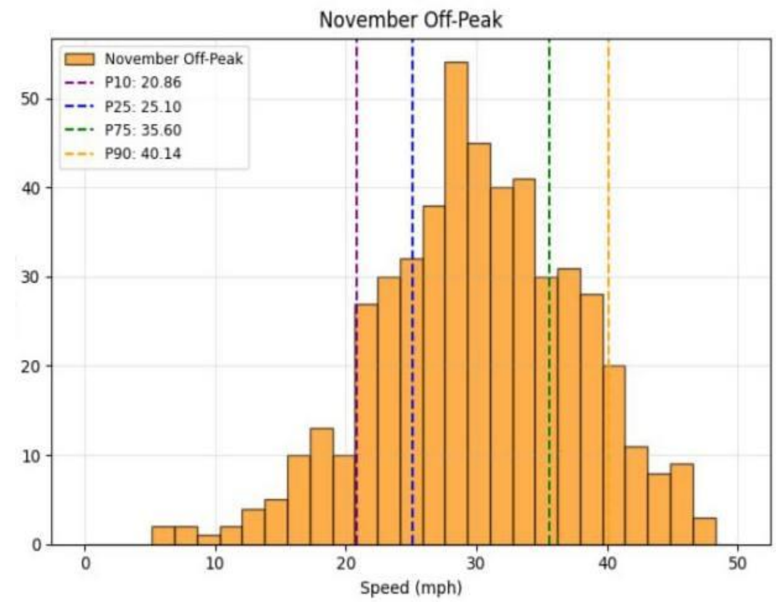


- **10th Percentile (P10): 18.84 mph**
- **25th Percentile (P25): 21.50 mph**
- **75th Percentile (P75): 28.18 mph**
- **90th Percentile (P90): 31.40 mph**

$$\boldsymbol{\beta_2 = \frac{28.18 - 21.50}{31.40 - 18.84} = 0.532}$$

The calculated value of $\beta 2$ is 0.532

Since $\beta 2$ is greater than 0.26315, the data distribution is classified as Platykurtic, meaning it has a flatter peak compared to a normal distribution.This indicates that the data has fewer extreme values and is less peaked, showing a wider spread of data around the center.



- **10th Percentile (P10): 20.86 mph**
- **25th Percentile (P25): 25.10 mph**
- **75th Percentile (P75): 35.60 mph**
- **90th Percentile (P90): 40.14 mph**

$$\boldsymbol{\beta_2 = \frac{35.60 - 25.10}{40.14 - 20.86} = 0.545}$$

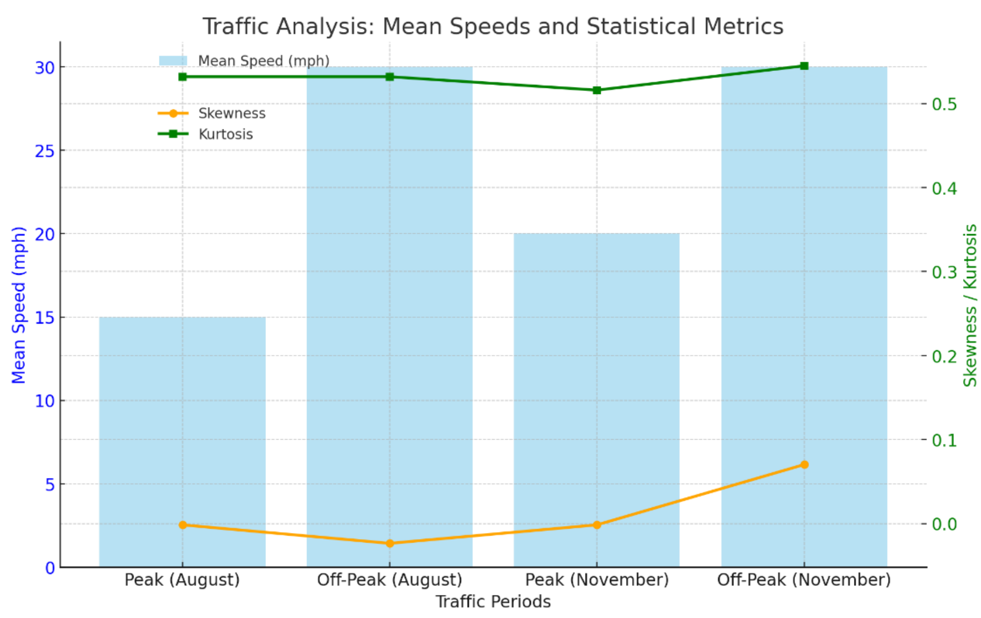
The value of β_2 is approximately 0.545.

Since β_2 is greater than 0.26315, the data distribution is classified as Platykurtic, meaning it has a flatter peak compared to a normal distribution. This suggests the distribution has fewer extreme values and a broader spread.

Results of Analysis & Management Applications

The analysis indicated that peak traffic hours in November have skewness less than 0 and kurtosis greater than 3, which shows that during peak traffic hours the vehicles are slower in November. In August, off-peak hours had more balanced distributions with less dispersion.

The following chart presents a comparison of mean speeds, skewness, and kurtosis across peak and off-peak hours for August and November. This visualization provides a comprehensive overview of traffic dynamics.



As shown in the chart, the Mean Speed during peak hours, especially in August, is significantly higher than during off-peak hours. However, the Skewness and Kurtosis values indicate that August Peak and November

Off-Peak have more consistent traffic flow, with Skewness values close to zero, suggesting nearly symmetric distributions.

On the other hand, the November Peak period exhibits higher Kurtosis, indicating a more peaked distribution, with traffic speeds concentrated around the mean. These patterns emphasize the varying traffic dynamics across different periods, with peak hours showing more variability and off-peak hours being more stable

These insights could help urban managers and policymakers implement more effective measures to alleviate congestion and enhance traffic flow

Impact of External Factors on Traffic

Aside from the time of day and month, external factors such as weather, public holidays, and special events can significantly impact traffic patterns. These factors can cause sudden shifts in traffic flow, making it difficult for city planners and traffic managers to accurately predict and control congestion.

Pleasant weather tends to increase traffic, while rainy or snowy conditions can reduce speeds due to slippery roads and poor visibility. This increases the risk of accidents, forcing drivers to adjust their speed and driving habits, which in turn causes more congestion. Similarly, fog or extreme heat can slow traffic as drivers reduce speed to drive safely.

Public holidays, like Christmas or New Year, also have a major effect on traffic volumes. During these times, many people travel for shopping or to visit family, leading to a spike in traffic, especially on major travel routes or in tourist-heavy areas. This surge is particularly noticeable in the days leading up to long weekends or national holidays.

Special events such as concerts, sports games, or festivals further disrupt traffic patterns. A large event can attract thousands of people to a specific area at once, overwhelming local roads and transit systems, causing bottlenecks and delays. To manage these traffic spikes, cities often implement street closures and adjust public transit services.

Therefore, effective traffic management requires taking these external factors into account. Traffic managers can use real-time data, dynamic traffic signals, and predictive analytics to respond to changes. By integrating weather forecasts, event schedules, and holiday patterns, cities can ensure smoother traffic flow and reduce congestion during high-impact times, ultimately improving the commuting experience for all.

Conclusion

Traffic analysis in New York City during peak and off-peak hours using statistical measures like skewness and kurtosis highlights key differences in traffic speed distributions. The most significant finding is the differential nature of traffic behavior during these periods. During peak hours, a positive skewness was observed, indicating more congestion as most drivers travel at lower speeds, while fewer drivers maintain higher speeds. Conversely, off-peak periods showed tighter, more consistent traffic flow around the mean.

Skewness and kurtosis metrics provided deeper insights into traffic patterns, with higher congestion during peak times and greater consistency during off-peak hours. These findings can help improve road network efficiency and reduce congestion.

Practical recommendations include optimizing traffic signals, improving public transit systems, and encouraging the use of alternative routes. Intelligent signage and driver information systems can also enhance trip planning and reduce delays.

This study demonstrates how statistical analysis of traffic data can identify complex patterns and lead to realistic solutions. Further research incorporating additional parameters like vehicle types and public transport usage can offer even deeper insights. Cities, like New York, can use such data-driven approaches to develop smarter, sustainable transportation systems, ultimately improving quality of life and saving time, energy, and resources.

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