

Public Transportation Ridership Trends

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Abstract

This project examines urban mobility through the lens of three significant research questions: (1) How does the time of day affect traffic patterns? (2) How has public transportation usage changed post-COVID-19? and (3) What are the peak traffic hours on weekdays versus weekends, and how do they differ? By analyzing traffic and public transit datasets, this study identifies critical trends in daily traffic dynamics, evaluates the pandemic's effects on transit ridership, and explores the contrasts between weekday and weekend travel behaviors. The findings offer practical insights into improving traffic management and public transportation systems.

Keywords: traffic patterns, regression analysis, public transportation, COVID-19, ridership trends, urban mobility, machine learning

Introduction

Understanding traffic patterns and public transportation trends is essential for optimizing urban mobility and addressing challenges such as congestion, pollution, and accessibility. The COVID-19 pandemic introduced significant disruptions to traditional mobility patterns, making it even more critical to evaluate both historical and contemporary trends. This study investigates three questions:

- 1) How does the time-of-day influence traffic patterns?
- 2) How has public transportation ridership evolved in the wake of COVID-19?
- 3) What are the key differences between weekday and weekend traffic peaks?

Using comprehensive datasets, this report analyzes traffic volume data from Minneapolis-St. Paul and public transit ridership data spanning pre-, during-, and post-pandemic periods. These analyses aim to uncover actionable insights for traffic management, transit planning, and urban policy development.

Datasets

Both datasets are publicly available, reliable, and widely used in academic studies of urban mobility.

- **Traffic Volume Dataset:** Sourced from the UCI Machine Learning Repository, this dataset contains hourly traffic volume data for westbound I-94 in Minneapolis-St. Paul from 2012 to 2018.
- **Public Transit Ridership Dataset:** Extracted from the Filtered Monthly Ridership dataset, covering January 2019 to December 2023. This dataset provides monthly ridership data for various U.S. transit agencies and modes of transit.

Character of the Datasets

- **Traffic Dataset:**

- 48,204 rows and 9 columns.
- Features include hour, weekday, holiday, temp, and traffic_volume.
- Preprocessed to add is_holiday and normalized continuous variables such as temperature and precipitation.
- Public Transit Dataset:
 - 2,313 rows and 65 columns.
 - Key columns: Agency, Mode, Monthly Ridership.
 - Aggregated monthly ridership across all agencies to evaluate national trends.

Methodology

Traffic Analysis

To analyze traffic patterns, two regression models were employed:

- Linear Regression: Suitable for identifying linear relationships but less effective for capturing non-linear dynamics in traffic.
- Random Forest Regressor: A tree-based ensemble model that effectively captured non-linear patterns and provided the best performance with $R^2 = 0.94$.

Public Transit Analysis

Ridership data was divided into three periods to assess the pandemic's impact:

- Pre-COVID (2019): Baseline ridership patterns.
- During COVID (2020-2021): Sharp declines due to lockdowns and restricted mobility.
- Post-COVID (2022-2023): Gradual recovery as restrictions eased and mobility resumed.

Python libraries such as Pandas and Matplotlib were used for data aggregation, visualization, and analysis. Monthly ridership data was summed across agencies to identify overarching trends.

Evaluation Metrics

Traffic Models: Mean Squared Error (MSE) and R^2 to measure accuracy and model fit.

Transit Analysis: Comparison of total ridership across the three defined periods.

Results

Traffic Volume by Time of Day

Traffic volume displayed predictable peaks during morning (7-9 AM) and evening (4-6 PM) rush hours on weekdays. Weekends exhibited a flatter distribution, with a midday peak around 12:00 PM. The Random Forest model captured these patterns effectively, achieving an MSE of 217,955 and R^2 of 0.94. These results underscore the consistent influence of daily routines on traffic patterns.

Weekdays vs. Weekends

Weekdays:

- Peak hour: 4:00 PM (16:00).
- Average traffic volume: 6,189 vehicles/hour.

Weekends:

- Peak hour: 12:00 PM (noon).
- Average traffic volume: 4,372 vehicles/hour.

The sharper peaks on weekdays highlight the structured nature of commuting patterns, while weekend traffic reflects more varied travel purposes, such as leisure or errands.

Public Transit Ridership Trends

- Pre-COVID (2019): Stable seasonal ridership patterns with minor fluctuations.
- During COVID (2020-2021): Ridership plummeted, with the steepest drop in March and April 2020 during the initial lockdowns. Recovery was slow and uneven, with lingering effects of reduced mobility and service adjustments.
- Post-COVID (2022-2023): Ridership began recovering in mid-2022, surpassing 2020 levels. Recovery trends varied by city and transit mode, reflecting regional differences in mobility and public health policies.

Visualization Highlights

Line graphs comparing weekday and weekend traffic revealed sharper weekday peaks.

Bar charts illustrating total ridership across pre-, during-, and post-COVID periods emphasized the pandemic's impact and gradual recovery.

Discussion

This analysis demonstrates the complex interplay of time, weather, and external events like COVID-19 in shaping urban mobility. Weekday traffic, driven by structured commuting routines, exhibited sharp peaks during morning and evening hours, while weekend traffic patterns were more evenly distributed. Public transit ridership faced unprecedented disruptions during the pandemic but showed promising recovery trends in the post-pandemic period.

Limitations:

- The traffic dataset is limited to a single highway, which may not represent broader urban traffic patterns.
- The transit dataset aggregates national data, potentially masking city-specific variations.
- The analysis did not include demographic factors like income or car ownership, which could provide deeper insights.

Future Research:

- Incorporate demographic and geographic data to explore how socioeconomic factors influence mobility.
- Extend the study to include multiple cities for a more comprehensive understanding of urban traffic and transit trends.
- Analyze the effects of emerging trends like remote work and electric vehicle adoption on mobility patterns.

Conclusion

This project provides key insights into traffic and transit trends, emphasizing the importance of time-of-day effects, pandemic-induced disruptions, and weekday-versus-weekend differences in urban mobility. Key findings include:

- Morning and evening rush hours dominate weekday traffic, highlighting opportunities for targeted congestion mitigation strategies.
- Public transit ridership faced severe declines during COVID-19, but post-pandemic recovery indicates resilience in urban transit systems.
- Weekend traffic patterns reflect diverse travel behaviors, suggesting potential for tailored transit services.

These results can inform smarter urban planning and more adaptive transportation policies. Addressing the limitations of this study, such as expanding to multiple cities and including demographic data, would enhance future analyses and provide even greater value for improving urban mobility systems.