Documentation – Group 102

Parking Analysis

CIP-Project FS2025

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1 Introduction

The parking situation in cities is a recurring problem that drivers face on a daily basis. Particularly in densely populated areas like Zurich, parking availability can fluctuate significantly. A better understanding of these patterns can help make more informed decisions when searching for parking or predicting future availability.

This project investigates parking availability in Zurich using real-time and historical data. The goal is to identify patterns and trends influenced by various factors such as time of day, seasonal variations, and weather conditions. By analyzing these influences, valuable insights can be gained that assist both city administrations and drivers in optimizing parking strategies and decision-making.

To explore trends in parking availability in Zurich, this project focuses on the following key research questions:

- How does parking availability in Zurich change throughout the day, the week, and the seasons?
- How does the average parking availability in Zurich compare to that in Basel?
- What is the relationship between weather conditions and parking availability in Zurich?

Answering these questions will provide insights into the dynamics of parking usage and reveal potential patterns in availability.

2 Methods

This chapter describes the data sources, the data acquisition process, as well as the cleaning and transformation of the data. Additionally, the second part addresses the analysis methods used..

2.1 Sources and Transformation

The Parkendd API provides information on parking availability in Zurich. This API offers detailed data on various parking garages in Zurich, including the number of available spaces, the total number of spaces, and temporal changes in occupancy. Both current and historical occupancy data can be retrieved via the API. To include trends and seasonality in the analysis, data for the entire year 2024 was collected. However, the API only allows the retrieval of data in intervals of up to seven days. To analyze a full year of parking data, multiple requests were made over an extended period, and the collected data was systematically stored for further analysis.

Basel was chosen for comparison with another Swiss city. Like Zurich, Basel is an important economic center with a high density of workplaces. Both cities are heavily influenced by commuter and shopping traffic and exhibit similar commuting patterns. This comparable traffic structure was documented, for example, in the "Urban Mobility Comparison 2021," which showed that Zurich and Basel have similar patterns in terms of modal split, use of transportation modes, and urban mobility burdens (City of Zurich, 2023). Basel's parking data was obtained from the City of Basel's Open Data portal and downloaded as a CSV file.

The parking garage data from Zurich was enhanced with timestamps, time of day, weekdays, and seasons. Additionally, daily and hourly averages were calculated. The data was segmented into categories such as working vs. off-peak hours and weekdays vs. weekends to optimally prepare for answering the research questions. Data cleaning included handling missing or incorrect values (e.g., negative numbers), which were replaced using forward fill. Parking garages near exhibition centers were excluded, as their occupancy is highly event-dependent and they tend to show an above-average number of available spaces throughout the year. The Basel parking data was processed in a similar manner.

In addition, weather data was collected from the Wunderground platform using web scraping. A dedicated scraper was developed for each city to collect daily information for the year 2024. The results were automatically stored in CSV files. The extracted weather data included, among other things, daily average temperature, maximum wind speed, and air pressure. Before further processing, temperature values were converted from Fahrenheit to Celsius.

2.2 Analysis Methods

For the analysis of Zurich's parking garage data, the data was first aggregated using pandas by grouping values per parking garage (grouped by lot_id and lot_name) and calculating the average number of available parking spaces.

The results were then visualized in a sorted bar chart using seaborn (sns.barplot) and matplotlib, with additional elements such as gridlines added to improve readability. In addition, a time series analysis was conducted. A line chart visualizes the progression of daily average values over the year 2024. The goal was to identify trends or notable anomalies, such as unexpected low values at certain points in time.

The second part of the analysis investigates the extent to which weather affects parking availability in Zurich. First, the weather data (e.g., daily average temperature) was merged with the daily parking data based on the date. Using SciPy, the Pearson correlation coefficient was then calculated to quantify the statistical relationship between temperature and the number of available parking spaces. To visualize this relationship, a scatter plot with an overlaid regression model (created with seaborn's regplot) was used, which illustrates both the graphical and statistical connection between the two variables.

For the comparison between Zurich and Basel, the daily average number of available parking spaces was aggregated for both cities. For visual representation, a dual line chart was created using plotly.graph_objects, displaying both time series on a shared timeline. Additionally, a scatter plot with a regression line (via seaborn regplot) was created to examine the linear relationship between the daily averages of both cities. Again, the Pearson correlation coefficient was calculated using SciPy to statistically validate the strength of the relationship.

3 Discussion of the Results

This chapter addresses the individual research questions and discusses the corresponding analyses and results.

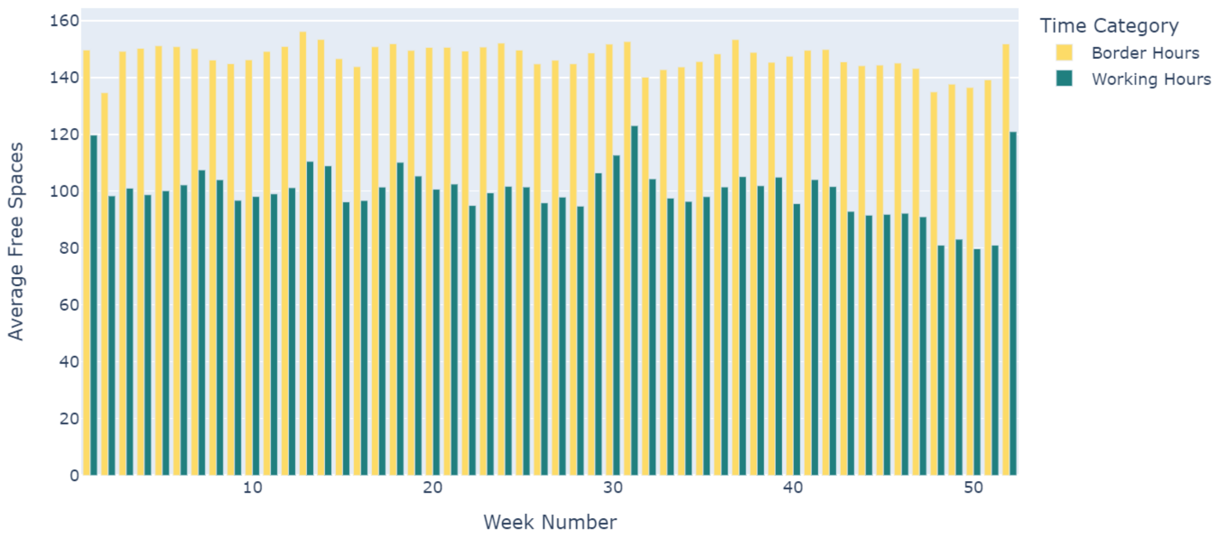
3.1 Research Question 1: How does parking availability in Zurich change throughout the day, the week, and the seasons?

The analysis clearly reveals structured temporal patterns. The daily time series plot, for example, shows significant fluctuations throughout the year. Apart from a distinct low point at the beginning of the year, the fluctuations appear to follow a regular pattern. Toward the end of the year, the average number of available parking spaces decreases. This could be due to the Christmas season and the associated markets and increased shopping tourism.

An analysis of the difference between weekends and weekdays revealed that, on average, more free parking spaces are available on weekends than on weekdays. The median number of free parking spaces is slightly below 100 on weekdays and slightly above 100 on weekends. This can be explained by higher occupancy due to commuter traffic during the workweek.

A more compelling picture emerges when comparing working hours and off-peak hours. The grouped bar chart, which distinguishes available parking during working hours (08:00–18:00) from border hours (all other times), illustrates the fluctuations throughout the day. This chart confirms that significantly fewer parking spaces are available during working hours compared to times outside of this core period.

Figure 1: Working vs border hours - average free spaces



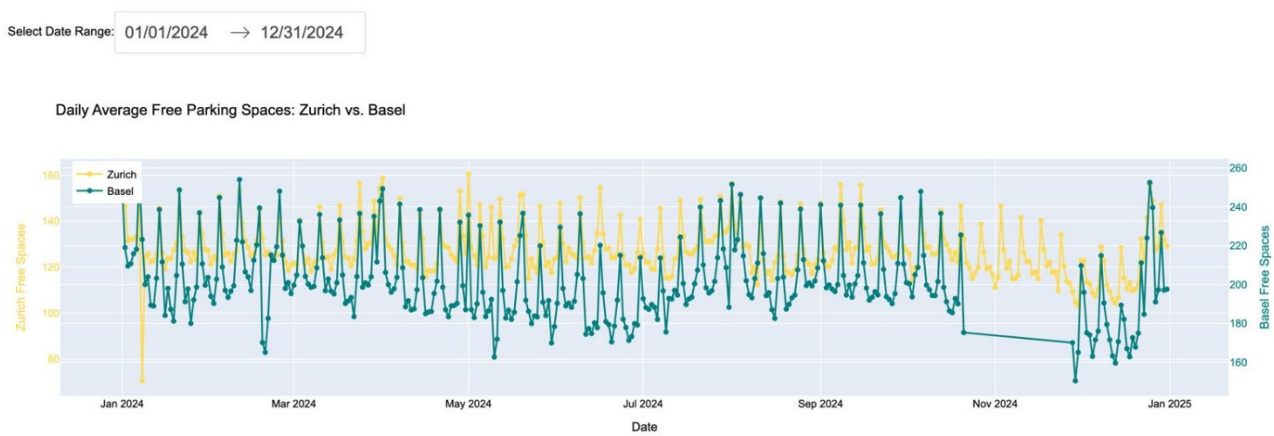
An additional analysis was conducted to determine whether parking availability varies significantly between seasons. The evaluation showed no significant differences. However, it was observed that during the autumn months (September to November), the average number of available parking spaces was slightly lower than in other seasons. Possible reasons for this could include more frequent events, wet weather conditions, or changes in the public transport network that may have led to increased car usage. It is important to note that only data from the year 2024 was considered. Therefore, no generalizable statements about seasonal fluctuations can be made.

Overall, the findings present a coherent picture. Both the time of day and the day of the week have an impact on parking availability in Zurich. The various visualizations illustrate that peak demand is mainly concentrated during core working hours on weekdays.

3.2 Research Question 2: How does the average parking availability in Zurich compare to that in Basel?

For the comparison between Zurich and Basel, the daily average of available parking spaces in both cities was first calculated and then compared in an interactive dashboard.

Figure 2: Interactive Dashboard with Average free parking spaces in Zurich and Basel



This plot shows that the trends in both cities are nearly synchronous, with high and low occupancy observed on the same days. These synchronized patterns suggest that comparable external factors—such as weekday patterns, holiday periods, or seasonal fluctuations—have a similar impact on parking availability in both cities.

To further examine the relationship between the daily average values of both cities, a scatter plot with an overlaid regression line was created.

The calculation of the Pearson correlation coefficient resulted in a value of $r = 0.78$ with a p-value of < 0.001. This statistically highly significant correlation indicates a moderate to strong positive relationship. In other words, days with high parking availability in Zurich tend to coincide with similarly high availability in Basel. This implies that both cities exhibit comparable traffic and mobility patterns.

Despite possible city-specific characteristics, the synchronous trends and high correlation coefficient clearly show that external factors such as holidays, weekly usage patterns, or seasonal effects influence both cities in a similar way. Overall, the analyses conducted support the conclusion that mobility patterns in Zurich and Basel are closely linked in terms of parking availability.

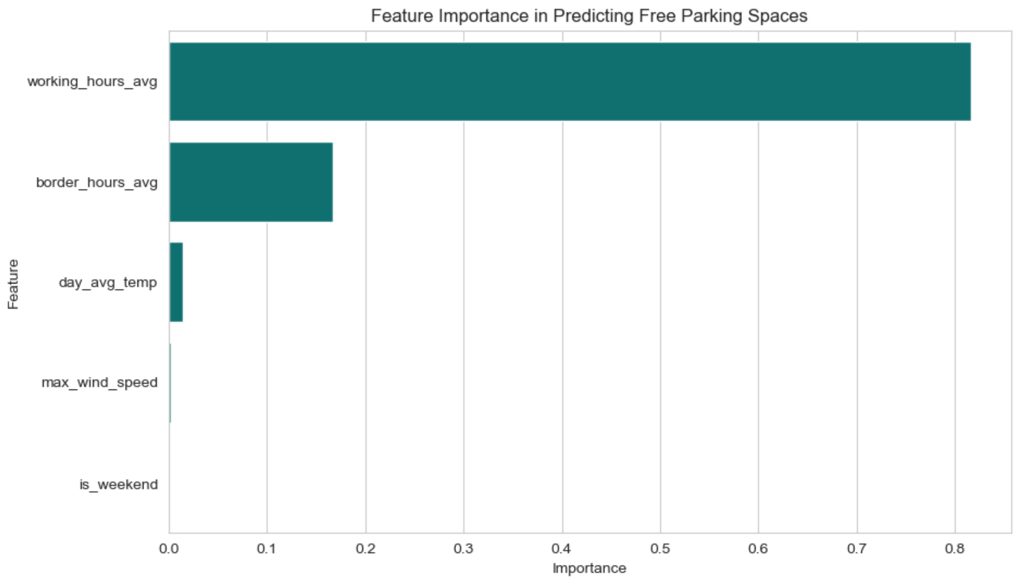
3.3 Research Question 3: What is the relationship between weather conditions and parking availability in Zurich?

To investigate the influence of weather conditions on parking availability in Zurich, daily average temperatures were linked to the daily measured average values of available parking spaces. For this purpose, the corresponding datasets were merged based on the date. A scatter plot with an overlaid regression line revealed that higher temperatures tend to be associated with a slightly increased number of available parking spaces. This is supported by the calculated Pearson correlation coefficient, which yielded a value of $r = 0.12$ with a p-value of 0.024. Although this relationship is statistically significant, the low correlation value indicates that temperature alone has only a minor impact.

Additionally, the variability in parking availability was examined. The standard deviation of the daily average values was 11.26. This relatively high dispersion suggests that, in addition to temperature, other factors have a significant influence on parking availability.

To quantify the impact of the previously analyzed features on parking availability, predictive models were included in the analysis. The feature importance analysis of the random forest model showed that time-related features (such as availability during "Working Hours" and "Border Hours") have a significantly higher influence than temperature.

Figure 3: Feature Importance in predicting free parking spaces



Overall, this suggests that while there is a slight positive correlation between higher temperatures and somewhat improved parking availability in Zurich, the impact of temperature plays only a subordinate role compared to other factors.

4 Conclusion, Limitation, Outlook

The results of the study provide a nuanced picture of parking availability in Zurich. Overall, it becomes clear that availability in the city follows systematic temporal patterns. For example, the analysis shows that occupancy is significantly higher during core weekday hours ("Working Hours") than during off-peak hours and weekends. The comparison with Basel further highlights that both cities exhibit nearly synchronous trends, suggesting similar mobility and traffic conditions. At the same time, the analysis of weather conditions reveals a slight, though only minor, positive correlation between higher temperatures and improved parking availability. However, it is also evident that time-related features have a much greater influence on parking availability.

Despite the meaningful findings, some limitations of this analysis must be considered. First, the analysis is based solely on data from the year 2024, which is a limitation particularly in terms of seasonal fluctuations. For instance, it cannot be determined with certainty whether the lower availability observed during the autumn months (September to November) is a lasting seasonal effect or merely a one-year phenomenon. A multi-year comparison would be necessary to make robust statements about seasonal trends. Moreover, other influencing factors such as daily traffic volumes, construction sites, or large events were not included in the present analysis.

For future work, it would therefore be beneficial to select a longer observation period and integrate additional variables into the analyses. In addition, the development of a predictive model using advanced machine learning methods could help not only to gain retrospective insights but also to generate forecasts of future parking availability. A continuously updated real-time visualization via a publicly accessible dashboard would be another step forward, offering significant practical value to both city decision-makers and citizens.

5 Sources

Stadt Zürich. (2023). *Städtevergleich Mobilität 2021: Benchmarking der Mobilität in den sechs grössten Deutschschweizer Städten*. Stadtentwicklung Zürich. https://www.stadt-zuerich.ch/de/aktuell/publikationen/2023/staedtevergleich-mobilitaet-2021.html

Open Data Zürich. (o. J.). *Parkendd API – Parkplatzbelegung Zürich*. https://opendatazurich.github.io/parkendd-api/

The Weather Company. (o. J.). *Weather history for Zurich Airport (LSZH)*. Wunderground. https://www.wunderground.com/history/daily/ch/zurich/LSZH/date

Kanton Basel-Stadt. (o. J.). *Parkhausbelegung Basel – Open Government Data*. https://data.bs.ch/