Tübingen on Two Wheels: Profile a Typical Cyclist

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Abstract

Profiling a typical cyclist, bike counter data was examined considering the factors weather, fuel prices, and events through visual analysis and correlations. An increasing trend of cyclists, influences from holidays, school breaks, and weekends were identified. Rush hours were found, indicating a strong connection to educational or work commitments. While weather showed minor effects, no connection to fuel prices could be noted.

Figure 1. Locations of the counter stations Hirschau (orange), Steinlachallee (blue), and Fahrradtunnel (red), the "Neckartalradweg" (dark blue line) and city center (purple area).

1. Introduction

When does one prefer riding their bike over other means of transportation? On the way to work? Fun or fitness on the weekends? Which factors might change one's motivation? By creating a profile of the typical cyclist living around the city of Tübingen (Germany) this study attempts to investigate possible factors influencing bicycle usage.

Tübingen currently has a population of 91 249. It would be interesting to see, what part of the population most likely uses their bikes based on bike counters (Universitätsstadt Tübingen, 2024). The location of Tübingen was chosen due to its current investment into bicycle infrastructure (Stadtwerke Tübingen, n.d.; Universitätsstadt Tübingen, n.d.c). A dedicated bike lane network, including heated bike bridges, is planned to lead throughout most of the city and connect to neighboring towns (Universitätsstadt Tübingen, n.d.b;n).

Working with data from bike counting stations similar to those in Tübingen, previous studies have found significant impacts of weather regarding bicycle use (Flynn et al., 2012; Schmiedeskamp & Zhao, 2016). Another paper separated counter locations depending on their typical usage: entertainment or practical (Nosal & Miranda-Moreno, 2014). Since none of these studies took place in Europe, the current work is novel and extends possible factors through further context.

In this study we aim to create a profile of the general cyclist based in or around Tübingen. Three bike counting stations in Tübingen allow for investigation of patterns ranging from hourly to annually (Figure 1). Additional factors considered are events, weather, and fuel prices. Events and holidays are used to clearly differentiate between free-time activities and educational or work commitments. Weather is considered through temperature, precipitation, days with potential black ice build up and days with extreme conditions. Changes in fuel prices, especially out of the ordinary situations such as the war in Ukraine and the "Spritpreisbremse" are looked into. The relations between these factors are explored through visual analysis, seasonal decomposition and correlation calculations as explained in Section 2.

Conclusions include a differentiation of bike counters depending on their distance to the city center. Better weather, especially during summer, seems to lead to more bike counts, even more so outside the city. In winter a consistent number of cyclists stay true to their bikes, presumably to get to work, school or university. In case of the fuel price investigation, no clear conclusion can be drawn.

All analysis can be viewed, retraced and reproduced on Github: https://github.com/SATHDKTT/data literacy-project

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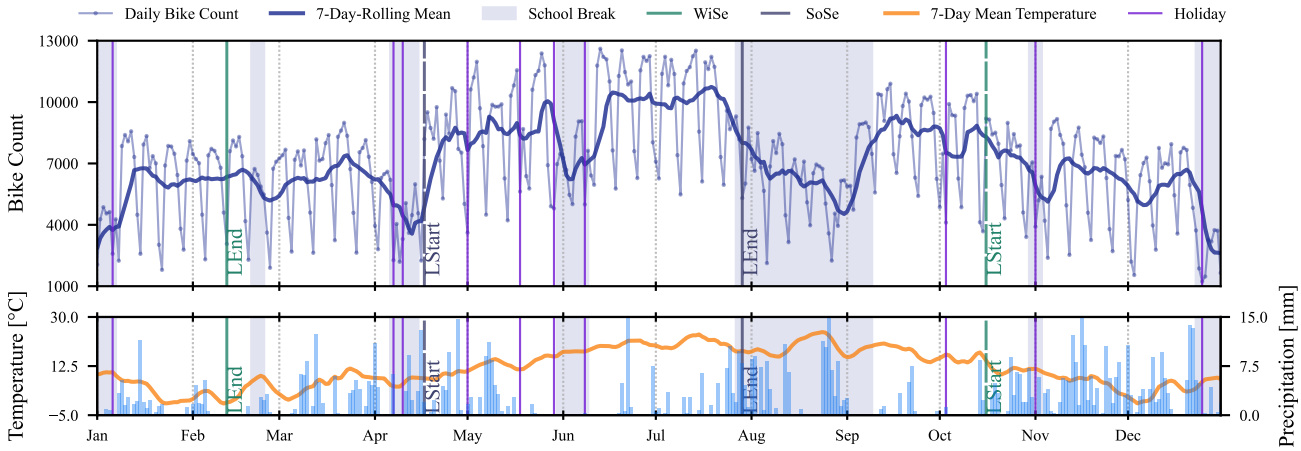

Figure 2. Daily bike counts at SC in 2023. Daily bike count data over the year is shown, providing an average mean window to show the smoothed trend. Holidays, school breaks and lecture period start (LStart) and ends (LEnd) are depicted. In the bottom of the figure the seven-day mean of temperature and daily precipitation are shown and can be compared to the top.

2. Data and Methods

The used data ranges from 2014 to 2023 and was gathered in four distinct data sets: bike data, weather data, fuel price data and an event log.

The **Bike Dataset** contains records of cyclists riding over induction loops placed underground. Since 2013 three counter stations have been set up at Steinlachalle (SC), Fahrradtunnel (FC) and in Hirschau (HC), which are marked in Figure 1. Data collected by Eco-Counter for Baden-Württemberg can be downloaded as CSV-files through MobiData BW (Eco-Counter, n.d.). For SC and FC data from 2014 to 2023 was used, HC was added in 2016, resulting in 484 662 total rows for the prepared data.

The initial exploratory analysis, as visualized in Figure 2 involved extracting relevant information for Tübingen. The final data includes timestamp information of the hourly recordings, count of cyclists per hour, cycling direction and counter information. New cycling direction entries per counter were observed since 2020, which led to correspondence with the city administration. They confirmed that this was due to upgrades of the counter stations, installing additional induction loops to better cover the pathways. Furthermore, it was validated that e-scooters do not get counted. Days with no recorded cyclists were verified to be caused by maintenances or malfunctions. Therefore, such days were removed from the dataset.

An **Event Log** was created collecting information on events and holidays from 2014 to 2023, which might impact bike traffic (Feiertagskalendar, 2024; Eberhard Karls Universität Tübingen, n.d.; Die Bundesregierung, 2022; Eberhard Karls Universität Tübingen, 2023). It can be found under evd.

To examine the bike data annually, the total and mean bike counts per day were considered for years and counters separately including events. The rolling seven-day mean was included to find trends over the weeks of a year. To further specify the impact of holidays, the mean counts for holidays and non-holidays were compared per work day and counter.

Seasonal decomposition was used to consider at trends, seasonal patterns and residual information (statsmodels, 2024). This was done by applying windows of 365 and seven days for all counters separately. To compare the similarities between decomposed bike counter data, correlation was calculated between two counters at a time for both the yearly and weekly window (SciPy, n.d.). Concluding from the results, FC and SC were combined and denoted as FSC for the remainder of this study to compensate counter downtime.

Further investigating the weekly patterns from the seasonal decomposition, the mean and standard deviations of cyclists were computed for FSC and HC per weekday. To better understand seasonal differences, the data was partitioned into meteorological summer and winter.

Breaking the data further down into days for FSC and HC, the hourly direction counts of cyclists were examined per weekday, separately.

Weather Data is provided by Meteoblue, which supplies hourly weather estimations using local weather stations (Meteoblue, 2024). The statistics timestamp, temperature (°C), precipitation (mm/m^2) and snowfall (cm/m^2) are used. The data from 2014 to 2023 totals at 87 649 rows.

To investigate possible relations between weather and cyclists, correlations were calculated with FSC. HC was not inspected, since connections with free-time bicycle use were

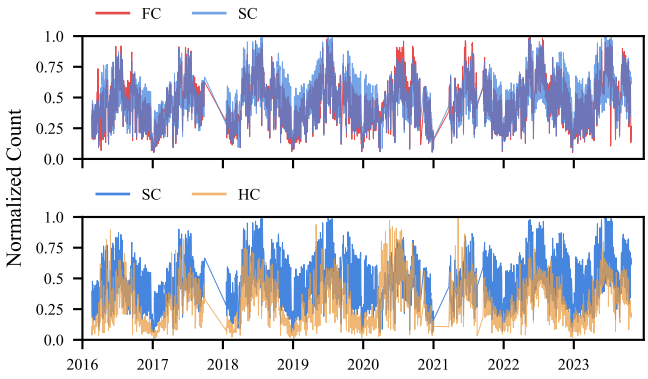

Figure 3. Correlation between FC and SC (top) and SC and HC (bottom) counters. Overlay of normalized daily counts since 2016.

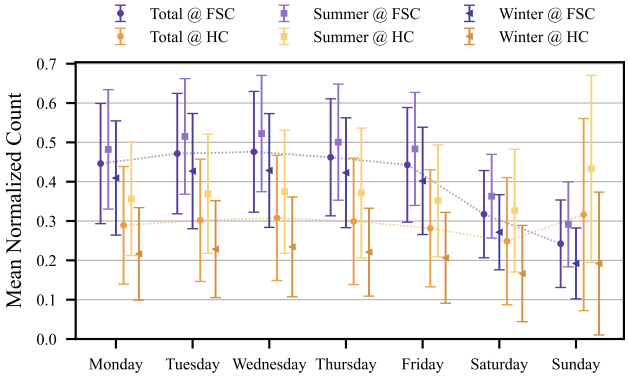

Figure 4. Seasonal comparison of normalized FSC and HC for all years. Mean and standard deviation are depicted per weekday.

deemed sufficiently examined. Due the likelihood of nighttime temperature drops, only data points from 6 am to 6 pm were analyzed. Weather correlation was looked into considering all data points and limiting them to days with extreme weather conditions. The latter were defined as the top five percent of hottest, coldest, and wettest days. Days with potential black ice formation were marked based on nighttime precipitation combined with sub-zero temperatures.

Fuel Price Data was obtained from Tankerkönig, which provides hourly information for gas stations in Germany (Tankerkönig, n.d.). CSV-file downloads are available for the years 2015 to 2023. Prices of gas stations within a three kilometer radius around Tübingen were averaged. The resulting data includes hourly timestamps and petrol prices, summing up to 83 871 rows.

Investigating fuel prices was done by exploring potential correlations with bike counter data. Initially, daily bike counts were compared to daily fuel prices. This was done with time shifts up to 14 days, taking into account the time necessary to use up fuel. Afterwards, to account for longer effects, the two-week average was calculated, since fuel prices don't rapidly change. Correlation with average two-week bike data was then examined. To reduce effects of seasonality identified during bike and weather analysis, the decomposed bike data was compared to fuel price data. Finally, to check for relations between specific parts of decomposed data, bike counter and fuel price data trends, seasonality and residuals respectively were computed and correlation between them calculated.

Extreme changes in fuel prices were investigated for 2020 specifically, taking into account the war in Ukraine and the "Spritpreisbremse", comparing bike count mean and standard deviation before, during and after an event.

3. Results

A pattern as depicted in Figure 2 can be found throughout all years in eva_1_CounterAnalysis. Weekly trends observed through the seven-day rolling mean are included as well as increased cyclists during summer. Declines aligning with holidays and school breaks can also be seen.

An increase in cyclists over all years is shown in the trend of the seasonal decomposition in eval_2_TrendAnalysis. The seasonal component aligns with the previously noted annual pattern.

Figure 3 displays comparisons between counters. High overlap can be noted for FC and SC, consistent with the calculated correlation resulting in 0.914. Considering this observation, the counters were averaged together as FSC. HC is shifted downward in relation to FSC and has comparatively higher counts during summer.

In line with the previously identified pattern, Figure 4 shows increased cyclist counts during summer. For FSC, work days show higher bike counts than weekends. In contrast, at HC, the opposite can be seen, especially on Sunday. This is accompanied with a more pronounced difference between increased counts during summer compared to winter.

Regarding the hourly cycle directions depicted per weekday in Figure 5 consistent structures can be seen. Work days show peaks of counts during morning and afternoon hours. For Fridays the last peak is less distinct. Crossing points of the directional counts occur in the morning and at noon. Weekends show fewer counts, are less homogeneously structured with only one peak per day and exhibit scattered crossing points.

In the weather analysis, which can be retraced in eva_5_WeatherCorrelation, a moderate correlation of 0.509 is found between bike counts and temperature. Precipitation

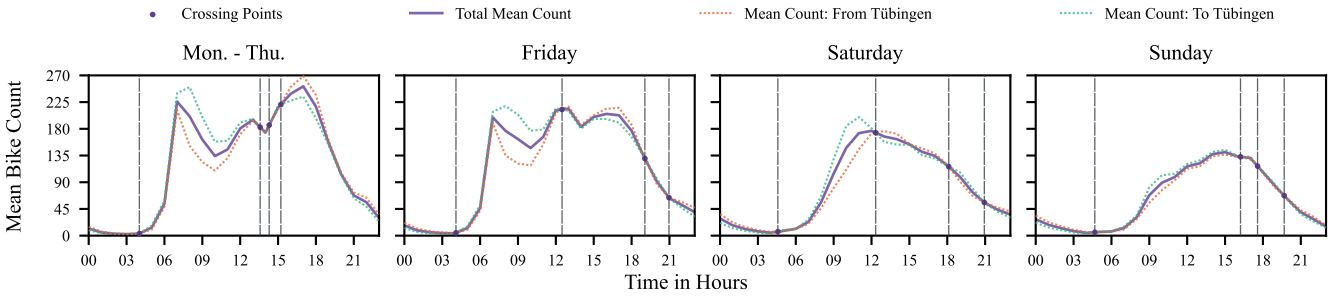

Figure 5. Hourly directional mean counts per day at FSC since 2016. Due to high similarity Monday to Thursday are combined. Each figure shows several flips in direction ratio.

shows a weak negative correlation of -0.15, while no significant correlation is identified for extreme weather conditions.

For the fuel price analysis, no considerable correlation could be found. Figures are accessible in eva_6_FuelPriceCorrelation.

4. Discussion & Conclusion

In 2023 on average 7090 cyclists passed SC per day, which corresponds to 7.8% of Tübingens' population (Figure 2). Although it is not only unclear if cyclists pass that counter, but also if cyclists originate from Tübingen itself or drive in from the outskirts.

To properly account for the effects of seasonality affecting commuters, they will be discussed first. The differences between summer and winter can be seen in the Figures 2, 4 as well as the results of the seasonal decomposition. The pattern of increased cyclist numbers in summer seems consistent, further supported by the results of the weather analysis showing positive correlation with temperature. There is, however, a consistent base of cyclists even during winter, which might likely be people going to work, school, or university. However, bike counts for HC increased more during summer in relation to overall traffic compared to the city counters, indicating possible differences in the decision making to use the bike.

To investigate these differences the purpose of riding a bike has been distinguished between leisure bike tours and commuting. Considering this, Figure 2 as well as the seasonal decomposition show connections to holidays and school breaks with declines of cyclists during those times.

Comparing work days against weekends showed the most traffic during the week, even down to rush hours aligning with common work or school hours (Figures 4, 5).

Considering the locations of the bike counting stations the seasonal decomposition and weekly pattern investigation both led to the indication that the HC counter is visited more often during weekends (Figure 4). This might be caused by its position on the "Neckartalradweg". Therefore, the HC counter can be viewed as "leisure counter", while the city counters are mostly passed by commuters.

No correlations could be found, indicating any impact of changes in fuel prices on motivation to ride a bike over other means of transportation.

Overall, an increasing trend of cyclists is evident. However, this is not necessarily connected to an increase of the relative amount of cyclists as the population of Tübingen is increasing.

Regarding the limitations of this study, it should be pointed out that the three counting stations likely do not cover enough ground to properly understand preferred bike routes or destinations. Especially considering commuters only a fraction can be tracked by HC. There is presumably a lot of traffic in the north around WHO, a student dorm hub, as well as Morgenstelle, where many clinics are located. So far counter stations have only been placed in the south.

In conclusion, the typical Tübinger might not be influenced by fuel prices or most weather conditions. But a consistent amount of people likely take their bike to school, university or work. Considering winter seasons, they might find the future heated bike bridges to their liking. Weekends seem to usually be reserved for shopping runs into the city or leisurely bike tours. During holidays, however, bikes are typically only picked up if the weather is exceptional.

Contribution Statement

Stephan focused on preparing the collected data. David and Tanja were responsible for the analysis phase. Tina lead the visualization part. All group members contributed to idea generation, data collection, and formulating research questions.

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