Impact of weather on bicycle use: Evidence from Helsinki in 2017-2021

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Abstract

This study describes the seasonal variations of cycling in Helsinki and analyzes their association with the weather conditions. The empirical data was obtained from the open data of cyclist counting stations at three locations in Helsinki (Baana, Merikannontie, Huopalahti). Weather data (including average daily temperature, sum of precipitation and average snow depth at the Kaisaniemi weather station) was obtained from the Finnish Meteorological Institute. Results show that there is a very strong seasonal variation of cycling in Helsinki. When analyzed individually, all three weather variables showed a statistically significant relationship with the daily number of cyclists. However, when all three variables were entered into the model together, temperature was by far the most influential variable while precipitation was also statistically significant. Snow depth was not significant in the model, and it is obvious that its role is dependent on various other factors, for instance snow clearing, that was not considered in the analyses of the study.

1. Introduction

Interest in cycling has in recent times increased in many regions and cities around the world (Pucher et al., 2011; Agervig Carstensen & Ebert 2012; Fishman, 2016; Ton et al., 2019). Cycling is seen as a sustainable commuting mode especially in urban areas (Kaplan et al., 2015; Agarwal et al., 2020), and potentially also in rural areas (Dickinson et al., 2009; McAndrews et al., 2017). Many people regard cycling as an attractive recreational and sporting activity (Lumsdon, 2000; Mullan, 2013) for advancing personal wellbeing and physical health (Oja et al., 2011; Ma et al., 2021). For urban planners, cycling offers a way to promote sustainability goals and increase the attractiveness of urban areas by substituting environmentally friendly personal transport modes for polluting and space-consuming cars (Meschik, 2012; Marquart & Schicketanz, 2022). Some of the recent projects (e.g. Style project in Finland, see https://www.styletutkimus.fi/) take a holistic view on sustainable growth by integrating transport policy and urban design issues with healthy lifestyle aspirations, cycling being one of the obvious areas where this can be accomplished.

Many factors determine a person's propensity for cycling (see e.g., Heinen et al., 2010; Ton et al., 2019; Piatkowski & Bopp, 2021). On an individual level, these factors include attitudes, age, habits, perceived effort, etc. Social norms and culture also determine the propensity to cycle – in some cultures, it is not common to use the bicycle. Among the environmental variables are the level of infrastructure (e.g., bicycle lanes and paths) and the quality of built and natural environment. The weather and climate play a crucial role in many regions, making cycling a highly seasonal activity especially in Northern countries such as Finland.

One problem for transport planning especially regarding cycling and its seasonal variations is the existence of reliable data. Studies related to bicycle use are typically based on survey data or travel diaries mapping the current travel behavior or intentions at certain time point or period. For instance, the national travel surveys in Finland are based on data obtained from a sample of respondents in different parts of the country at a few years' interval. These studies can give tentative indications of the seasonal variations, but more objective data sources are needed to show the true extent of variations and their associations with weather, for instance. In recent years, the improved availability of traffic counting data in many cities has offered a useful data source for analyzing these variations.

This study describes the seasonal variations of cycling in Helsinki and analyzes their association with the weather conditions. The study is based on cycling data from three counting stations in Helsinki (Baana, Merikoskenkatu and Huopalahti) and weather data at the Kaisaniemi weather station over a period of five years (2017-2021). The data were collected from two sources: cycling data were obtained from the open database of Helsinki Region Transport (HRT), while the weather data were retrieved from the database of the Finnish Meteorological Institute (FMI). The data were obtained on hourly level (cycling data) and on daily level (weather data), yet some hourly data were also used for checking up on exceptional weather conditions. The data were converted into daily, monthly, and annual figures with Excel's Pivot functionality. Statistical analyses were conducted using Excel functions (e.g., trend) and statistical tools (e.g., regression analysis).

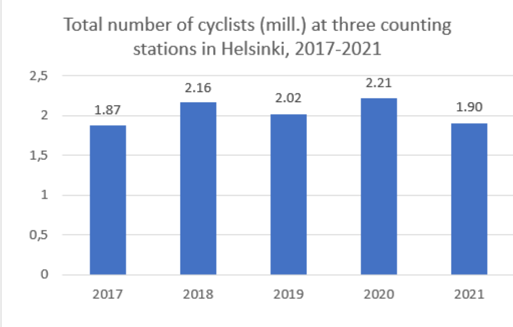
The study was limited to the period of 1.1.2017-31.12.2021. This selection resulted in a database with 1826 daily observations on three popular cycling locations in Helsinki and daily weather observations on temperature, precipitation (rain or snow) and snow depth. It was noted that many cyclist counting stations had some missing data (probably due to instrument malfunctions or pathway closures), but the selected locations (Baana, Merikoskenkatu and Huopalahti) showed consistent data throughout the study period and were thus selected for the study. The weather data were fully available for the entire study period; however, some modifications of the original data were needed to improve usability: average temperatures (ªC) were computed from minimum and maximum daily values, daily precipitation and snow depth were converted with Excel Pivot functionality into summed and average values (mm per day), respectively.

2. Cycling in Helsinki

Helsinki, the capital of Finland, is located in Southern Finland, by the Baltic Sea. It has a population of approx. 659,000 and with the neighboring cities (Espoo, Vantaa, Kaunianen) forms the wider Helsinki Metropolitan Area with almost 1.5 million inhabitants. Helsinki has a humid continental climate, with an average daily temperature of +5.9 ºC and an annual rainfall of 655 mm. The weather varies significantly through the year; in the winter months, the temperatures drop below freezing and normally there is also snow, but not necessarily every winter. The highest temperature ever recorded in Helsinki is +33.2 ºC (2019) and the lowest -34.3 ºC (1987).

Helsinki has an ambitious goal to make the city carbon neutral by the year 2035. To achieve this goal, the city promotes cycling since mobility is one of the main sources of greenhouse gas emissions in urban areas. The target has been set to raise the share of trips made by cycling from 9% (2018 and 2021) to 20% by the year 2035 and become the third best cycling city in the world after Amsterdam and Copenhagen. Currently there are some 35 kilometers of bicycle paths in central Helsinki and 1000 kilometers in the city area as a whole. As part of the cycling program, Helsinki is building the "Baana network", involving designated roads for bicycles that allow cycling at steady speed on high-quality, straight routes. Other measures to promote cycling include, for instance, a journey planner for bicycle traffic, attitude campaigns, guidance in bicycle maintenance, and developing a feedback system to improve the maintenance of pathways.

On annual level (2017-2021) the total number of cyclists at three counting stations (Baana, Merikannontie, Huopalahti) in Helsinki is shown in Figure 1. The total number of cyclists at these cycling stations varies between 1.87 and 2.21 million cyclists (2017 and 2020, respectively). The weather data show that the year 2020 has been exceptionally warm (average temperature +8.1 ºC) and, consequently, there has been little snow (average snow depth 0.01 mm). The weather will naturally have contributed to the number of cyclists during the year. At the same time, the Covid-19 pandemic landed in Finland in March 2020, leading to a situation where many people during 2020-2021 worked at home and educational institutions utilized distance teaching. Also many recreational activities and hobbies were temporarily suspended which reduced people's need for mobility.



Weather	T	P	S
2017	6.8	797	0.47
2018	7.3	462	3.47
2019	7.5	741	3.94
2020	8.7	745	0.01
2021	6.7	656	5.05

T = average temperature (ºC)
P = sum of precipitation (mm)
S = average snow depth (mm)

Figure 1. Total number of cyclists at three counting stations in 2017-2021

There is considerable seasonal variation in the level of cycling through the year (see Figure 2). The monthly figures show that 42.1 % of the total number of cyclists during the 5-year study period are registered in three summer months (June, July, August) while only 8.4 % of cyclists are registered in three winter months (January, February, March). It can be seen in Figure 2 that the seasonal pattern remains fairly stable over the study period. Besides the winter months, the number of cyclists goes down in July, which is the popular summer holiday month in Finland. In the summer of 2021, the numbers do not pick up in August, which is probably due to the Covid situation in fall 2021. Compared to other winters, the level of cycling in 2020 is quite high, maybe due to the warm winter mentioned above. It may also be that the pandemic has made many public transport users shift to the bicycle to avoid infection.

An exceptionally high number of cyclists can be observed in the summer of 2018. Again, this may be attributed to the weather; in May 2018 the average temperature was +13.8 ºC, compared to the average of +10.8 ºC during the entire 5-year period. However, also positive publicity may have affected people's willingness to use the bicycle. In May 2018 Helsinki was selected as the Cycling City of the Year in recognition of the efforts to advance cycling conditions.

The percentage shares of monthly bicycle use (Figure 3) show that there is only little variation between the three counting stations in 2017-2021. This can be taken as an indicator of data reliability in the study - with evenly distributed percentages, it can be assumed that the data is comprehensive without noticeable occurrences of missing data due to instrument malfunctions or cycling path closures, for instance.

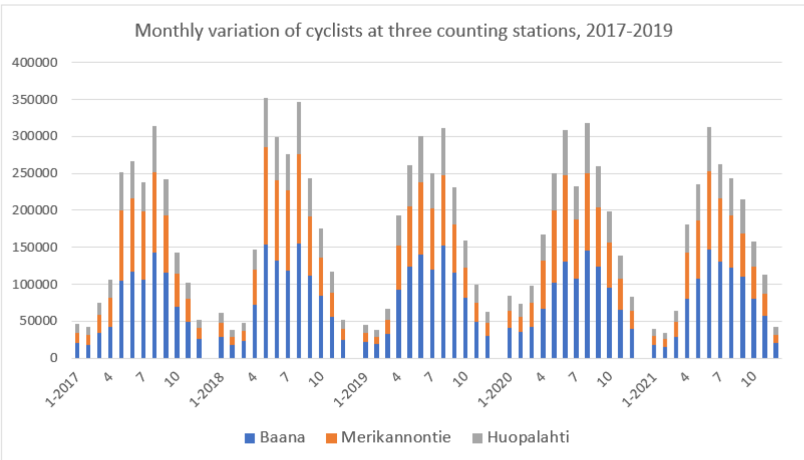


Figure 2. Monthly variation of cycling at the three counting stations in 2017-2021

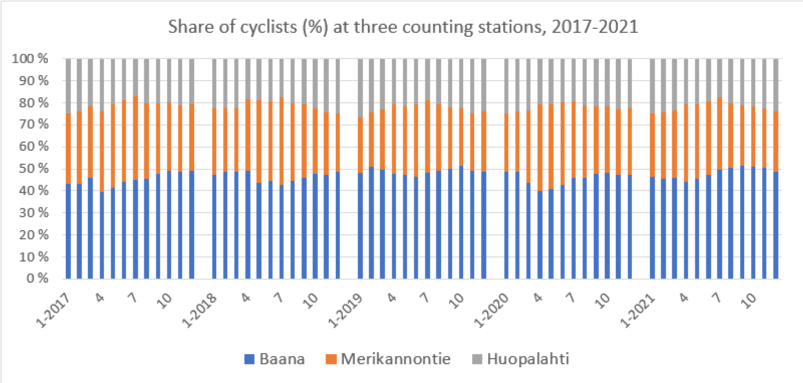


Figure 3. Monthly shares of cyclists between the three counting stations in 2017-2021

Besides monthly variations, there is also variability in cycling through the days of the week. Especially during the weekends, the number of cyclists goes down to approximately one half compared to other weekdays. To eliminate the impact of this variation, the following analyses are based on one weekday's figures only (Wednesday). After this change, the data set was reduced from 1826 days (all days) to 261 days (Wednesdays only). The total number of cyclists in the sample was reduced from the 10.16 million (all days) to 1.75 million (Wednesdays) during the entire 5-year observation period.

3. Impact of the weather

Using the new sample of Wednesdays in 2017-2021, it is possible analyze the impact of different weather conditions on cycling. As already discussed above, there is an association between the temperature and the level of cycling, but also the impact of precipitation (notably rain) and depth of snow can be investigated in more detail. The Finnish Meteorological Institute also offers various other weather parameters (such as wind speed and direction), but these were not included in this study.

A visual comparison of Figure 4 (number of cyclists, Wednesdays 2017-2021) and Figure 5 (average daily temperature) confirms a strong association between weather conditions and cycling. The analysis can be continued with a scatterplot chart (Figure 6) between the two parameters. The regression equation shows an R^2 statistic (coefficient of determination) of 0.73, indicating very high goodness of fit of the model.

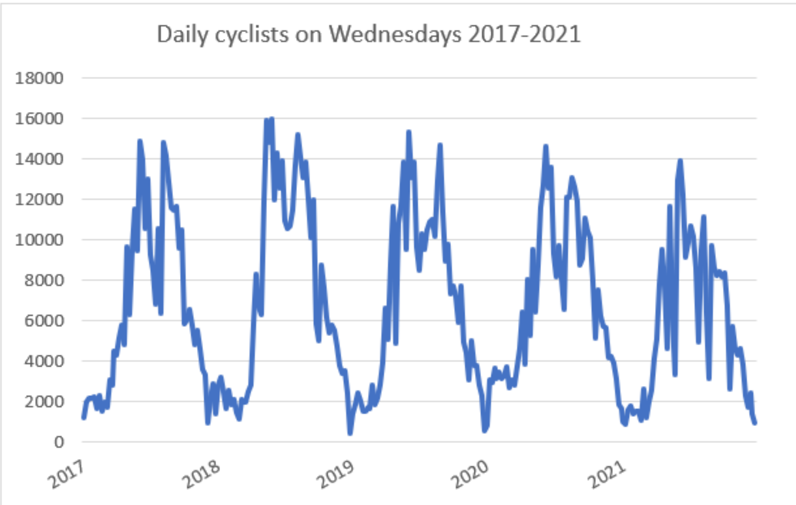


Figure 4. Number of cyclists on Wednesdays 2017-2021

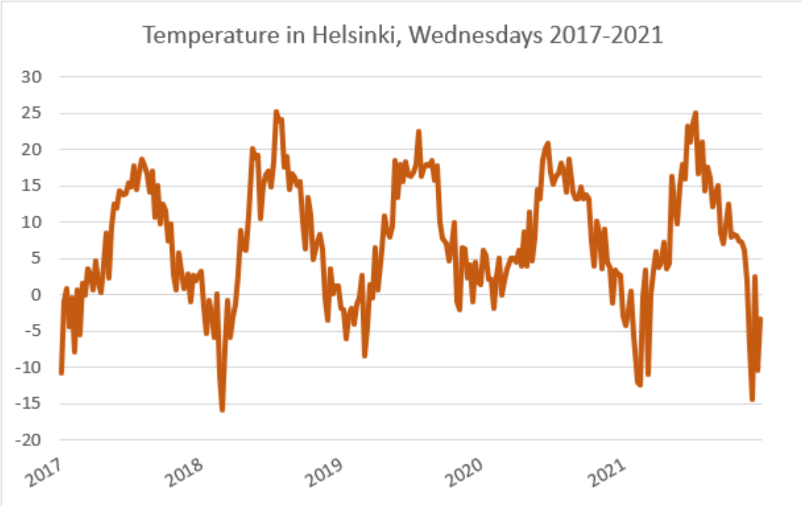


Figure 5. Average daily temperature on Wednesdays 2017-2021

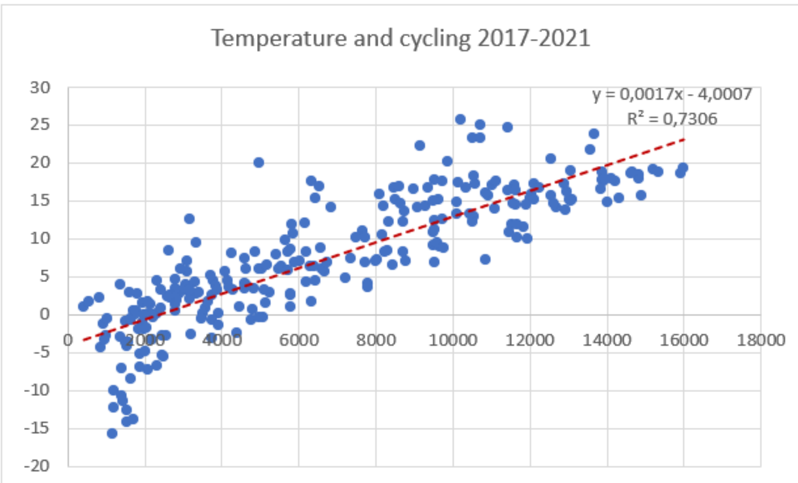


Figure 6. Association between daily temperature and cycling on Wednesdays 2017-2021

The association between the level of precipitation (mostly rain, sometimes snow) and cycling is far less obvious (Figure 7). The regression coefficient is negative and statistically significant, explaining 2.98 % of the total variation. As can be seen from the figure, there is a group of cyclists who use the bicycle even in harder rain; the data shows that 8.5 % of all cyclists use the bike when the daily rain exceeds the level of heavy rain (according to FMI, heavy rain means over 4.5 mm precipitation per day). An interesting case in the chart can be seen at 25 mm rain level when the daily number of cyclists exceeds 12,500 – it turned out from FMI's statistics that on 17. June 2020 there was heavy rain in the night, but the weather had already cleared by the morning. By contrast, there are some days in 2021 (e.g., 26 May., 25. Aug., see Figure 4) when the number of cyclists is conspicuously low compared to other days – on these days, there has been persistent rain through the day clearly exceeding the precipitation level of adjacent days.

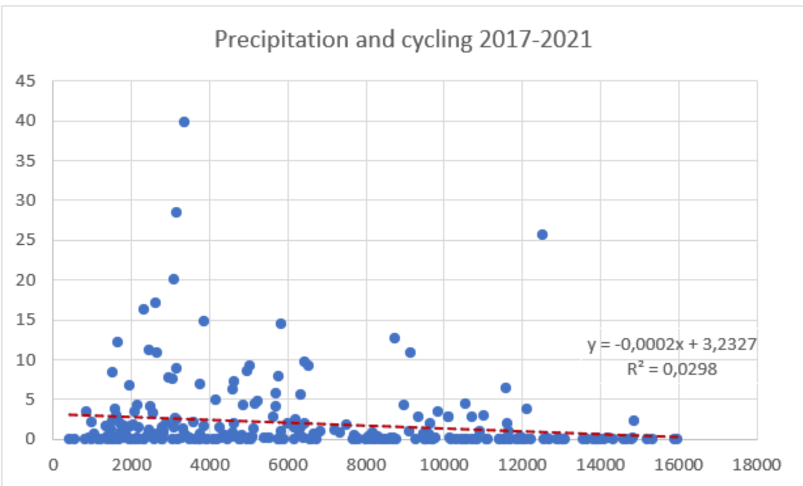


Figure 7. Level of precipitation (mm) and cycling, Wednesdays 2017-2021

Lastly, the association between snow depth and cycling is shown in Figure 8. Also, this variable is statistically significant and individually explains 18 % of the total variation. However, it is questionable whether the whole year's data is a meaningful starting point for this analysis, instead of just winter months. While the great majority of cyclists only use the cycle in snow-free conditions, there is a group of winter-cyclists who cycle on year-round basis even when there is a lot of snow. Naturally, the figures do not say anything about the condition of roads or cycle paths during the snowy periods. Cycling on snow-cleared roads or cycle paths is quite different from uncleared routes.

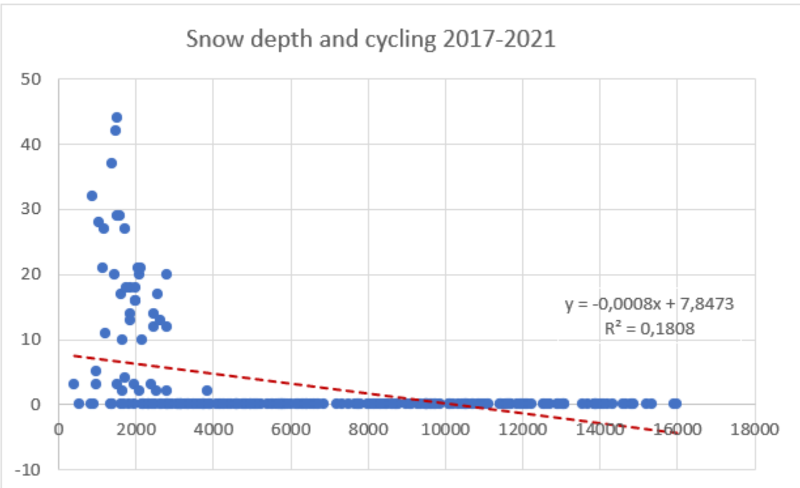


Figure 8. Snow depth and cycling, Wednesdays 2017-2021

Putting the three weather variables together, the relative impacts of each variable on cycling can be shown with multivariate regression equation. The resulting model shows that temperature and precipitation are statistically significant determinants of cycling whereas snow depth, in the presence of the other two variables, is not significant. Together, the two variables (temperature, precipitation) explain 76.4 % of the variation in cycling. However, a very basic visual analysis is enough to show that temperature is the variable that has the strongest impact on cycling.

4. Discussion and conclusions

Bicycle use is known for its advantages both on societal and personal level: it is an environmentally friendly mode of personal transport that offers positive health impacts and infrastructure savings through reduced parking space requirements, for instance. Many cities and regions have implemented programs and projects to promote cycling for commuting and free-time activities. In Finland, for instance, also other cities besides Helsinki – notably Oulu in Northern Finland – have actively developed the conditions for cycling on a year-round basis.

All transport modes are affected by external conditions, such as the weather. For cycling, the dependence on external conditions including climate and weather, geography, level of cycling infrastructure, and culture is exceptionally high. However, also personal attitudes have a significant impact on cycling propensity. For these reasons, it is difficult to get reliable information on bicycle use and its variations. Some of the common methods such as surveys and diaries involve uncertainties, but also human and automated counts have their problems related to sampling and instrument malfunctions.

In this study, automated counter data of three counting stations along popular cycling routes in Helsinki were used to estimate the impact of weather on bicycle use. The data of the three counting stations was very consistent, signifying high reliability in terms of problems such as counter malfunctions or closures of cycle paths. Weather data was obtained from the open data base of the Finnish Meteorological Institute. The data was collected from a five-year period (2017-2021) and the analyses were based on daily figures (number of cyclists, average temperature, amount of precipitation and snow depth).

As could be expected, there is a high seasonality in the level of cycling in Helsinki. The total count of cyclists during the three summer months (June, July, August) is on average 5.4 times greater than in winter months (January, February, March), even if there is a significant drop in the number of cyclists in July which is the summer holiday period in Finland. It would, in fact, be possible to create highly reliable forecasts of cycling activity by using advanced time-series methods alone without using any causal determinants.

The most important weather-related predictor of cycling is temperature, which explains 73.1 % of the total variation in the number of cyclists. As an individual variable, the amount of precipitation is also statistically significant, explaining 3 % of the total variation. The impact of snow depth was also tested individually and was found to be a highly significant predictor of cycling – but this is of course questionable because the analysis neglects the seasonality of snow; also, the impact of snow clearance on cycling paths should be considered if true association with cycling were to be measured.

When all three weather-related variables are included in the model, the coefficient of determination goes up to 76.4 % with two statistically significant variables in the model - temperature and precipitation. Although daily temperature is by far the most important predictor in the model, it is possible to detect the importance of precipitation by looking at individual rainy days in the summer. If the rain comes in only the nighttime, the number of cyclists is high, whereas rain in the daytime reduces the number of cyclists significantly.

The impact of the Covid-19 pandemic is not included in the analysis of this study. Finnish Cyclists' Federation has estimated the reduction in cycling to be around 14 % during the time frame of 2016-2021, 2020 and 2021 being the years affected by the pandemic. However, the analysis is based on purely linear trends during the time period of the study – if the dependence on weather were included in the analysis, the impact of the pandemic would be significantly different (the average temperature in 2020 was 2.0 degrees higher than in 2021, and 2020 was practically free of snow).

The results of this study confirm the importance of weather-related variables (especially temperature) on cycling, as has also been demonstrated in many studies in previous cycling research. However, this study also shows the usability of automatic counting information in traffic studies – and with the increasing availability of counting data from various transport modes, that potential is growing. Transport planners can greatly benefit when the analysis is extended to multiple transport modes, especially the relationship between cycling and public transport in different conditions should be of interest. Therefore, future research should focus on the cross-impacts between transport modes, considering different contextual variables, such as the weather.

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Data sources:

- https://www.avoindata.fi/data/fi/dataset/helsingin-pyorailijamaarat
- https://www.ilmatieteenlaitos.fi/havaintojen-lataus