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How does the weather affect the shared bicycle usage?

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Abstract

The shared bicycle trips from Oslo in the 2017-season are analysed, showing shared bicycles usage, the daily and seasonally variations that exists, and how rain and temperature influences the use of shared bicycles. The trips are categorized by the speed, length and by the height difference of the trips. Linear regression analyses were conducted to understand how weather impacts differentiated types of trips differently during the hours of the day. There are daily and seasonally variances in how the shared bicycles are being used. The weather has an impact on the number of trips as well as the type of trips being made. Rain has a negative effect on the usage of shared bicycles. The number of long trips as well as the trips being made at a slow pace are the trip categories most affected by the rain, whereas trips made at a fast pace as well as trips during the morning rush hours are least affected. There is a correlation between higher temperatures and the number of shared bicycle trips being made, with the largest effect observed in the evenings. Warm weather has a greater positive impact on the number of trips being made at a slow pace than on the number of trips made at a fast pace. The information gathered is useful in contributing to the understanding of how the weather can affect the attractiveness of the soft modes and is also useful in transport planning on a larger scale.

1. Introduction

Shared bicycles are schemes where a relatively large number of bicycles are distributed between several docks located in and around the city centre. The bikes are available for public usage through a membership. In Norway, a one-year membership costs approximately 400 NOK (about €40). As a member, one can use the bikes as many times as one wishes for no extra cost. The possibility of choosing freely where to park the bike and not having to necessarily cycle the same way back home, provide users of shared bicycle a freedom which regular bicyclists don’t have.

The unlocking and return of the bikes to the docks, are registered and logged. This way, the operator has continuous control over the bikes and the docks. The registered data also enables future analyses and detailed research on the usage of the shared bicycles.

In Oslo, there are close to 20.000 shared bicycle trips made every day and the shared bicycle scheme is an important part of Oslo's transportation service. In 2017, more than 2.6 million trips were conducted, with 11.000 unique daily users at a maximum (Oslo Bysykkel, 2018). The scheme had a total of 160 docks, whose geographical and topographical abilities are presented in Figure 1. The city centre of Oslo is low in the terrain, while surrounding districts are higher.

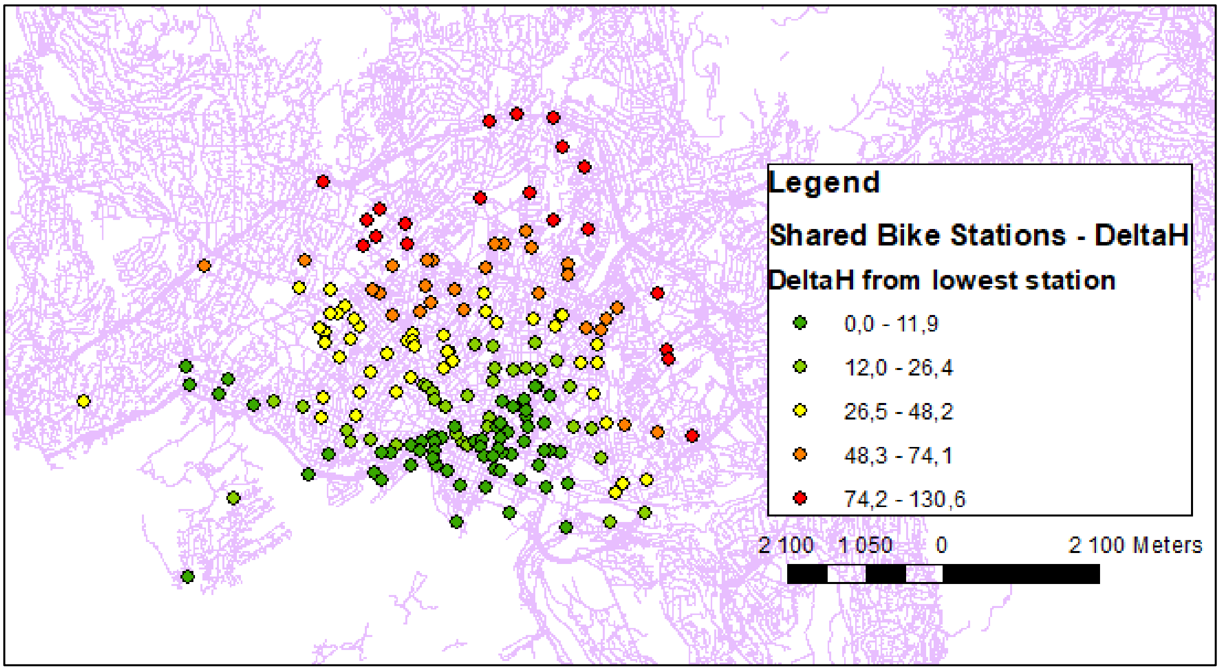

Figure 1 – The topography of Oslo and its shared bicycle docks [meters above sea level]. Print screen from ArcGIS.

The growth of shared bicycle schemes has introduced a new tool in analysing travel behaviour. The large amounts of registered trip data from shared bicycle schemes could prove very helpful to researchers, as large-scale data registration of pedestrian and bicycling can be time-consuming and difficult. This paper uses Oslo as an example in studying how existing registered trip data from shared bicycle schemes can be used in travel research and examines how the shared bicycle usage is affected by rain and temperature. The study can be replicated for other cities or prove as an inspiration for how existing registered shared bicycle trip data can be used in research.

The result of the paper is a detailed description on the impact of weather on the shared bicycle usage in Oslo, describing how temperature and rain impacts the attractiveness of shared bicycle trips.

2. Literature

2.1 Shared bicycle schemes

Shared bicycle schemes as we know them today, were first introduced in Lyon in 2005 (DeMaio, 2009). There are shared bicycle schemes on all continents, and by the end of 2016 more than 1000 schemes were existing all over the world (DeMaio & Meddin, 2017).

Positive aspects of shared bicycle schemes include offering the public an accessible and affordable transport service, having a positive health impact on its users, and possibly reducing congestion and emissions (Fishman, et al., 2013). Shared bicycle trips are mostly substituting public transportation, cycling and walking (Fishman, et al., 2014). Shared bicycles are used in multimodal trips (Fishman, et al., 2013), being used as a "first mile"-"last mile" connection, thus complementing public transportation (DeMaio, 2009) (Bachand-Marleau, et al., 2012). Shared bicycles can also be a competitor to public transportation (Levy, et al., 2017) (Shaheen, et al., 2011).

2.3 Members

Members of shared bicycle schemes are mostly young people (Fishman, et al., 2014) (DeMaio, 2004) and they often are highly educated and/or have a high income, though this may be caused by the fact that the level of service for shared bicycles are best in areas with attractive jobs and wealthy neighbourhoods (Ogilvie & Goodman, 2012) (Fishman, et al., 2014). Adjusting for the skewed level of service, Ogilive & Goodman (2012) finds that citizens in less wealthy areas are more frequent shared bicycle users.

Members of shared bicycle schemes describes the convenience of the service as the biggest motivational factor as to why they use shared bicycles (Fishman, et al., 2014). Shared bicycles being an economical sensible mode of transportation, is also an important factor. (LCD Consulting, 2012) (Fishman, et al., 2014)

2.4 Trips

At workdays the shared bicycle demand is at its highest during the rush hours. Furthermore, this is also the time of the week where trips are made at the highest average pace. At weekends the shared bicycle schemes have the highest usage during the period between 11-18 o'clock, which is also where the lowest average travel speed is observed (Mateo-Babiano, et al., 2016) (Oliveira, et al., 2016). During the morning hours on workdays, shared bicycles are used for travelling to the city centre, while in the evenings, they are used for travelling out of the city centre (Zhou, 2015).

Shared bicycles are much used for commuting (Caulfield, et al., 2017) (El-Assi, et al., 2017) – often trips between residential areas and commercial areas (Mateo-Babiano, et al., 2016). Shared bicycles are also used for recreational trips (Zhou, 2015). Kim (2011) finds that areas around parks, subways stations and schools helps generate shared bicycle trips, in addition to areas around commercial and residential buildings.

The trips in shared bicycle schemes are found to have an average travel time at 15-20 minutes (Mateo-Babiano, et al., 2016) and an average travel distance of 2.5 km (Jensen, et al., 2010). In comparison, bicycle trips in general in Norway in 2013/2014 were found to have an average travel time at 17 minutes and an average travel distance of 5.1 km, with 80% of the bicycle trips being shorter than 5 km (Hjorthol, et al., 2014). As expected, shared bicycle trips are shorter than regular bicycle trips as the shared bicycles are not primarily designed for longer trips, seeing as they have relatively tiny wheels and a 45 minutes rental time limit.

2.5 Factors influencing the shared bicycle usage

Multiple studies have been conducted, analysing the registered data from shared bicycle schemes to describe and explain the variance in the travel data.

Shared bicycle schemes are most popular in countries with an already existing cycling culture (DeMaio, 2004). A high quality cycling infrastructure helps increase the shared bicycle usage (Levy, et al., 2017).

The weather has an impact on the shared bicycle usage. Rain as well as extreme temperatures and strong wind results in a decrease in shared bicycle trips (Keenan, 2016).

The land usage is important (Kim, et al., 2011) (Mateo-Babiano, et al., 2016), seeing as it is important to the demand for travel. Locating docks close to the travellers start and end point of their preferred trips is therefore important.

2.6 Impact of weather

Research on bicycling in general finds that rain leads to a decrease in cycling and an increase in car use, whereas strong wind leads to a decrease in cycling and an increase in walking (Sabir, et al., 2007). Warm weather leads to an increase in cycling (Sabir, et al., 2010) (Sabir, et al., 2007) (Aaheim & Hauge, 2005). The number of recreational trips is especially affected by the weather (Sabir, et al., 2010).

Precipitation, cold temperatures and high humidity levels leads to a decrease in the demand for shared bicycles (Gebhart & Noland, 2014) (El-Assi, et al., 2017). There is a higher demand for shared bicycles in the lighter parts of the day as opposed to darker parts of the day (Gebhart & Noland, 2014).

3. Data description

3.1 Registered data on trips made from the shared bicycle scheme in Oslo

Registered data on trips made from the shared bicycle scheme in Oslo are accessible through the webpage of the scheme's operator, Oslo Bysykkel (Oslo Bysykkel, 2018). The original dataset consists of 2 712 804 trips for the 2017-season. The data includes the following information:

- The docks registered as the start and end point of each trip.
- The timing of the beginning and the end of the trip, described by the date and time in the format of hh:mm:ss.

The 2017-season lasted from Monday April 3rd 06:00 to Tuesday November 21st 23:59. The shared bicycle scheme was closed every day between midnight and 06:00 (Oslo Bysykkel, 2018). The maximum (free) bike rental time of each trip in Oslo is 45 minutes.

3.2 Limitations

Limitations were made as to which trips were included in the study. The limitations were made to reduce the number of faulty trips included in the analysis. The limitations made, and the number of shared bicycles trips affected by these limitations, are shown in Table 1.

Table 1 – Limitations as to which shared bicycles trips are included in the analysis.

Topic	Rule	Number of trips affected by this limitation
Travel distance	> 75 metres	145 110
Travel time	> 1 minute	57 980
Travel time	< 45 minutes	44 594
Estimated speed	< 40 km/h	13
Opening hours	06:00-midnight	239
Time of year	Apr 3rd-Nov 21st	62 before Apr 3rd 412 after Nov 21st

Some trips were affected by several limitations. In total, 2 527 874 trips were included in the analysis.

3.3 Data from weather observations

Weather observations are conducted by the Norwegian Meteorological Institute, and registrations are being made on an hourly basis. The detailed data from all of their observations are made publicly available on their webpage, yr.no. The weather registrations for Oslo are conducted at the "Blindern weather station", located approximately 4 km northwest from the city centre of Oslo.

Temperature and precipitation were the only factors analysed in this study. There is seldom strong wind in Oslo and the wind was assumed not to have an influence on the travel behaviour of the shared bicycle users, thus not included in the study.

4. Methodology

4.1 The ATP-model

The data from the shared bicycle scheme does not include any data concerning the length of the trips. It only includes the starting point and the end point of each trip. The coordinates of the shared bicycle docks were imported to ArcGIS. By using the ATP-model, the fastest route between the different docks were estimated, making it possible to examine the length and speed of each trip in the dataset.

The ATP-model [Norwegian name: ATP-modellen] is a planning tool for land use and transport planning created by Asplan Viak Trondheim (Asplan Viak AS, 2018). The model is used in ArcGIS with Network

Analyst and is available for free at their webpage, atpmodell.no. The model estimates the fastest route between two points, based on the length and inclination of the roads in the transport network.

4.2 Categorizing the trips

To examine the weather impact on different types of trips being made, the shared bicycle trips were differentiated into separate categories based on the estimated speed, travel length and height difference of each trip. The estimations for each trip were found using the ATP-model.

The following trip divisions were made based on **speed**:

- <u>Fast</u> trips: Trips with a registered rental time shorter than 1.4 times the estimated trip travel time.
- <u>Normal</u> trips: Trips with a registered rental time between 1.4 and 2.3 times the estimated trip travel time.
- <u>Slow</u> trips: Trips with a registered rental time longer than 2.3 times the estimated trip travel time.

The following trip divisions were made based on **travel length**:

- <u>Short</u> trips: Trips where the estimated fastest travel route is shorter than 1.2 km.
- <u>Medium</u> trips: Trips where the estimated fastest travel route is between 1.2 and 2.4 km.
- <u>Long</u> trips: Trips where the estimated fastest travel route is longer than 2.4 km.

The following trip divisions were made based on the absolute **height difference** between the start dock and end dock of the trip:

- <u>Downhill</u> trips: Trips with a height meter difference < -7 meters
- <u>Flat</u> trips: Trips with an absolute height meter difference less than 7 meters.
- <u>Uphill</u> trips: Trips with a height meter difference > +7 meters.

4.3 Regression analysis

Multiple regression analyses were conducted to examine how weather affected the shared bicycle usage.

Temperature was set to be the independent variable in all the regression analyses being conducted. The dependent variable varied, using the number of trips per hour for all the nine different trips divisions, as well as the total number of shared bicycle trips.

The effect of temperature on shared bicycle usage is presented as a coefficient, describing how a temperature change of one degree Celsius affects the number of shared bicycle trips being made. The average number of shared bicycle trips is presented in Figure 3 and Figure 4, while the temperature coefficient describes the absolute change temperature has on the number of trips. The effect of rain is presented through the relative percentage decrease in the average number of shared bicycle trips at rainy hours compared to non-rainy hours.

Weekends and workdays

The dataset was split, conducting separate analyses for weekends and workdays. Those are shown in Figure 2.

<u>Weekends</u> are all the Saturdays and Sundays in the shared bicycle season of 2017.

<u>Workdays</u> are all the Mondays-Fridays in the dataset, excluding vacation days and other public holidays.

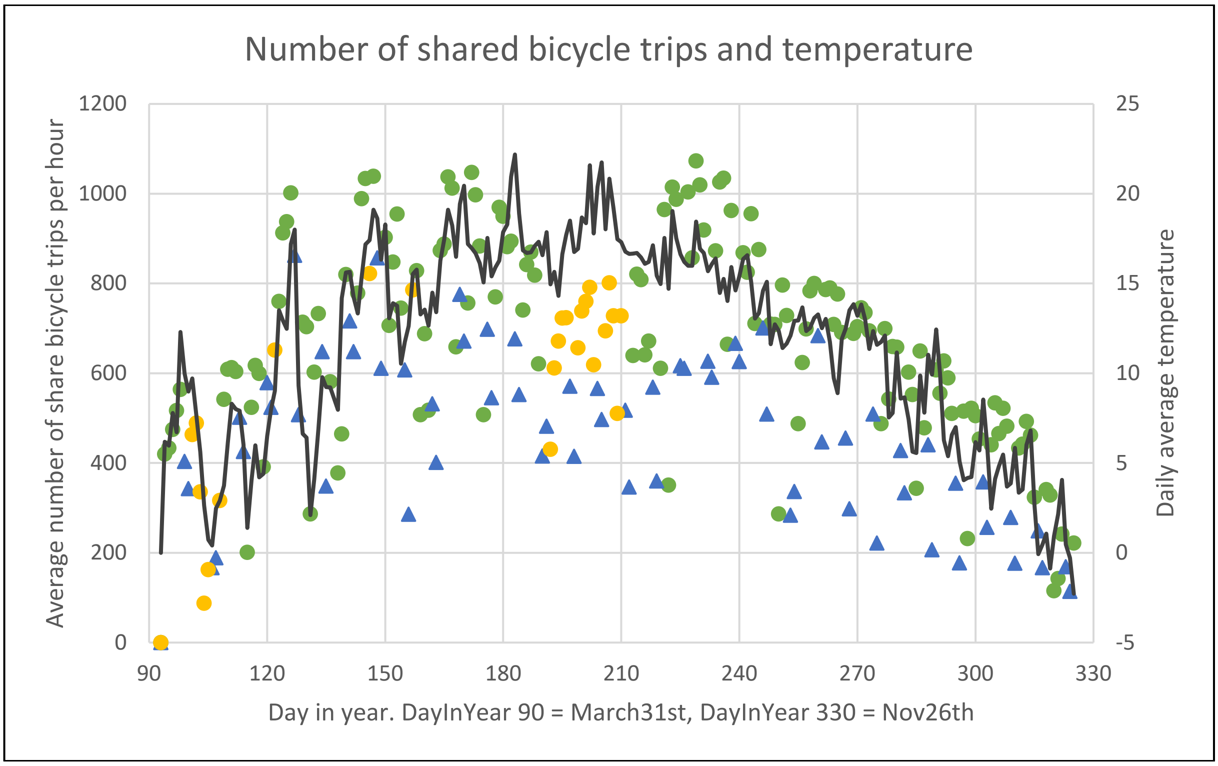

Figure 2 – Yearly variance in shared bicycle usage and temperature. Green points are illustrating workdays, blue points are illustrating weekend days and yellow points are illustrating public holidays. The black line represents the daily average temperature; the average registered temperature for the period 7-24 o'clock (Celsius degrees).

Time of the day

Separate analyses were conducted for different defined time intervals, both for workdays and weekends. 14 different time intervals (12 of the intervals an hour long) were defined for the workdays, and 5 different time intervals were defined for the weekends. The time intervals are presented in Table 5 and Table 7.

Precipitation

Hours with "no rain or an insignificant amount of rain" and hours with a "significant amount of rain" were analysed individually.

Rain is described as a variable of the three-hourly average rain. This variable is named three-hourly average rain; "RainAvg3H".

RainAvg3H for the hour X is given by the following formula:

$$RainAvg3H\ (x)\ [mm] = \frac{Registered\ rain\ for\ hour\ (X-1)}{3} + \frac{Registered\ rain\ for\ hour\ (X)}{3} + \frac{Registered\ rain\ for\ hour\ (X+1)}{3}$$

<u>Non-rainy hours</u> (or hours with an insignificant amount of rain) are defined as: Hours with three-hourly average rain < 0.10 mm.

<u>Rainy hours</u> are defined as: Hours with three-hourly average rain ≥ 0.10 mm.

Table 2 shows that in total, there were conducted 380 unique linear regression analyses to understand the effect weather has on the shared bicycle usage in Oslo in 2017 for different times of the day both for workdays and weekends for rainy and non-rainy hours.

Table 2 – The linear regression analyses conducted.

Dependent variable	Workdays: 14 intervals of time		Weekends: 5 intervals of time		Sum
	No rain	Rain	No rain	Rain	
Trips in total	14	14	5	5	38
Fast trips	14	14	5	5	38
Normal trips	14	14	5	5	38
Slow trips	14	14	5	5	38
Short trips	14	14	5	5	38
Medium trips	14	14	5	5	38
Long trips	14	14	5	5	38
Downhill trips	14	14	5	5	38
Flat trips	14	14	5	5	38
Uphill trips	14	14	5	5	38
Sum	140	140	50	50	380

The results of the linear regression analyses create a large basis that may explain how temperature and rain affects the shared bicycle usage at different times of the week.

5. Results

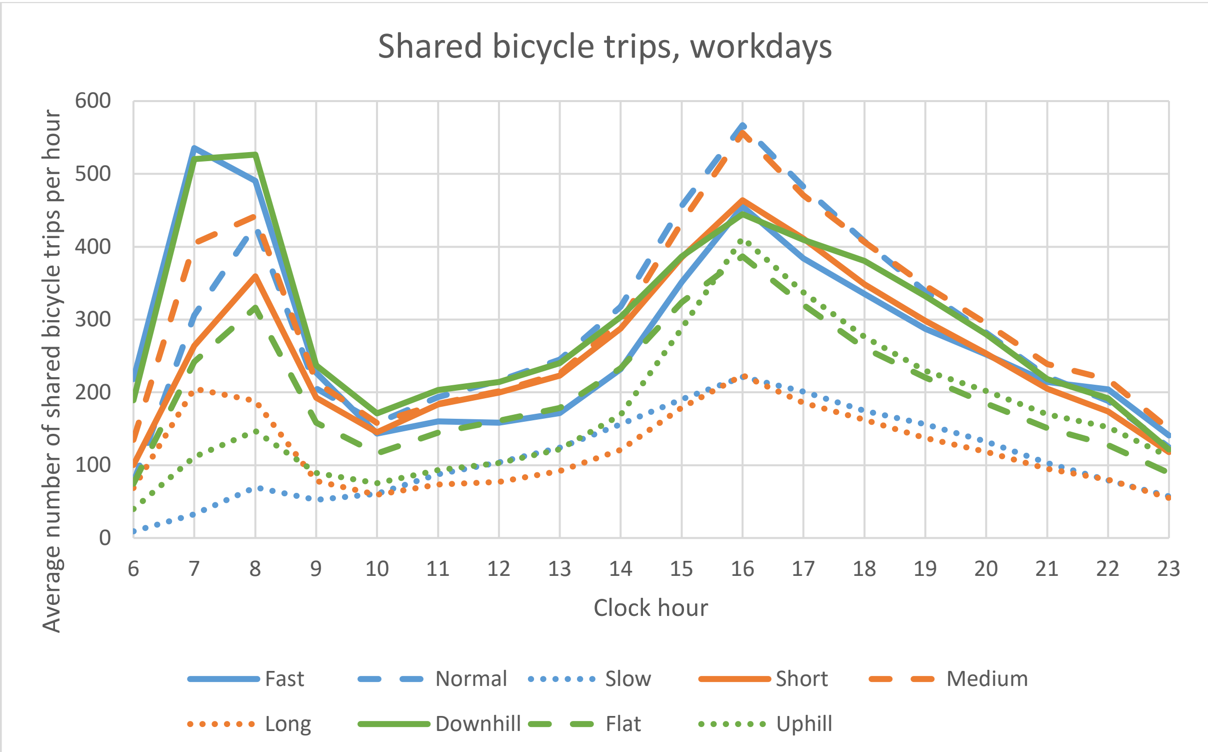

Figure 3 – Average number of shared bicycle trips per hour, different types of trips, any weather, workdays, Oslo 2017.

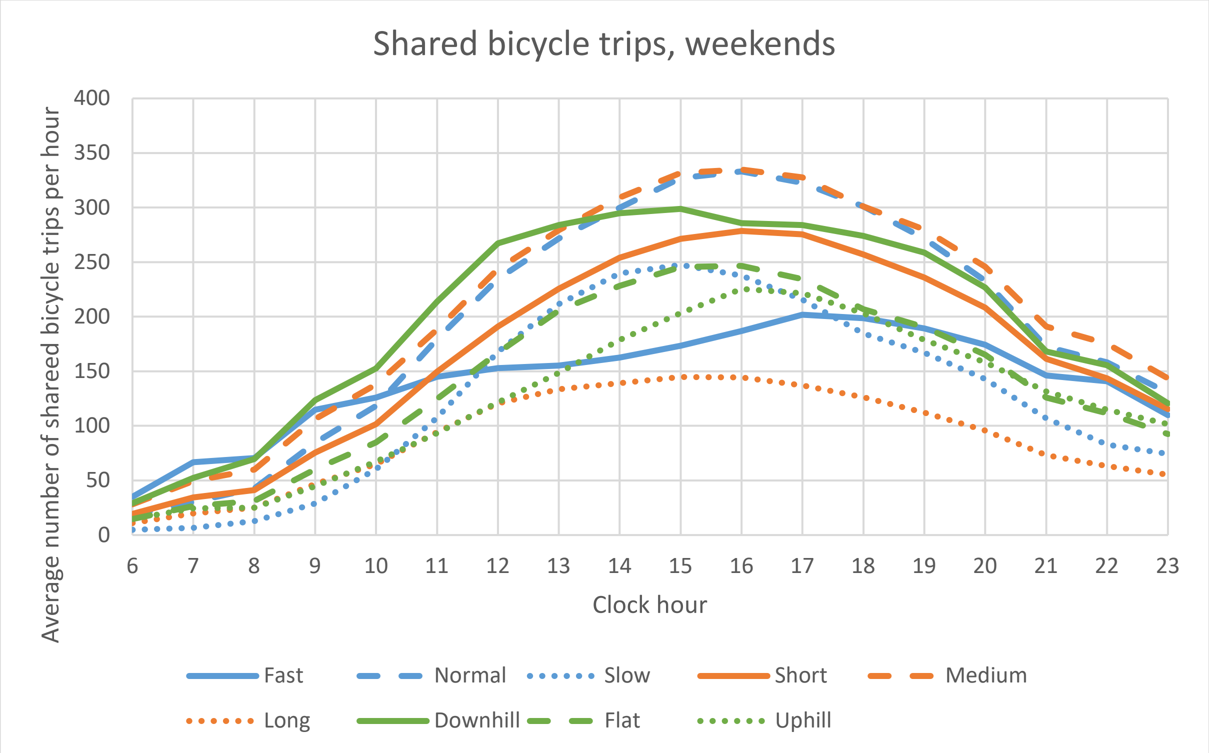

Figure 4 – Average number of shared bicycle trips per hour, different types of trips, any weather, weekends, Oslo 2017.

Figure 3 and Figure 4 shows large daily and weekly variations in the shared bicycle usage.

5.1 Rain

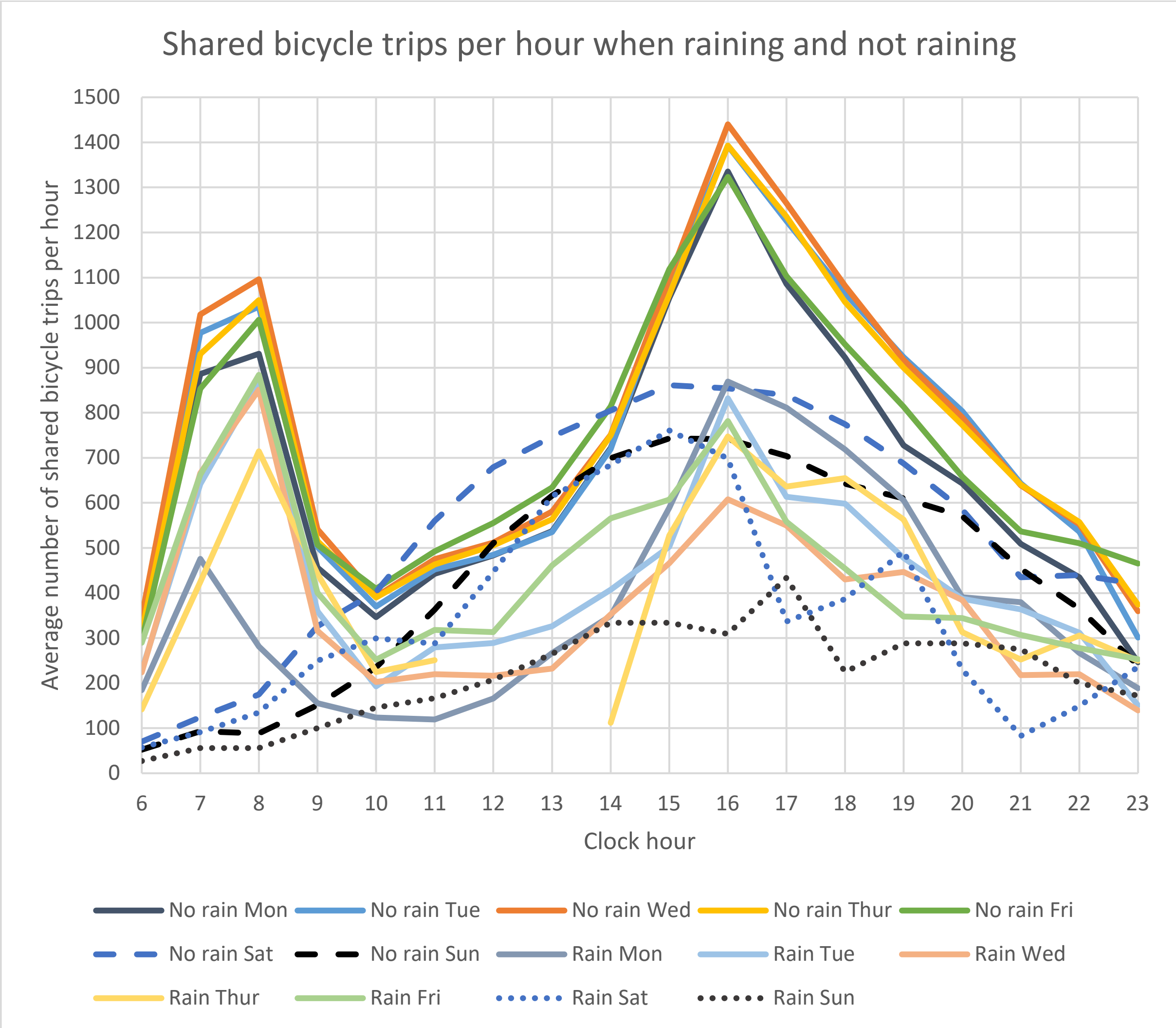

Figure 5 – Average number of shared bicycle trips per hour, all weekdays in the shared bicycle season, Oslo 2017.

Figure 5 illustrates how the travel patterns for workdays and weekends are recognisable. While the patterns are similar for hours with and without rain, the number of trips varies greatly, with variations in the weather. At workdays the trip demand for shared bicycles has a peak around the rush hours. At weekends, shared bicycles are used the most in the afternoon (12-19 o'clock).

There is registered a large decrease in the shared bicycle usage at rainy hours compared to hours without rain. The smallest difference is observed in the morning rush hours.

Table 3 and Table 4 shows the relative change in the number of shared bicycle trips at rainy hours compared to non-rainy hours, for workdays and weekends respectively. The tables are formatted with the same rules, and thus the two tables are easily comparable.

5.1.1 Workdays

Table 3 – The relative percentage decrease in the average number of shared bicycle trips at rainy hours compared to non-rainy hours, presented for all nine trip divisions, for different times of the day on workdays.

Clock hour	Speed			Length			Height difference		
	Fast	Normal	Slow	Short	Medium	Long	Downhill	Flat	Uphill
6	-38 %	-26 %	-29 %	-27 %	-36 %	-43 %	-36 %	-30 %	-35 %
7	-40 %	-30 %	-36 %	-30 %	-35 %	-47 %	-38 %	-32 %	-37 %
8	-25 %	-20 %	-39 %	-24 %	-22 %	-26 %	-17 %	-30 %	-33 %
9	-26 %	-29 %	-53 %	-27 %	-31 %	-35 %	-28 %	-28 %	-39 %
10	-42 %	-48 %	-61 %	-46 %	-47 %	-56 %	-45 %	-50 %	-53 %
11	-42 %	-47 %	-64 %	-46 %	-47 %	-62 %	-47 %	-51 %	-50 %
12	-45 %	-53 %	-67 %	-47 %	-54 %	-66 %	-52 %	-52 %	-57 %
13	-41 %	-49 %	-62 %	-45 %	-49 %	-60 %	-47 %	-50 %	-53 %
14	-40 %	-47 %	-59 %	-43 %	-47 %	-58 %	-46 %	-47 %	-50 %
15	-46 %	-52 %	-56 %	-46 %	-51 %	-59 %	-50 %	-50 %	-52 %
16	-40 %	-46 %	-55 %	-42 %	-46 %	-51 %	-46 %	-45 %	-46 %
17	-42 %	-47 %	-52 %	-42 %	-47 %	-52 %	-46 %	-45 %	-48 %
18	-38 %	-44 %	-54 %	-41 %	-44 %	-49 %	-43 %	-44 %	-45 %
19	-36 %	-42 %	-56 %	-39 %	-44 %	-46 %	-42 %	-43 %	-43 %
20	-43 %	-49 %	-65 %	-46 %	-51 %	-57 %	-49 %	-50 %	-52 %
21	-44 %	-48 %	-57 %	-43 %	-50 %	-54 %	-47 %	-47 %	-51 %
22	-41 %	-45 %	-59 %	-43 %	-47 %	-50 %	-42 %	-47 %	-50 %
23	-35 %	-45 %	-57 %	-42 %	-42 %	-47 %	-42 %	-43 %	-44 %

Table 3 shows that rain influences all types of trips, but the effect is the greatest on the number of slow trips and long trips. The types of trips least affected, are fast trips and short trips.

Rain has the least effect on the number of trips made in the morning rush. This shows that commutes in the morning rush are influenced by rain only to a small degree, and that shared bicycles are a regular part of the travel habits of the shared bicycle members in the morning rush hours, no matter the weather.

5.1.2 Weekends

Table 4 – The relative percentage decrease in the average number of shared bicycle trips at rainy hours compared to non-rainy hours, presented for all nine trip divisions, for different times of the day on weekends.

Clock hour	Speed			Length			Height difference		
	Fast	Normal	Slow	Short	Medium	Long	Downhill	Flat	Uphill
6	-42 %	-14 %	-53 %	-23 %	-39 %	-40 %	-38 %	-33 %	-27 %
7	-42 %	-32 %	-50 %	-35 %	-38 %	-53 %	-41 %	-46 %	-32 %
8	-41 %	-40 %	-62 %	-38 %	-42 %	-53 %	-44 %	-37 %	-48 %
9	-41 %	-46 %	-55 %	-41 %	-44 %	-53 %	-46 %	-41 %	-45 %
10	-37 %	-48 %	-59 %	-45 %	-44 %	-53 %	-44 %	-48 %	-48 %
11	-45 %	-61 %	-73 %	-54 %	-59 %	-67 %	-58 %	-60 %	-58 %
12	-48 %	-56 %	-65 %	-52 %	-56 %	-65 %	-55 %	-60 %	-57 %
13	-30 %	-45 %	-59 %	-42 %	-46 %	-53 %	-41 %	-52 %	-47 %
14	-19 %	-40 %	-62 %	-37 %	-44 %	-53 %	-39 %	-46 %	-46 %
15	-27 %	-41 %	-59 %	-37 %	-45 %	-56 %	-39 %	-47 %	-48 %
16	-26 %	-43 %	-56 %	-36 %	-44 %	-54 %	-38 %	-47 %	-46 %
17	-37 %	-48 %	-59 %	-40 %	-52 %	-55 %	-46 %	-48 %	-50 %
18	-48 %	-56 %	-67 %	-50 %	-59 %	-65 %	-57 %	-54 %	-60 %
19	-34 %	-38 %	-61 %	-39 %	-43 %	-52 %	-39 %	-46 %	-46 %
20	-48 %	-53 %	-62 %	-49 %	-52 %	-65 %	-53 %	-50 %	-58 %
21	-33 %	-47 %	-60 %	-43 %	-47 %	-46 %	-41 %	-49 %	-47 %
22	-49 %	-57 %	-69 %	-53 %	-56 %	-66 %	-55 %	-57 %	-58 %
23	-28 %	-41 %	-48 %	-35 %	-41 %	-37 %	-37 %	-33 %	-44 %

Table 4 illustrates how rain on weekends influences the number of slow trips and long trips the most. Rain leads to a decrease larger than 50% in shared bicycle usage for those types of trips, through almost the entire day.
During the weekends, fast speed trips made with shared bicycles are least sensitive to rain. The biggest effect from rain can be observed on the shared bicycle usage in the period from 11-13 and late at night.

5.2 Temperature

5.2.1 Workdays

Table 5 and Table 6 shows how shared bicycle usage is correlated to temperature. The temperature effect is greatest in the afternoon. During the morning hours trips such as fast trips, medium long trips and downhill trips are hugely affected by the temperature.

Normal fast trips, medium long trips and trips downhill are affected the most by temperature. One can observe an increase in attractiveness of these types of trips when the weather is at its best.

Table 6 illustrate that the types of trips most sensitive to temperature at rainy hours are fast trips, normal fast trips, short trips, medium long trips and downhill trips.

Table 5 and Table 6 uses the same formatting rules and can therefore easily be compared. There is a rather huge difference in the temperature variance on the shared bicycle usage for rainy and non-rainy hours.

Normal fast trips and slow trips are less sensitive to temperature variance at rainy hours than that of non-rainy hours. Fast trips are more sensitive to temperature variance at rainy hours than that of non-rainy hours. This underlines that there is a great demand for cycling trips at a fast pace, even when it is raining. Short trips are also cycled much at warm rainy hours.

The biggest difference in the sensitivity to temperature variance between non-rainy and rainy hours seems to be at night-time. This might be explained by people being more active later at night when the weather is nice than when it’s raining.

Table 5 – The coefficient value between the number of different types of shared bicycle trips per hour and the temperature, non-rainy hours, workdays.

Clock hour	Non-rainy hours, workdays								
	Fast	Normal	Slow	Short	Medium	Long	Downhill	Flat	Uphill
6	9.3	2.0	0.5	2.6	5.5	3.7	7.8	2.3	1.7
7	21.0	8.0	1.4	6.6	13.1	10.7	20.0	5.9	4.5
8	9.9	9.2	2.8	4.8	10.2	6.9	11.2	6.3	4.4
9	5.4	7.1	3.3	4.5	7.6	3.6	7.9	4.4	3.4
10	4.2	7.3	4.9	5.1	7.6	3.8	7.9	4.7	3.9
11, 12, 13	5.3	12.4	9.4	8.8	12.3	6.0	12.3	8.4	6.4
14	5.9	16.0	12.7	10.7	16.0	7.9	14.1	10.5	10.1
15	8.6	21.8	14.9	13.2	21.0	11.1	15.2	14.0	16.1
16	9.8	26.1	16.8	15.2	24.8	12.7	18.7	15.1	18.9
17	10.3	23.8	16.1	15.7	22.5	12.1	19.6	14.7	16.0
18	9.6	22.0	14.7	14.1	20.8	11.3	19.2	13.2	13.8
19	9.4	19.1	13.9	13.2	19.3	9.8	17.3	12.0	13.0
20, 21, 22	10.4	15.8	10.8	11.9	17.0	8.1	14.7	10.3	11.9
23	7.6	10.1	6.2	7.9	11.3	4.8	9.2	6.3	8.3

Table 6 – The coefficient value between the number of different types of shared bicycle trips per hour and temperature, rainy hours, workdays.

Clock hour	Rainy hours, workdays								
	Fast	Normal	Slow	Short	Medium	Long	Downhill	Flat	Uphill
6	4.0	1.8	0.2	1.5	3.0	1.5	4.1	1.1	0.8
7	12.0	5.9	0.8	4.7	9.0	5.0	11.9	4.5	2.3
8	12.1	10.9	1.9	8.2	10.4	6.3	14.0	6.8	4.3
9	7.3	6.1	1.6	5.5	5.6	3.9	7.7	4.7	2.5
10	2.8	2.6	1.7	2.1	3.0	2.1	3.8	1.8	1.7
11, 12, 13	3.3	5.1	2.1	3.7	5.0	1.8	5.2	2.9	2.4
14	7.6	12.3	6.5	9.1	12.7	4.5	12.1	7.6	6.7
15	6.7	11.0	7.9	8.7	11.4	5.5	9.2	7.6	8.8
16	16.2	21.5	9.5	16.4	21.4	9.4	16.1	13.3	17.8
17	16.8	22.5	11.2	18.6	22.6	9.3	19.6	14.8	16.2
18	14.9	19.4	9.6	15.8	19.1	8.9	17.8	11.7	14.4
19	13.6	17.8	9.5	14.6	18.2	8.1	16.7	11.0	13.1
20, 21, 22	5.8	8.3	4.3	6.4	8.1	3.9	8.0	4.7	5.7
23	3.6	3.9	2.0	3.1	4.6	1.8	3.0	2.5	3.9

5.2.2 Weekends

Table 7 and Table 8 uses the same formatting rules and can therefore easily be compared.

The sensitivity to temperature for the shared bicycle trip demand at weekends seems to be much of the same both for non-rainy hours (Table 7) and rainy hours (Table 8) for all types of trips.

The temperature does not have a considerable effect on the shared bicycle usage during the morning hours in the weekends. Temperature has the biggest effect on the shared bicycle usage in the afternoon as well as in the evenings. At hours without rain, shared bicycles are also attractive late at night when the weather is warm.

At weekends, fast trips and long trips are least sensitive to temperature variances. In general, very few trips are made at a fast pace during the weekends.

Table 7 – The coefficient value between the number of different types of shared bicycle trips per hour and the temperature, non-rainy hours, weekends.

	Non-rainy hours, weekends								
Clock hour	Fast	Normal	Slow	Short	Medium	Long	Downhill	Flat	Uphill
6, 7, 8	2.5	1.4	0.5	1.1	2.1	1.2	2.4	0.9	1.1
9, 10, 11	4.3	6.6	4.9	4.5	6.7	4.5	8.2	4.3	3.3
12, 13, 14, 15, 16	4.1	12.1	13.2	8.1	13.4	7.9	10.7	10.2	8.6
17, 18, 19, 20	6.8	15.2	13.2	11.0	15.8	8.4	12.8	11.0	11.5
21, 22, 23	6.6	10.9	8.5	8.8	11.8	5.4	10.5	7.6	8.0

Table 8 – The coefficient value between the number of different types of shared bicycle trips per hour and the temperature, rainy hours, weekends.

	Rainy hours, weekends								
Clock hour	Fast	Normal	Slow	Short	Medium	Long	Downhill	Flat	Uphill
6, 7, 8	2.2	1.4	0.4	1.6	1.8	0.6	2.2	0.8	1.0
9, 10, 11	4.4	4.3	1.8	3.2	5.1	2.2	5.4	3.5	1.6
12, 13, 14, 15, 16	6.4	16.6	14.7	13.8	16.7	7.1	15.1	12.7	9.8
17, 18, 19, 20	4.9	11.8	8.3	9.4	10.5	5.2	8.4	8.2	8.5
21, 22, 23	2.8	4.4	2.5	3.1	4.4	2.2	4.5	2.5	2.8

6. Discussion

6.1 About the study

6.1.1 Shared bicycle schemes ability to explain travel habits

The findings and results from this study are not necessarily transferable to walking and cycling in general, but the variation in the shared bicycle usage can explain the attractiveness under different weather conditions for bicycling in general.

Most shared bicycle trips can quite easily be substituted by walking, cycling and public transportation. Hence, making it difficult to say whether a registered decrease in shared bicycle usage is caused by less travelling in general or if the trips are being substituted by other travel modes. Further research on the relationship between shared bicycles and other travel modes will create possibilities to use the existing data from shared bicycle schemes to better understand travel habits, also for other travel modes.

6.1.2 Oslo compared to other cities

Oslo is a city with rather large height differences in and around the city centre (Figure 1). Different topographies in other cities might lead to different variance in shared bicycle usage.

Wind was not included and therefore not examined in this study. Cities with stronger wind capacities might find that the wind might have an influence on the travel patterns. Oslo has a rather cold climate. Cities with different climate conditions might find that the weather variances affects the shared bicycle usage differently than it does in Oslo.

The shared bicycle scheme in Oslo opened early April and closed late November due to snow during the winter season. It is possible that cities with shared bicycle schemes open all year round might have a larger portion of travellers that use shared bicycles as a permanent part of their travel habits compared to Oslo and other cities who close during the winter season.

6.1.3 The availability of data from shared bicycle schemes

The data from the shared bicycle scheme in Oslo used in this study are publicly available. The analyses conducted in this study show only a small portion of how these datasets can be used to gain knowledge on travel behaviour, among other things. Knowing that it is increasingly difficult to recruit participants to undertake travel surveys (Hjorthol, et al., 2014), it is important to find other ways of registering travel patterns. Finding ways of utilizing “big data”, for instance data from shared bicycle schemes, is therefore important.

There is great potential in using “big data” in studies on travel patterns and travel behaviours. However, gaining access to those types of data, in addition to processing and analysing them, can be rather time consuming and difficult for students and researchers. It is therefore important that these datasets are made available to researchers. The shared bicycle schemes are often run by private businesses, but the government or municipalities are involved in buying the schemes and services and/or giving the companies access to doing business in the cities. When making those deals the public offices have a responsibility to make sure that the data are accessible for free to relevant research.

6.2 Shared bicycle trips

Shared bicycles are used to a variety of different purposes. Trips are made at a fast, normal and slow pace, over short and long distances, and both uphill and downhill. There are great daily, weekly and yearly variances in the shared

Downhill trips are more popular than uphill trips, making it necessary for the operators of the shared bicycle schemes to regularly move bikes between stations. The possibility to cycle one direction without having to cycle back later is one of the largest advantages to shared bicycle schemes for the members (Fishman, et al., 2014).

6.2.1 Temperature

Shared bicycle usage is strongly correlated to temperature. All the nine types of trips defined in this study were found to be positive correlated to temperature – the number of trips made were greater at warm days than at those of cold days, both for workdays and weekends. This was also true for both rainy and non-rainy hours.

The different categories of trips most affected by the temperature are the number of trips made at a normal pace and trips made over medium long distances. This illustrates the challenge Norwegian cities are facing in making cycling and walking more attractive during the cold and rainy periods of the year.

6.2.2 Rain

Rain has the smallest impact on the demand for shared bicycle in the morning rush hours. Those trips are a regular part of most individuals travel habits, illustrating that shared bicycles are regularly used for commuting.

Slow trips and long trips are the categories of trips most affected by rain, both at workdays and weekends. The former, typically recreational trips, are not popular and probably not taken at all when the weather is bad. Long trips on the other hand, are more likely to be substituted by other transport modes like public transportation and cars when the weather is bad.

Short trips and fast trips are two categories least affected by rain. Especially for short trips, other transport modes rarely represent good alternatives – besides walking. When raining, cycling is still attractive for short trips and fast trips. This is likely due to cycling being the faster means of travel, thus travellers will be exposed to rain for a shorter period.

Trips cycled at a fast pace are less sensitive to rain relative to trips cycled at normal speed and slow speed. Fast trips are likely to be made on a more regular basis, like commutes, and they are an important part of the cyclists' travel routines, thus having less change in demand from day to day based on changes in weather. The relatively small percentage decrease in the number of fast trips when raining may also be due to some regular trips being cycled at a higher pace than usual when raining – travellers changing travel behaviour from normal speed cycling to fast speed cycling, thus increasing the relative number of trips made at a fast pace.

6.2.3 Other

During the study it became clear that the shared bicycle usage at one part of the day rarely gets affected by the weather at a different part of the day. For instance, the shared bicycle usage will be *normal* in the morning if the weather is *normal*, even if there might be forecasted a great amount of rain in the afternoon. This illustrates the travel flexibility that shared bicycle schemes offer and underlines how the shared bicycles offer a different travel alternative to what regular cycling does.

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