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Bike share use among young people in Tartu: a demographic and spatial analysis

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Abstract

Bike share use among young people in Tartu: a demographic and spatial analysis

Cycling is a sustainable transportation alternative, while bike share represents a potential means of popularising it. Moreover, bike share use is generally higher among relatively younger people. Considering that young people including university students, may be regarded as a target market for bike share, it is reasonable to suggest that the success of bike share in Tartu might be at least partly attributable to its substantial population of students. This master's thesis sought to assess young people's use of Tartu's bike share system relative to those of older ages while also analysing the effects of seasonal, temporal, and built environment factors on its ridership across age groups. The study mainly employed bike share trip data with pseudonymised user information spanning one year. Negative binomial regression was used to investigate the variables' effects on ridership across age groups. The results showed that young people (14–24 years) accounted for roughly half of Tartu's bike share users and trips, considering both total distance and duration travelled. The younger group rode more in connection with shopping and recreational facilities while also being willing to ride farther and in less favourable seasons. Seasonal, temporal, and built environment factors appear to influence ridership overall, but their effects vary across age groups.

Keywords: Bike share system, active transportation, youth mobility, regression analysis.

CERCS code: S230 – Social geography

Abstrakt

Rattaringluse kasutus Tartu noorte hulgas: demograafiline ja ruumiline analüüs

Jalgrattasõit on jätkusuutlik alternatiiv motoriseeritud transpordiviisidele ja rattaringlus on selle potentsiaalne populariseerimise vahend. Rattaringluse kasutajate hulgas on suhteliselt rohkem noori inimesi. Seega, kui rattaringluse sihtrühmaks on eelkõige noored, sealhulgas tudengid, on mõistlik oletada, et rattaringluse edukus Tartus võib olla vähemalt osaliselt seotud suure üliõpilaste ja noorte hulgaga piirkonnas. Siinse magistritöö eesmärk on võrrelda noorema- ja vanemaealiste kasutajate rattaringluse kasutamise mustreid Tartus, analüüsides samal ajal ajaliste ja ruumiliste tegurite mõju rattaringluse kasutusele vanuserühmade lõikes. Uuringu peamine andmeallikas on pseudonüümitud rattaringluse andmed (laenutuste andmed rattaringlusjaamade lõikes)ühe aasta kohta. Töös on kasutatud negatiivset binoomregressiooni, et selgitada muutujate mõju rattaringluse kasutusele vanuserühmade lõikes. Tulemused näitavad, et noored (14–24-aastased kasutajad) moodustavad Tartu rattaringluse kasutajatest ja kasutuskordadest ligikaudu poole, arvestades nii läbitud kogudistantsi kui ka -kestust. Nooremaealised kasutavad rattaringlust rohkem seoses ostu- ja puhkevõimalustega, olles samal ajal valmis sõitma ka kaugemale ja rattasõiduks vähem soodsatel aastaaegadel kui vanemaealised. Üldiselt mõjutavad rattaringluse kasutust hooajalised, nädalapäeva ja tehiskeskkonnaga seotud tegurid, kuid nende mõju on vanuserühmades erinev.

Märksõnad: Rattaringlus, aktiivne transport, noorte mobiilsus, regressioonanalüüs, Tartu.

CERCS kood: S230 – sotsiaalne geograafia

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1. Introduction

Humans are bound to move daily, and the impact of human mobility on society is immense; therefore, understanding the statistical patterns that characterise the temporal rhythm of human mobility in their daily activities is highly valuable (Song et al., 2010). The study of human mobility is an ever-evolving concept as new methodologies are regularly introduced. In recent years, emerging technologies such as GPS, Call Detail Record (CDR), Wi-Fi, and Bluetooth have provided a greater understanding of human mobility (Noulas et al., 2012; Palchykov et al., 2014; Silm et al., 2021).

It has become necessary to continually meet the mobility demands of the rapidly growing urban population while addressing equity and environmental issues. Inhabitants of cities will persistently demand quick, efficient, cost-effective, reliable, and eco-friendly transportation. Providing such mobility options is one of the critical challenges for future cities. Transportation contributed nearly 25% of all greenhouse gas emissions in 2017, and about 71% of transportation emissions were attributed to road transport, with over 60% produced by cars in the European Union (European Commission, 2022). These trends mean that car travel contributed almost 11% of all greenhouse gas emissions in the EU. Recent studies have established short car trips as the main culprits of car emissions, with less than 3 km journeys accounting for 30% of European car trips (Karanikola et al., 2018).

The provision of sustainable transportation represents an ideal opportunity to reduce greenhouse gas emissions from transportation. Walking, cycling, and public transport have generally been used to improve sustainable mobility in cities. Walking and cycling for short journeys have been established to offer enormous benefits for human health and the environment in urban areas (Chen et al., 2022). Bike share systems (hereinafter: BSS) have become a sustainable mobility option in many cities for short distances and car trips (Lee et al., 2022; Zainuddin et al., 2016). The European Commission has emphasised that investments of this kind are relatively environmentally friendly, sustainable, and more beneficial to society than other transport systems (Stead, 2007).

In recent years, numerous studies have assessed circumstances surrounding the dynamics and success of BSS. Key performance indicators of BSS are typically reductions in greenhouse gas emissions, health improvements, time, cost savings compared to other modes, safety, trips per day per bike (TDB) and accessibility (Mattson & Godavarthy, 2017; Yanocha et al., 2018). In general, most studies of BSS reveal that small cities with a population of less than 100,000 have been outside the top performers. In a global study of 75 BSS, cities with a population of less than 200,000 were outside the top 15 (Médard de Chardon et al., 2017). A further review of BSS in 51 European cities showed that bike share in small cities generally performed less effectively (Büttner & Petersen, 2011).

The great popularity of the bike share system in Tartu, Estonia, stands out as it is rare to find strongly performing bike sharing systems in smaller cities. Bike share use is generally higher among younger people, with a small proportion of the population being responsible for a large portion of ridership in many cities (Médard de Chardon, 2019). Considering that young people, including university students, may be regarded as a target market for bike share, it is reasonable to suggest that the success of bike share in Tartu might be at least partly attributable to its substantial population of students and young people.

Thus, this master thesis explored young people's use of Tartu's bike share system by gathering and analysing bike share trip data with pseudonymised user information. The following research questions were asked to achieve the aim of the thesis:

1. How do young people in Tartu use the bike share system relative to older people?
2. How do built environment, seasonal, and temporal factors affect Tartu's bike share ridership across age groups?

This research will contribute to future sustainable mobility infrastructure planning and studies employing bike share datasets. The study will help to understand the factors influencing the success of Tartu's bike share performance. The results may further improve the city's bike share program and inform the implementation of bike share in other cities, particularly small cities.

2. Theory

2.1 Human mobility

Mobility is the movement of humans and groups from one point to another in space and time. The activity of humans has continuously been undistinguishably linked with their existence (Barbosa et al., 2018). Past movement patterns of humans were influenced mainly by factors including climate change, dilapidated landscapes, war, and food shortages. With increasing globalisation, current influences include socio-economic and environmental factors such as disparities in income inequality, welfare and living standards (González et al., 2008). The temporal and spatial dimensions of urban movements are known to be shorter than migratory flows and are frequently characterised by the consistencies that define the life of a human (Barbosa et al., 2018).

Even though research into human mobility presently spans numerous fields, geography is the first discipline to investigate mobility data and recommend techniques to explain human mobility patterns (Barbosa et al., 2018). The importance of the dynamics surrounding human mobility cannot be underestimated, as they form a foundation for generating insights in fields ranging from urban planning, population estimation, and traffic assessment to disaster management (Lu et al., 2012; Noulas et al., 2012; Palchykov et al., 2014).

Over the years, the emergence of positioning systems and technologies, such as the global positioning system, cellular radio tower geo-positioning, and Wi-Fi positioning systems, has driven efforts to collect human mobility data and to identify patterns of interest within these data for the promotion of the development of location-based services and applications (Silm et al., 2021; Toch et al., 2019). These datasets considerably vary in their reach and resolution; however, the results settle on several quantitative models of human mobility (Song et al., 2010).

2.2 Urban transportation

Urban transportation refers to how people move in cities, with mobility patterns such as walking to school, cycling to the market, driving to workplaces or using public transport. About 68% of the projected world population will be urban dwellers, with vehicles on the road doubling to nearly two billion by 2050 (United Nations, 2019). With the increasing urban population, the demand for transportation is on the rise. Vehicular traffic increase creates additional mobility-related problems (traffic congestion, noise, and accidents), especially in cities (Farahani et al., 2013). Road-based networks and individual modes of transportation, including single-occupant vehicles, single-passenger cars, personal cars, and taxis, serve the transportation needs of most urban residents for commuting. These lead to minimal traffic efficacy caused by low utility, lack of sharing, and low occupancy levels (Zhu et al., 2016). In as much as cars provide convenient transportation for city inhabitants, the surge in vehicles increases energy utilisation and carbon dioxide (CO_2) emissions, which causes significant environmental pollution. It has become necessary to optimise the transport system to enhance the sustainable development of urban transportation (Qiang et al., 2018).

Transportation emissions are responsible for approximately 20% of global greenhouse gas emissions. Road travel alone equated to about 77% of transport emissions, with passenger vehicles contributing almost 47% in 2018, as shown in Figure 1 (Hall & Lutsey, 2019; Ritchie, 2020). In 2019, approximately 25% of the EU's total greenhouse gas emissions were from the transportation sector, which has increased in recent years (European Commission, 2022). Short car trips have been established as one of the main contributors to transportation (passenger vehicle) emissions (Unger et al., 2010), with journeys of less than 3km accounting for nearly a quarter of European car trips (de Nazelle et al., 2010).

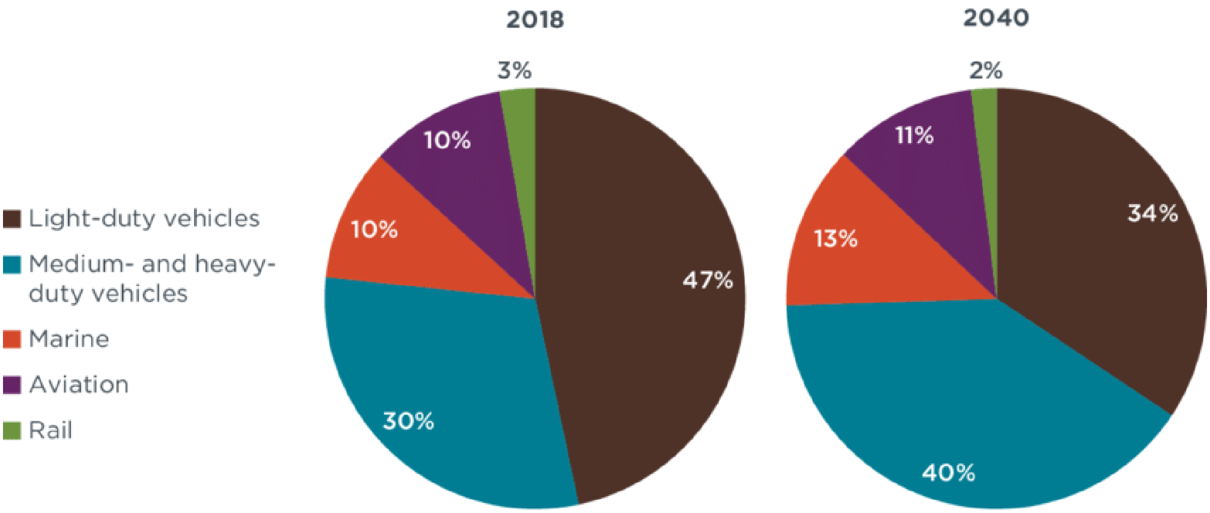

Figure 1: Global transport sector greenhouse gas emissions by transport mode in 2018 and a forecast in 2040 (Source: Hall & Lutsey, 2019)

These facts show how society's reliance on cars substantially increases greenhouse gas emission rates (Banister, 2008). As greenhouse gases contribute significantly to global warming, changes in transportation will be crucial in achieving the Paris Agreement goal of keeping the global temperature rise below 2°C (United Nations, 2015). The achievement of a drastic reduction of CO_2 emissions from the transportation sector over the next half-century will be a difficult task. Reaching this milestone requires policies to promote modal shifts to the least carbon-intensive mobility alternatives, as well as actions to lower the carbon footprints of all transport modes (International Energy Agency, 2022).

2.3 Sustainable transportation alternatives

Sustainable and inclusive mobility concepts are critical for operating transportation in an eco-friendly, socially appropriate, and economically practical approach (Poltimäe et al., 2022; Semanjski et al., 2016). Promoting sustainable transportation is highly valuable with respect to the fight against global warming and fostering human well-being, especially in cities (Gillis et al., 2016; Rajak et al., 2016). A modal shift has been claimed to enhance the operationality of sustainable transportation. More environmentally sound transportation modes, such as bicycles and public transportation, have been linked with reduced car travel (Gössling et al., 2018; Sdoukopoulos et al., 2019). Walking and cycling are both healthier and more eco-friendly than car travel and have frequently been advocated as active alternative transport modes (Banister, 2008). Cities are trying to accomplish this modal shift by upgrading their cycling and walking infrastructure, supporting multimodality, restricting car parking spots, and enforcing higher fees for the use of roads (Hickman & Banister, 2019).

Sharing vehicles and bicycles instead of owning them privately as well as using modern innovations to connect users and providers, is a form of mobility in the shared economy (Santos, 2018; Shaheen et al., 2010). These emerging forms of alternate transport can reduce the number of vehicles, easing traffic congestion and the demand for parking spaces (Machado et al., 2018). Shared mobility allows urban dwellers to schedule and pay for trips and rent bicycles or cars. (Shaheen et al., 2010), which has been associated with decreased motorised vehicle use (Fishman et al., 2014). Sustainable modes like bike share systems for short car trips are gaining ground as residents have become increasingly aware of the need to combat climate change, especially in European cities (Rojas-Rueda et al., 2011).

2.4 Bike share systems

Bike share systems (BSS) have evolved from manually managed bike rentals to the modern and technologically developed systems available in numerous cities today. This idea of bike sharing has stayed the same, enabling riders to pick up bikes from one point and return them to the same or another spot (Macioszek et al., 2020; Yanocha et al., 2018). The demand for

BSS have been around longer in Europe than in other continents, with the overall popularity of the system having progressed rapidly in European, Asian, and American cities (DeMaio, 2009; Karanikola et al., 2018).

Several cities have created extra space for car travel, sacrificing alternative land uses and streetscapes scaled to the pedestrian (Macioszek et al., 2020). As governments increasingly implement policies that prioritise space for people, BSS represent a promising way to promote alternative travel modes (Karanikola et al., 2018; Macioszek et al., 2020; Mattson & Godavarthy, 2017). BSS are seen as an essential supplement to public transportation and ridesharing services, with the system playing a vital role in enabling urban inhabitants to live car-free, significantly alleviating short car trips and decreasing vehicle travel and traffic congestion (Yanocha et al., 2018).

Bike share systems are presently operating in over 3,000 cities, offering a flexible mobility alternative for short trips and switching between various means of transport (Meddin et al., 2021). With larger cities mostly implementing BSS, its sustainability and efficiency have encouraged relatively less populated cities to introduce similar systems (Godavarthy & Rahim Taleqani, 2017; Shaheen et al., 2010). BSS comprises docked or dockless bikes, and users can usually unlock bikes through an application or specific cards. These bikes are sometimes fitted with GPS and a timer that records the bike's origin, destination, and tracks, as well as the duration of usage. Understanding the trip purpose in docked BSS has sometimes proved challenging to ascertain (Lee et al., 2022; Wang et al., 2018; Xing et al., 2020). This phenomenon is mainly due to the obligation of the user to check out the bicycle at one station and return it to a dock station which is likely not their actual origin and destination. However, due to data sensitivity, linking additional user-level information involves compliance with strict data integrity rules, individual consent, and complete adherence to research ethics (Willberg et al., 2021). Therefore stand-alone data derived from docked BSS cannot fully account for why riders select bike share for trips (Xing et al., 2020).

2.4.1 Demography and bike share systems

Studies of bike share use across demographic groups other than age and gender are limited, given that most systems do not collect extensive demographic data (Mattson & Godavarthy, 2017). However, evidence reveals that a particular demographic group is often responsible for a large portion of bike share membership and trips (Médard de Chardon, 2019).

A study of Dublinbikes in Dublin (Ireland) showed that 58.8% of its users were between the ages of 25 and 36, with a predominantly male-dominated membership (Murphy & Usher, 2015). A similar trend was seen in a BSS study of five North American cities (Montreal, Toronto, Salt Lake City, Minneapolis-Saint Paul, and Mexico City), with users between 25 and 34 years strongly represented (Shaheen et al., 2017). According to studies in London, people under 45 years contributed about 78% of bike share travel time (Woodcock et al., 2014), whilst male users made up more than 80% of bike share memberships (Goodman & Cheshire, 2014). Great Rides Bike Share, Fargo (North Dakota, USA), launched in 2015, had 95% and 96% of trips made on the college campus in 2015 and 2016, respectively (Mattson & Godavarthy, 2017). Lyon's Velvov bike share in France appeared to achieve rapid success due to the socio-demographic characteristics of members residing or working around bike stations (students, qualified professionals, and one-person households). This phenomenon was associated with the unbalanced spatial distribution of its bike stations, which seemed to have targeted socio-economically active areas, universities, and transport interchange areas (Ricci, 2015).

Limitations to a more egalitarian bike share use include the frequent requirement for a debit or credit card as a payment medium (Goodman & Cheshire, 2014; Murphy & Usher, 2015). However, in determining the biased composition of bike share user membership, several underlying factors are possible contributing factors (Ricci, 2015). The demography of bike share users may be significantly influenced by spatial coverage, pricing, inadequate bicycle infrastructure, poor knowledge and negative perceptions of bike share (McNeil et al., 2018). This demographic phenomenon was also evident through the case studies on Barclays Cycle Hire in London, U.K (Goodman & Cheshire, 2014; Ogilvie & Goodman, 2012).

2.4.2 Factors affecting the demand for bike share systems

Natural and physical environmental features are considered to impact the general performance of bike share systems. Ambient temperature in cities is one of the factors affecting BSS's patronisation (Mattson & Godavarthy, 2017). Precipitation, snowfall, and humidity were found to correlate negatively with ridership in a study in Canada (El-Assi et al., 2017). This phenomenon explains, for example, why the BSS in Fargo (North Dakota, USA) is not in operation during winter; the operation period spans from March to October due to the harsh winter weather (Mattson & Godavarthy, 2017). Questions were raised in small cities where the BSS depended heavily on college students, whether they should operate during college vacation. These BSS witnessed low patronage during the summer when these students returned home (Gilbert et al., 2021).

The location and distribution of bike docks are considered to significantly influence the success of any BSS (Lin & Yang, 2011). Also affecting bike share use is the quality of cycling infrastructure, with evidence indicating that bike share is likely to be more successful when available (Mattson & Godavarthy, 2017). Recent studies also discovered that participation in BSS increased with the proximity of docks to bike lanes (Dill & Voros, 2007; Kabak et al., 2018). In other studies, it was evident that the desire to cycle declines when the bicycle routes pass through heavily congested roads and intersections (Hoe, 2015; Mattson & Godavarthy, 2017). Bike share demand is generally high at stations closer to city centres, recreational areas, schools, restaurants, and shopping centres (Kabak et al., 2018; Wang et al., 2018). This phenomenon is usually reflected in the geographical distribution of bike stations relative to the built environment, with bike stations usually centred around these points of interest (Eren & Uz, 2020).

2.5 Tartu bike share system

The development of Tartu's bike share system was financed by the urban development measure of the European Regional Development Fund and the Horizon 2020 Programme for European Research and Innovation. According to the Tartu City Government, bike usage is a lifestyle choice that citizens and visitors value (*Bike Share*, 2023). Tartu's bike share system communicates in real-time with the bike share system's data infrastructure, giving information about each bike's current state and location. Software installed in the bikes collects statistical data on origin, destination, speed, distance covered, time and duration of usage. Each bicycle is fitted with a GPS device that logs the location after every five seconds (*Bike Share*, 2023).

The bike share system was a crucial part of the EU-funded "Smart City" initiative of Tartu. The city's main objective under this project included the development of sustainable mobility. Tartu City Government aims to reduce the number of cars, promote physical activities and maintain the "15 minutes to anywhere" concept with the help of the bike share system (*Bike Share*, 2023).

Several studies have used bike share data from Tartu to study topics ranging from urban connectivity to usage patterns. A usage patterns study showed that Tartu's bike share system is becoming integral to public transportation (Kaup, 2021). Furthermore, using the bike share cycling flows as indicators, areas that needed urgent and improved bicycle infrastructure were highlighted (Kaup, 2021). A study of Tartu's urban connectivity from 2021 found that Tartu is a monocentric city, with high connectivity between its central districts regarding trips and user movements compared to other districts (Zubair, 2021).

Figure 2: A bike share station in Tartu (Photo credit: Author)

3. Data and methodology

3.1 Study area

Tartu is the second-largest city in Estonia and the largest urban centre in Southern Estonia. It is located 186 km southeast of Tallinn, the capital of Estonia. Tartu is situated at the banks of River Emajõgi, which connects Lake Võrtsjärv and Lake Peipus, the two largest lakes in Estonia. The population of Tartu, as of December 2022, was 97,299 inhabitants.

The bike share system of Tartu was unveiled on June 8, 2019, and it is operated by Tartu Linnatransport, a division of the city's government. It currently comprises over 750 bikes and more than 90 stations. Two-thirds of the bikes are electrically powered, providing riders an extra boost when pedalling. The electric-assist bikes are actively in use until temperatures fall below freezing. However, regular bikes remain in circulation during cold periods. The city's bike share system is set up so that users with a free ride on the urban lines in Tartu or joint Tartu public transport tickets do not need to buy a separate bike share season ticket. The personalised bus card needs to be connected to the BSS to check the existence and validity of a bike ticket. Users with a season or day ticket can use a bicycle for 60 minutes for free, after which a charge per hour applies. Users without a valid season ticket for the urban lines must acquire a one-hour ticket, a one-day ticket, a 5-day ticket, a 30-day ticket, a 90-day ticket or an annual ticket for the bike share system. The maximum period of bike usage without docking is 5 hours, after which a fee of 80 euros applies (*Bike Share*, 2023). The map of the city showing the bike stations is shown in Figure 3.

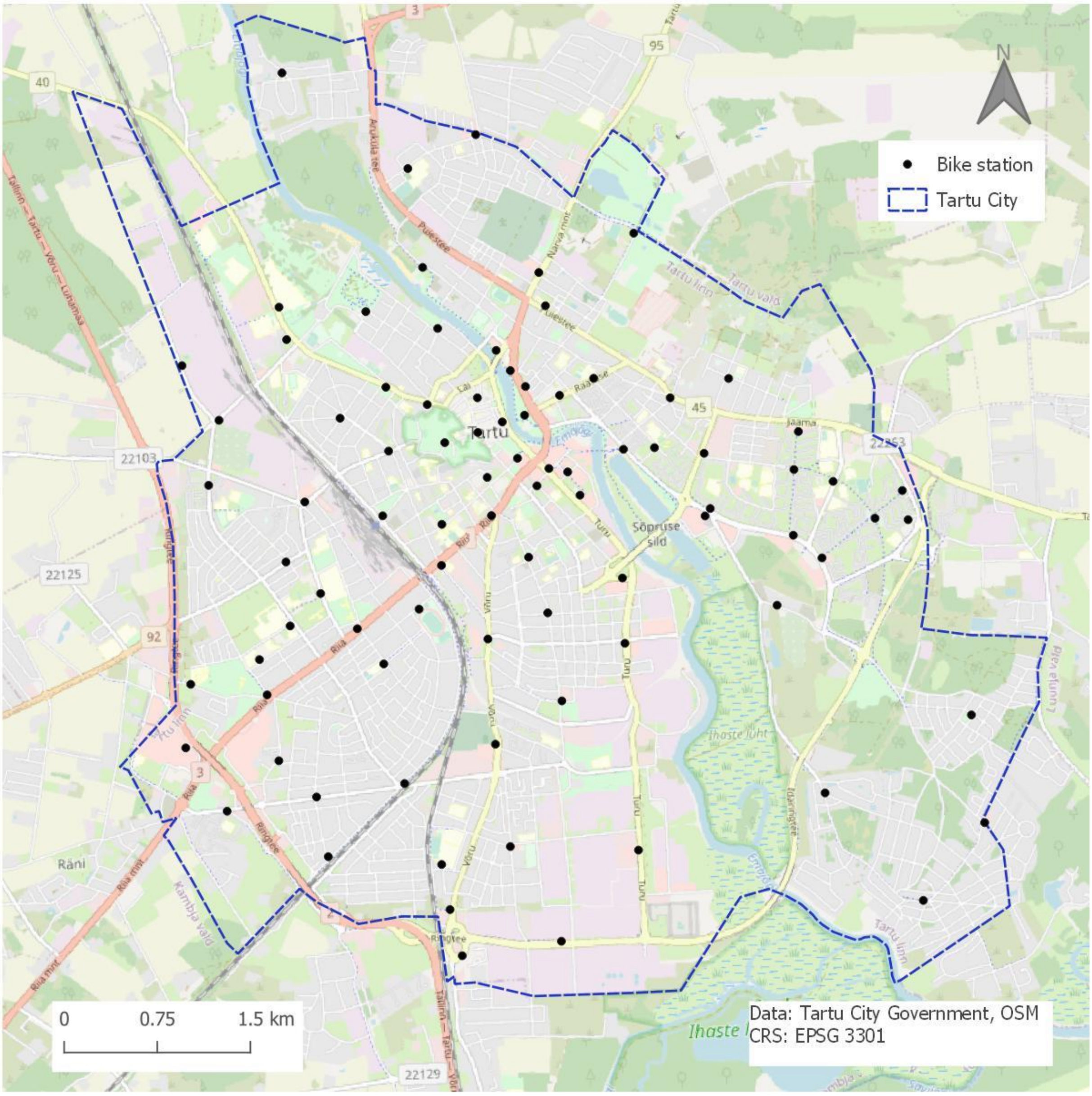

Figure 3: Map of Tartu showing bike stations

3.2 Data

The primary data for the study was sourced from the Tartu City Government through the Mobility Lab of the University of Tartu based on a confidentiality agreement. The data contained bike share trips spanning one year from July 1, 2021, to June 30, 2022. The dataset contained information on 832,391 registered bike trips combined from 18,271 different users. The bike trip dataset entailed the following information on each trip, exemplified in Table 1.

1. UserID: unique Pseudonymised identification for each user.
2. Cycle No: the ID number of the bike used for the trip.
3. Start date: the date bike was unlocked from the dock.
4. Start station: name of the station where the bike was unlocked from the trip's start.
5. End station: name of the station the bike was locked after the trip.
6. Length: the distance the trip covered
7. Duration: the duration of the trip
8. Year: user's year of birth.

Table 1: Sample data from Tartu's bike share system

Cycle No.	Start date	Start station	End station	Length(km)	Year	Duration(min)
2784	2022-01-01	Papli	Soola	1.04	1998	13.36
2639	2021-09-23	Tarmeko	Delta	3.75	2000	21.02
2783	2022-03-12	Uueturu	Paju	3.54	1999	35.65
2758	2021-08-18	Kannikese	Raatuse	2.35	2002	24.44

The supplementary dataset used in this research was the Tartu City boundary shapefile from the Estonian Land Board. 2020 population grid data (500 m x 500 m) was sourced from Statistics Estonia, Point of interest (POI) data from Google, and the location of educational facilities in Tartu (high schools and University infrastructures) from the Ministry of Education and Science, Estonia.

3.3 Methodology

The flowchart in Figure 4 gives an overview of the main processes involved in the research.

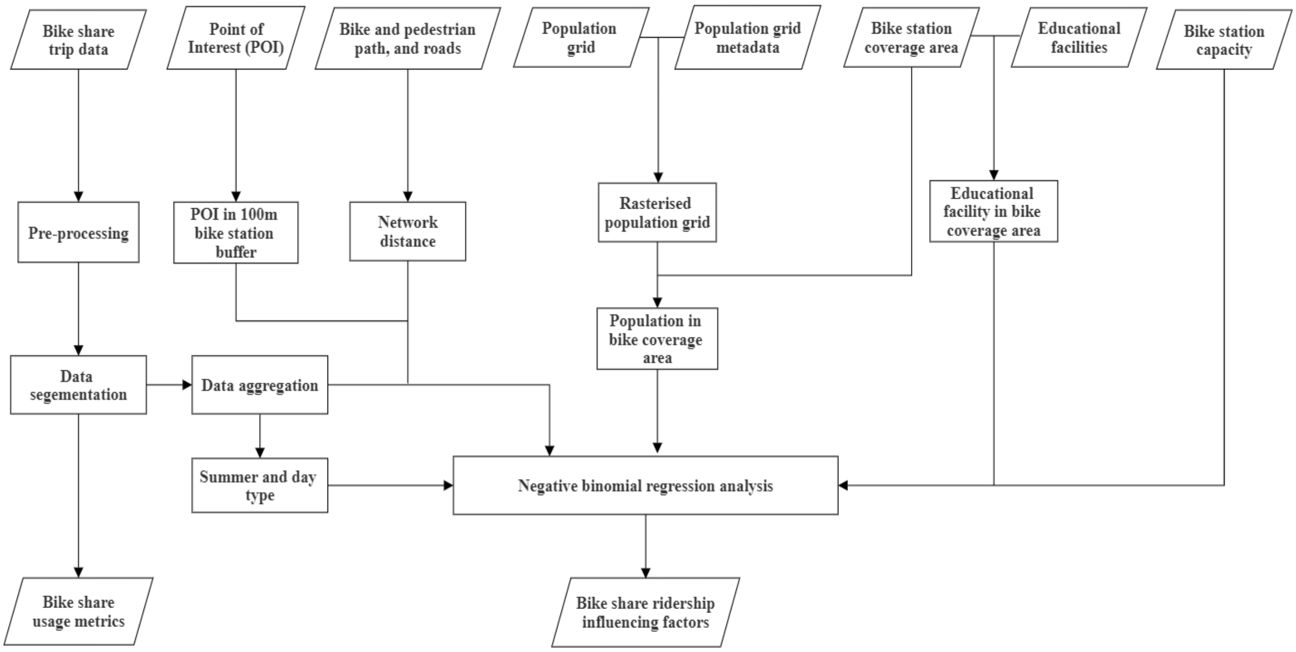

Figure 4: Flowchart of methodology

3.3.1 Data processing

The raw bike trip data was cleaned in the Python environment to make it usable in the research. Trips with null values in relevant columns, like date, start or end station, were removed. Columns with different data types were converted into their appropriate data type. Trips under 1 minute, including those with the same start and end station, were removed. Trips with less than a 1-meter distance recorded were also removed. These trips were assumed not to have taken place, or the user changed the bike. The resulting dataset had 776,725 trips, accounting for 93.31% of the initial data. The month and day of each trip were extracted from the date column and used in creating new columns. The year of birth (YOB) was converted into the user's age at the time the bike trip was made. Columns that were deemed irrelevant to the research were dropped.

3.3.2 Data segmentation

Exploratory data analysis was undertaken to investigate trends in the distribution of the dataset. The cleaned data were plotted to ascertain the statistical variability in terms of the trip length, trip duration, and trip frequency of ridership among these groups. The bike trip dataset was segmented based on the user's age. This procedure was necessary to check for young people's bike share usage relative to older users. The data was sliced to extract the young people's trips (14 – 24 years) in the dataset to enable further comparison with older users.

3.3.3 Data aggregation

Previous studies aggregated bike station ridership data in various forms (i.e. daily, weekly and monthly) (He et al., 2019; Mattson & Godavarthy, 2017; Scott & Ciuro, 2019). This study aggregated the daily number of check-outs and check-ins at each bike station to capture the influence of seasonal, spatial and temporal attributes. The data were grouped to extract the total number of check-outs and check-ins at each bike dock per day during the study period for each group. A dummy data was initially created to include days that recorded no check-outs or check-ins. This dummy data spanned the study period with each row displaying information on the date and each bike station on that day. The dummy data was merged with aggregated data on the date and bike station. The resulting data included no values for bike stations which recorded no bike trips on particular days. These rows were filled with zero to reflect ground data.

The dataset represented 94 bike stations in total, with 86 stations within the Tartu City boundary. The locations of the stations within the city boundary were relatively compact, as the ones outside the city limits were spread out. The stations within Tartu City were extracted as they form the study's focus area. The total number of check-outs and check-ins at these bike stations formed the dependent variable that was modelled further in the analysis. Table 2 represents a sample of the aggregated daily trip at the station level.

Table 2: A sample of the bike share trip data in Tartu aggregated by station and date

Date	Station	Total
01/01/2022	Soola	5
01/01/2022	Tarmeko	4
01/01/2022	Vabadussild	3
01/01/2022	Raudteejam	8

3.3.3 Ridership model

A regression model enables an assessment of the influence of several independent variables on a dependent variable. The model is supposed to be a function of variables affecting the daily rate of trips per bike station and variables affecting the tendency of people to use Tartu's bike share system. Various temporal, spatial, and seasonal variables were selected. The Poisson regression model is a commonly used multivariate count data model (He et al., 2019; Mattson & Godavarthy, 2017). However, the negative binomial regression is better suited for over-dispersed count data with a high differential between the variance and the mean, as discovered with the research data (Hilbe, 2011). The negative binomial regression model is an extension of the Poisson regression model, which makes room for overdispersion by introducing an additional parameter that regulates the variance (Cameron & Trivedi, 1986). Maximum likelihood estimation is employed in fitting the model in negative binomial regression, where the dependent variable follows a negative binomial distribution. The expected difference in the log count for a unit change in the relevant predictor variable can be deduced from the model coefficients.

The general formula for negative binomial regression is as follows:

$$log((\boldsymbol{Y}) = \boldsymbol{\alpha} + \boldsymbol{\beta X}$$

Where $\boldsymbol{Y}$ is the dependent variable vector, α is the intercept, $\boldsymbol{\beta}$ is the vector of the regression coefficients, and $\boldsymbol{X}$ is the vector of the independent variables. The independent variables used in the negative binomial model are described as follows. Summer is generally warm and usually, a season of high bike ridership, while other seasons usually record relatively low ridership because of snow, low temperatures, and increased precipitation (He et al., 2019; Mattson & Godavarthy, 2017). Rides in the summer season for this research ranged from June to August. Therefore, a dummy variable stating the season is included as an independent variable to investigate the statistical influence of the summer season on ridership. Weekends or weekdays are included as independent variables in the model as well. This research calculated the shortest network distance from each bike dock to the city centre using bike paths, pedestrian paths, and road networks. Tartu city is not fully connected with well-defined bike paths; therefore, bike riders sometimes use pedestrian paths and road shoulders to their destination. The city centre of the model was the connection between four roads (Narva mnt, Riia, Vabaduse pst and Turu) in the central business district.

Each bike station's area of influence (coverage area) within the city limit was constructed using Voronoi polygons. Voronoi polygons are space-filling, convex polygons generated around a set of points, or centres, where each polygon consist of all the points closer to its centre than the centres of other polygons, as seen in Figure 5 (Evans & Jones, 1987). The presence of an educational facility in a station's coverage usually attracts bike ridership at that station. Their presence in each polygon were explored, with the results recorded as a binary variable for each bike station. The Voronoi polygons of the bike stations covering the city are visualised in Figure 5.

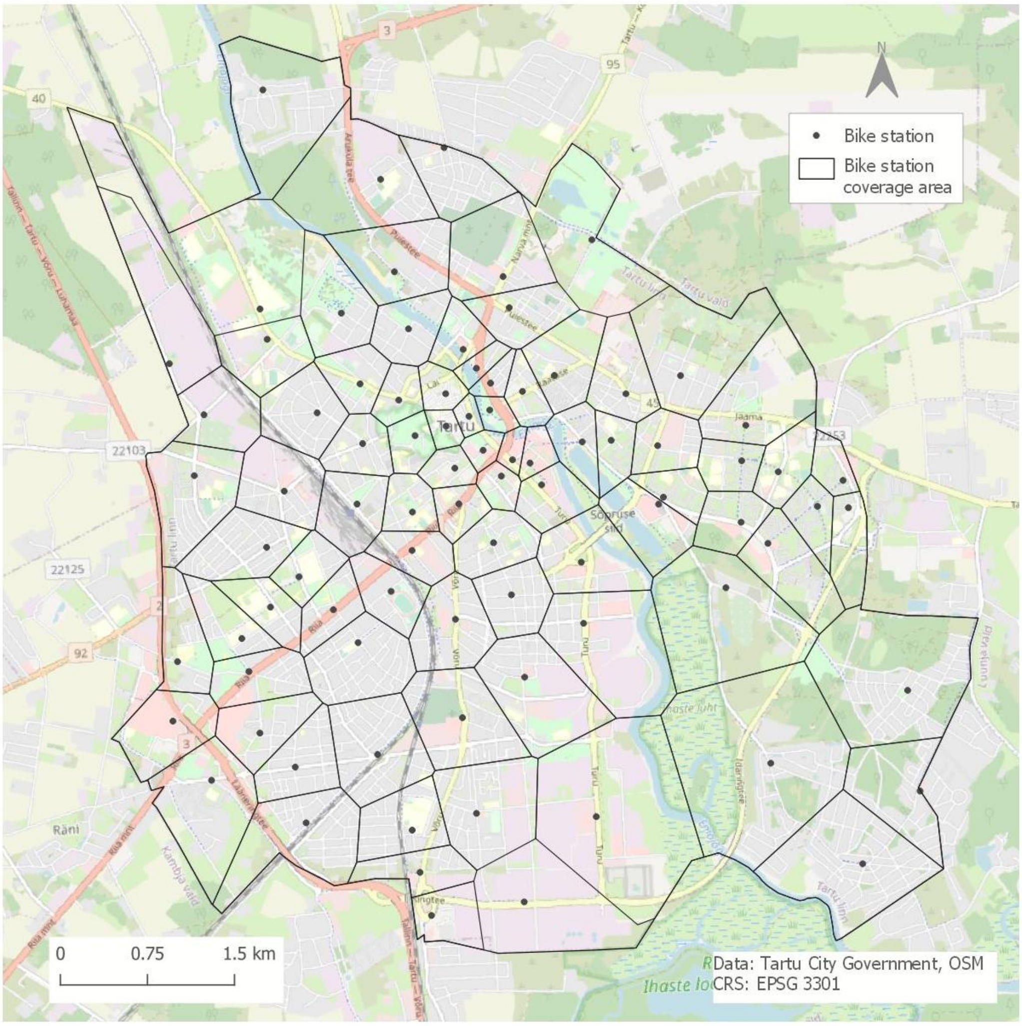

Figure 5: Tartu bike share system station's coverage area

The population density of eligible riders in each polygon was investigated using data from the 2020 population census. The population data was available in a 500 m x 500 m vector grid with an adjoining Excel sheet containing the metadata. Each grid's population of eligible users was computed and joined with the grided vector data. This vector format data was clipped and rasterised, converting it to a raster file. Raster zonal statistics was employed to calculate the population density in each polygon to ascertain the eligible users living in the coverage area of each polygon.

Points of interest (POI) affect bike trip frequency, such as parks, commercial shopping, restaurants, and businesses within a specified buffer around a bike station (Scott & Ciuro, 2019). The presence of a POI around a bike station was investigated from Google POI data and included in the regression model. Varying bike station buffer zones have been used in previous literature based on the study's purpose (Eren & Uz, 2020; Lee et al., 2022; Sa & Lee, 2018; Xing et al., 2020). It was established that the ideal station buffer radius for determining the immediate effect of the built environment influences on bike trip usage was 100 m (Lee et al., 2022; Xing et al., 2020). Therefore, this study adopted a similar 100 m buffer radius to determine the presence of POIs around a bike station. The categories of the POIs are shown in Table 3.

Table 3: The categories and types of POIs derived from Google

Category	POI types
Leisure	Amusement Park, nature park, tourist sites, cinema, bar, night club, casino, gym, stadium, beauty salon and spa
Shopping	Book shop, bicycle store, clothing store, department store, electronics store, florist, furniture store, hardware accessories, general home goods store, jewellery store, pet store, pharmacy, supermarket
Dining	cafe, restaurant, and bakery

The negative binomial regression model developed for the daily ridership at each station is as follows:

$$\text{Log } (R_{it}) = \beta_0 + \beta_1 Capacity_i + \beta_2 Distance_i + \beta_3 Population_i + \beta_4 Education_i + \beta_5 Leisure_i + \beta_6 Shopping_i + \beta_7 Dining_i + \beta_8 Weekday_t + \beta_9 Summer_t$$

where R_{it} = the number of check-outs and check-ins at station *i* on day *t*, $Capacity_i$ = the number of docking slots at station *i*, $Distance_i$ = distance from station *i* to the city centre, $Population_i$ = population of eligible users in the coverage area of station *i*, $Education_i$ = a dummy variable for the presence of an educational facility in the coverage area of station *i* (1 for availability and 0 for otherwise), $Leisure_i$ = a dummy variable for the presence of a leisure facility in the 100 m buffer around station *i* (1 for availability and 0 for otherwise), $Shopping_i$ = a dummy variable for the presence of a shopping facility in the 100 m buffer around station *i* (1 for availability and 0 for otherwise), $Dining_i$ = a dummy variable for the presence of a dining service in the 100 m buffer around station *i* (1 for availability and 0 for otherwise), $Weekday_t$ = a dummy variable for working days, Monday to Friday (1 for weekdays and 0 for weekends), $Summer_t$ = a dummy variable for summer season (1 for summer and 0 for otherwise), and β_0 = intercept, $\beta_1 - \beta_9$ = coefficients of the independent variables. The descriptive statistics of the variables used in the regression analysis for the age groups is shown in Table 4.

Table 4: Descriptive statistics of regression variables

Variable	Description	Mean	SD	Min.	Max.
R_{it} *(all ages)*	daily number of check-outs and check-ins at each station from all users	55.0	60.5	0	661
R_{it} *(14 – 19)*	daily number of check-outs and check-ins at each station of users aged between 14 and 19	24.8	22.3	0	124
R_{it} *(20 – 24)*	daily number of check-outs and check-ins at each station of users aged between 20 and 24	32.6	34.8	0	371
R_{it} *(25+)*	daily number of check-outs and check-ins at each station of users above 24 years	22.6	22.3	0	174
$Capacity_i$	Number of bike station docks	14.5	4.6	5	26
$Distance_i$	Distance from the bike station to the city centre (km)	2.2	1.1	0.2	5.5
$Population_i$	Number of people aged 14+ in the service area of a bike station	951	822	41	3859
$Education_i$	Dummy variable for the presence of an education facility in the service area of a bike station	0.3	0.5	0	1
$Dining_i$	Dummy variable for the presence of a dining service in a 100m buffer around the bike station	0.3	0.5	0	1
$Leisure_i$	Dummy variable for the presence of a leisure facility in a 100m buffer around the bike station	0.6	0.5	0	1
$Shopping_i$	Dummy variable for the presence of a shopping facility in a 100m buffer around the bike station	0.5	0.5	0	1
$Weekday_t$	Dummy variable for Monday to Friday	0.	0.5	0	1
$Summer_t$	Dummy variable for the summer season	0.3	0.5	0	1

4. Results

4.1 Bike share usage

4.1.1 Preliminary analysis

The initial exploratory analysis shows that most of the bike trips are for short trip purposes. The distribution, as seen in Figure 6, shows most trip distances within 5 km. These trips accounted for 86.3% of total trips during the study period. The most frequent distance recorded was around 1 km, with the average bike trip around 2.8 km. Bike trip lengths were generally below 15 km, with a small proportion above 20 km. The median bike trip length recorded was 2.19 km, as shown in Figure 6 with the red dashed line.

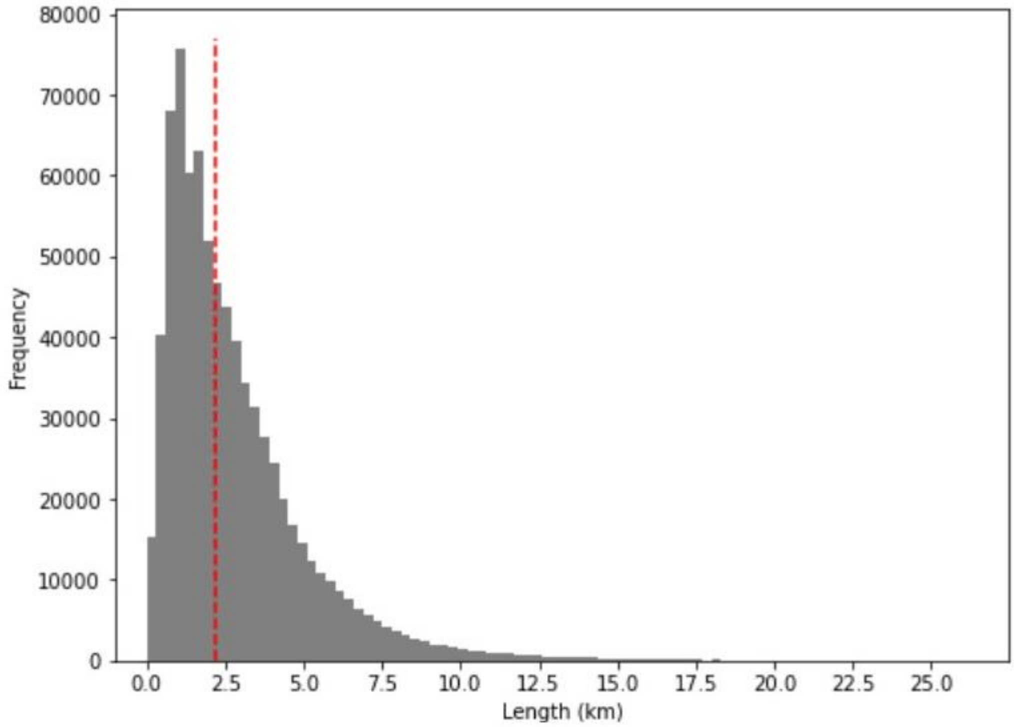

Figure 6: Trip distance distribution with the median

A similar pattern is seen in the bike trip durations distribution. Most trips were completed within 20 minutes, as shown in Figure 7. Trips of this nature constituted approximately 74.5% of recorded bike trips during the study period, whilst the average trip duration recorded was 16 minutes with a median of 10.8 minutes. The most frequently recorded duration of bike trips fell between 4 – 5 minutes, with rides above 60 minutes uncommon.

These trends, especially regarding average trip distance and durations, show that Tartu's bike share is mainly used for short-trip purposes. With nearly 75% of the bicycles being electric-powered, the bike share system may have been anticipated to be more frequently used for long-distance trips. However, the analysis indicates that short-duration and short-distance trips are dominant.

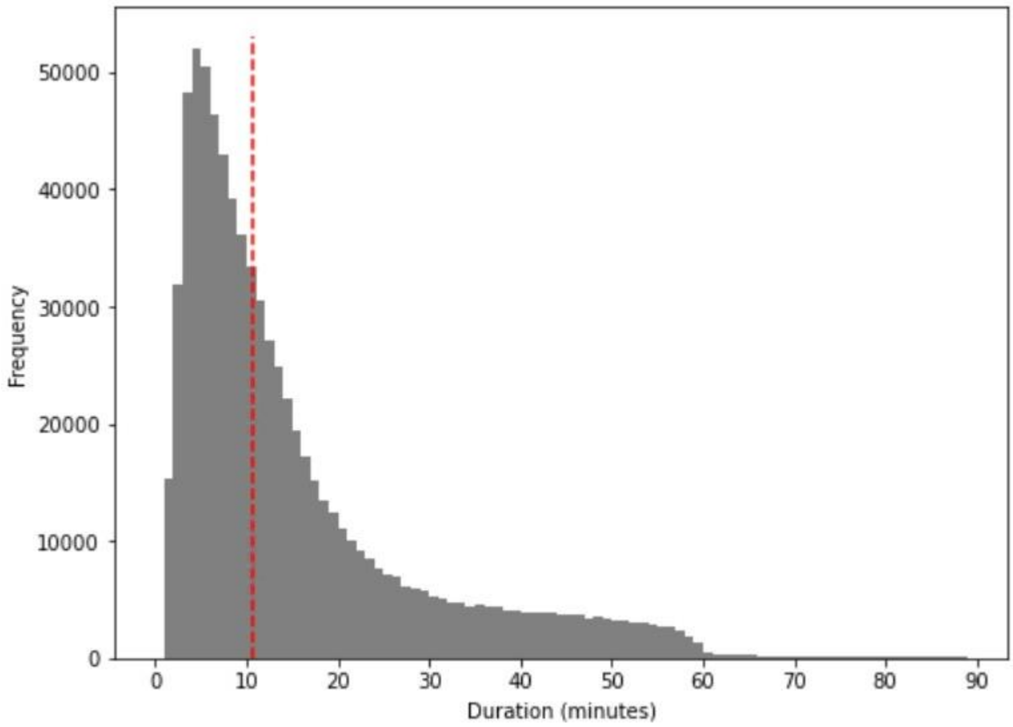

Figure 7: Trip duration distribution with the median

Further exploration into the origin and destinations of bike trips offered an additional explanation for Tartu's bike share's short-distance trip purpose. As shown in Figure 8, a greater share of the trips were made within the central part of the city, which had a tighter distribution of bike stations. Stations outside the central part of the city had relatively fewer rides between them, with most of the rides from these stations being in the direction of the city centre.

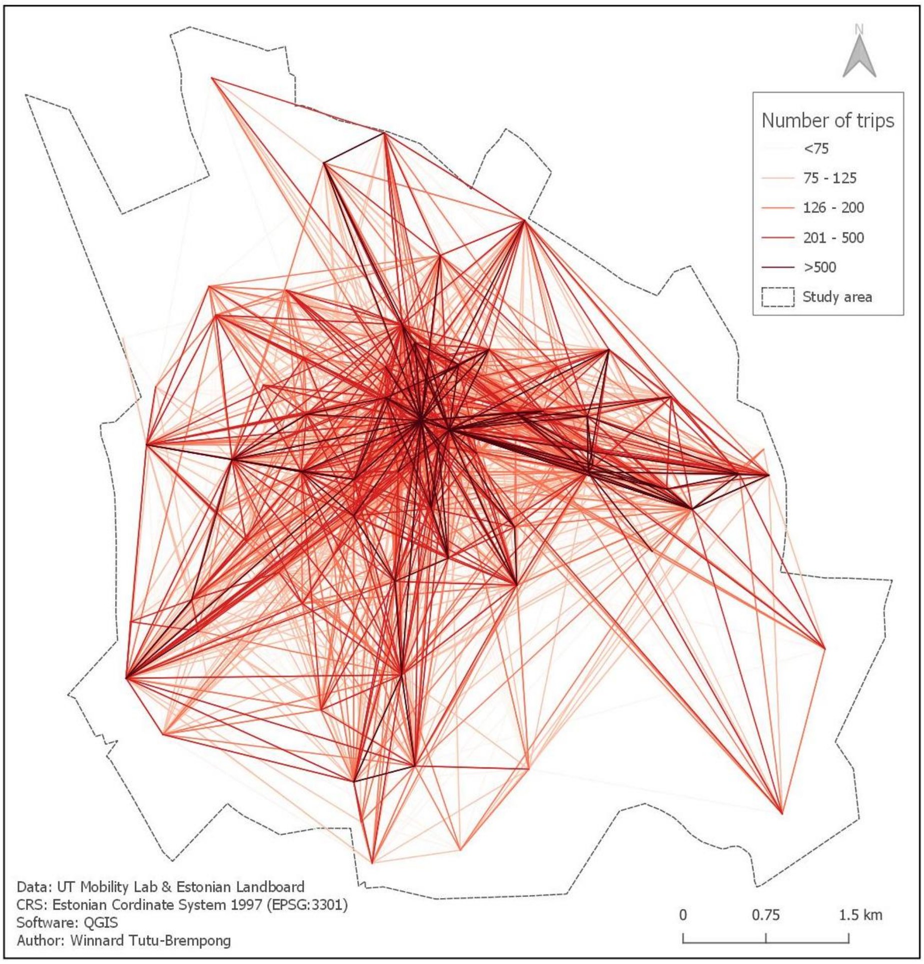

Figure 8: Map of bike share trip origin and destination

4.1.2 User characteristics: age distribution

The usage of Tartu's bike share by young people was explored using the distribution of membership and trip counts. The distribution of the age of users of Tartu's bike share shows a significant concentration of users between the ages of 14 – 24 (in Figure 9). With 18,271 distinct users from the data, users of 19 years formed the highest proportion at approximately 5.6%. The share of users within the young age group (14 – 24 years) was 48%. This group of users can be classified as being of high school and university age. The influence of the young people on Tartu's bike share is further highlighted in the number of trips, durations, and distances of the total trip recorded.

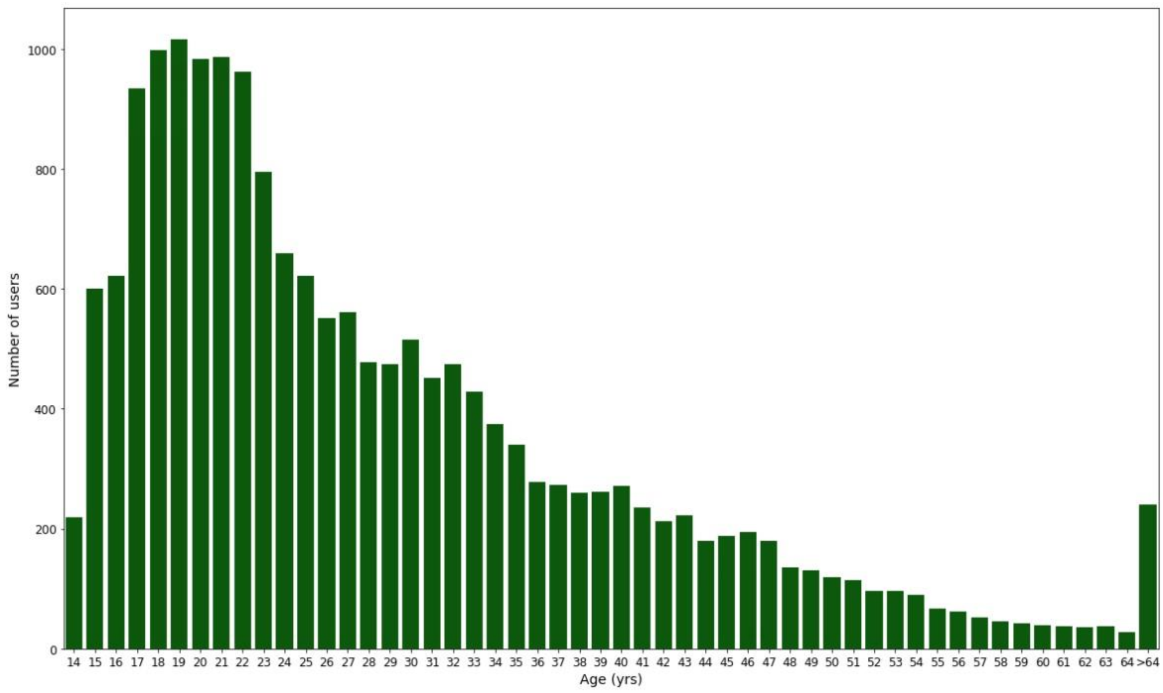

Figure 9: Age distribution of Tartu's bike share ridership

4.1.3 User characteristics: trip frequency

The impact of young people with respect to their portion of trips is shown in Figure 10. From the 776,715 bike trips in the dataset, the users of age 17 made the most trips, accounting for approximately 7.1% of the total. Young people made 414,139 bike trips representing 53.3% of the total bike trips in the dataset.

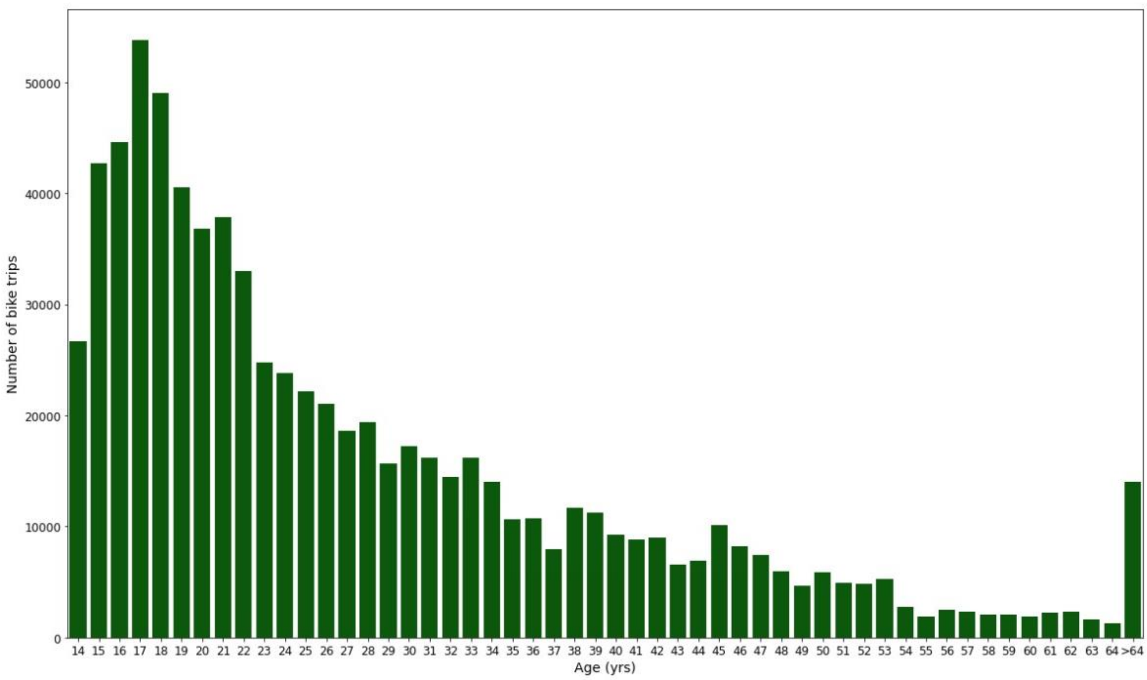

Figure 10: User's age distribution with the trip count of Tartu's bike share

4.1.4 User characteristics: trip duration distribution

The maximum allowed duration of any trip with Tartu's bike share system is 5 hours. Therefore, trips with a recorded duration exceeding the allowable threshold were excluded from the total trip duration and distance calculations. These trips may have occurred but were most likely to have encountered a technical issue or user negligence with respect to docking. The distribution of the total duration by users is visualised in Figure 11. A total of approximately

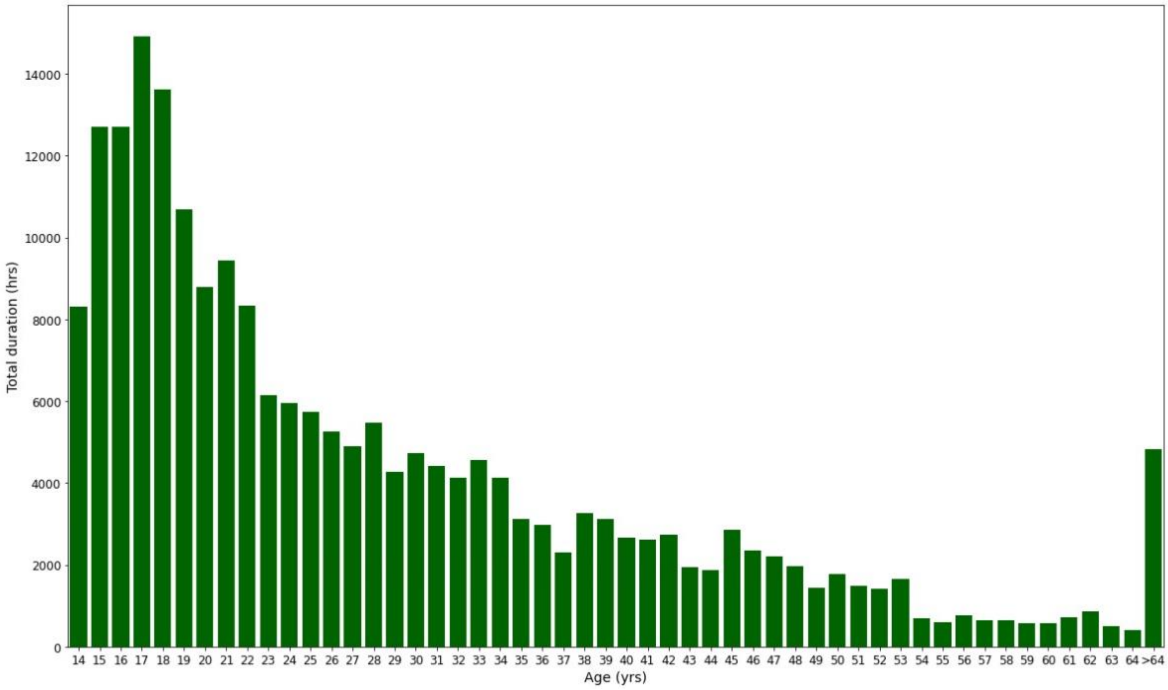

Figure 11: User's age distribution with the total trip duration of Tartu's bike share

214,786 hours was the sum of the time recorded by all bike trips in the dataset. Users of 17 years recorded the highest total duration of about 15,000 hours, translating into approximately 7% of the total duration recorded. Young people's (14 – 24 years) influence was still present in their proportion of the total bike trip duration. They represented 52% of the total duration, equalling 111,607 hours during the study period.

4.1.5 User characteristics: trip distance distribution

All the individual trips totalled a distance of 22 million km. Young people represented a share of roughly 53.3%, which translates to about 11.7 million km of the total distance covered in the study period. The highest trip distance was recorded by users of 17 years old, equalling about 161,000 km (7.3%) (see Figure 12). The general distribution of the bike trip distances was right-skewed. A high distance was covered among teenagers with a gentle downward reduction as the ages increased. This trend may be considered linked to teenagers holding a high share of Tartu's bike share membership.

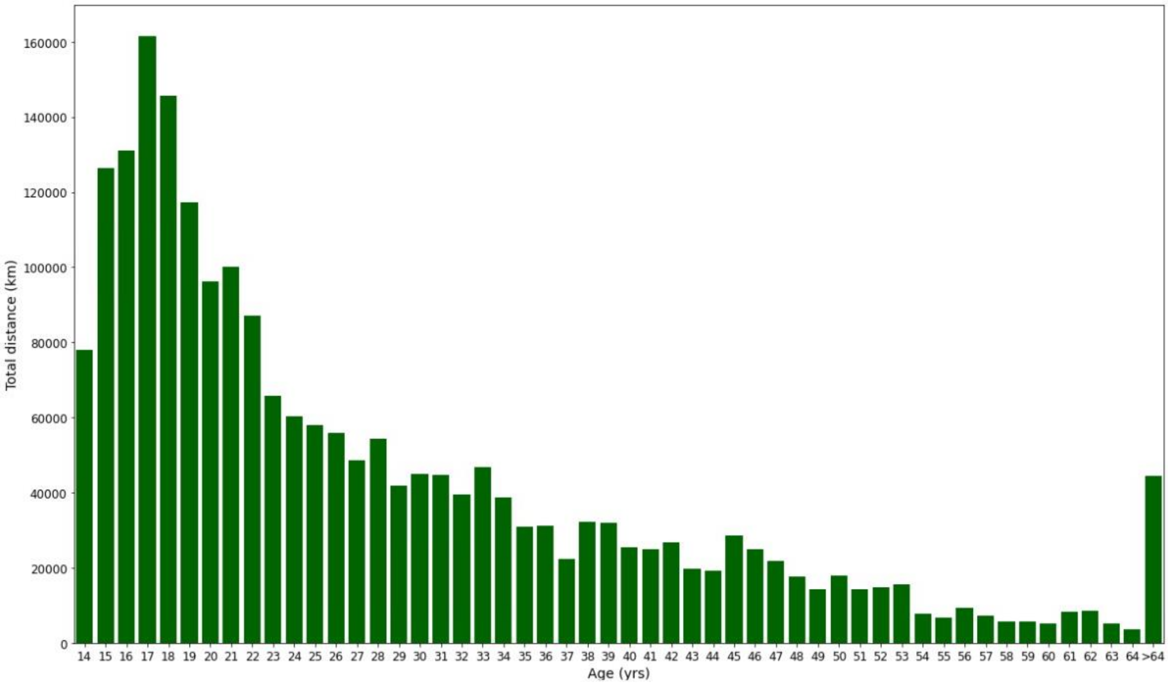

Figure 12: Total bike trip distance distribution of Tartu's bike share

4.1.6 User metrics comparison

Based on the 2020 population census, almost 17.5% of the population is ineligible to register for the bike share program as they fall below the minimum age requirement of 14. The proportion of eligible users was 79,398 from the total population of 98,086. The preliminary analysis shows that Tartu's bike share attracts people of all ages. However, it is especially popular among people between 14 and 24 years old, whose share of the total population of Tartu was about 12% as of 2020. The 14 – 19 years group held a 6.3% share, while the 20 – 24 years was about 5.7% of the city population. Their modest share of the city population translated into a combined 48% (24% each) of bike share users, as seen in Figure 13.

The influence of teenagers (14–19 years), typically considered high school age, was particularly strong concerning their share of the total trip counts, durations and distances recorded, translating into 33.2%, 34% and 34.6%, respectively. The 20 – 24 years group had relatively less influence than the teenagers. This group covers what might also be termed the university age bracket, and Tartu is thought to have many of them. The 20 – 24 years age group accounted for 20.1% of the total trips recorded, with a similar pattern evident in the total trip durations and distances recorded, at approximately 18% and 18.7%, respectively.

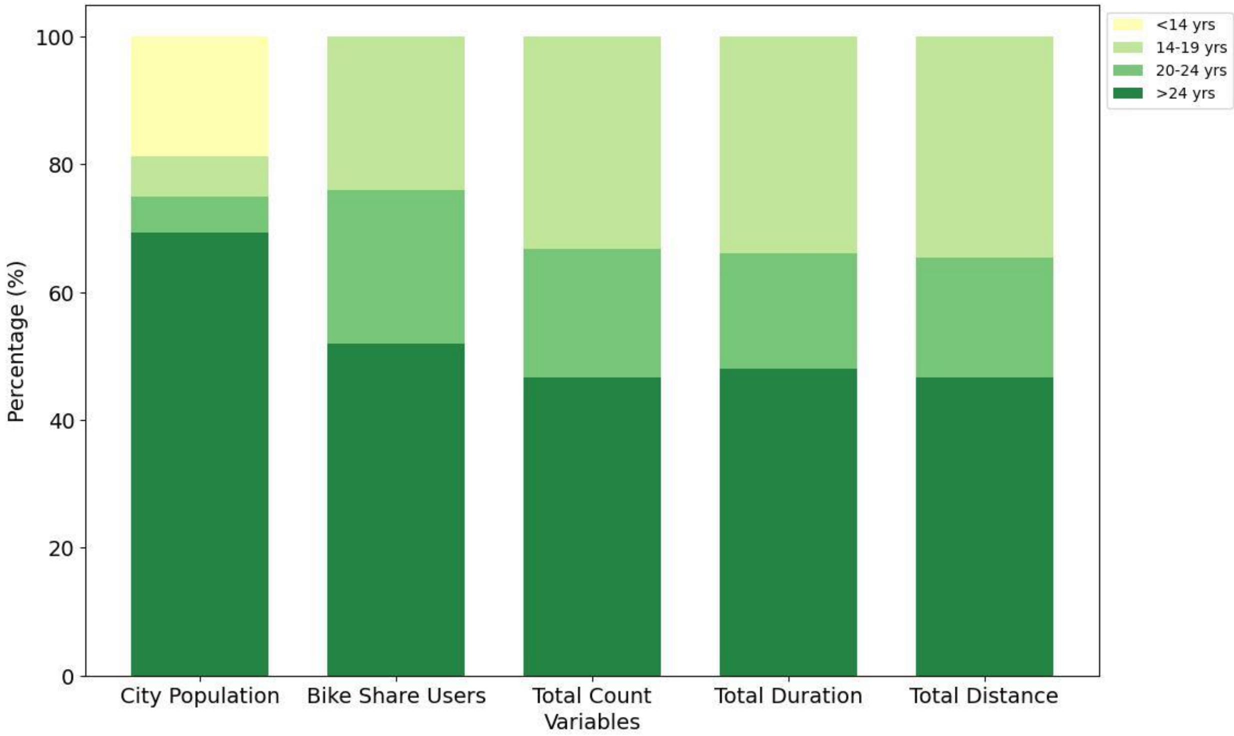

Figure 13: Bike share metric comparison

4.2 Factors affecting bike share usage

The results of the negative binomial regression to ascertain the level of influence of the independent variables are shown in Table 5. The variables' p-value was below 0.05 at the 95% confidence level. This demonstrates that all the independent variables are significant within the model. The coefficients of the independent variables account for the expected ridership demand variation. The extent of this change is based on the value of the coefficient in the regression results. The standard statistical measures used to test the goodness of fit for negative binomial regression models are the scaled deviance and scaled Pearson Chi-square (Cameron & Trivedi, 1986; Maher & Summersgill, 1996). These two statistical measures were used to assess the goodness of fit of the negative binomial regression model. The anticipated value for both statistical tests should be equal or close to the degrees of freedom (DF) for the model to be considered adequate. The values of scaled deviance/DF and Pearson Chi-square/DF are close to 1 from the goodness of fit results shown in Table 6 for all four models. This indication shows that the model is adequate and relatively fits well.

Table 5: Negative Binomial regression analysis results on bike share ridership by age group

	All ages trip		14-19 years trip		20-24 years trip		25+ years trip	
Variables	Exp(β)	Standard error	Exp(β)	Standard error	Exp(β)	Standard error	Exp(β)	Standard error
Intercept	31.233*	0.0341	13.810*	0.0382	17.614*	0.0349	17.984*	0.0317
Distance	0.830*	0.0060	0.901*	0.0067	0.871*	0.0061	0.787*	0.0057
Capacity	1.013*	0.0014	1.002*	0.0015	1.012*	0.0014	1.013*	0.0013
Population	1.000*	0.000	1.000*	0.0000	1.000*	0.0000	1.000*	0.0000
Education	0.890*	0.0142	0.706*	0.0163	0.843*	0.0146	0.914*	0.0130
Shopping	1.267*	0.0150	1.339*	0.0173	1.282*	0.0156	1.247*	0.0137
Leisure	1.181*	0.0151	1.280*	0.0175	1.289*	0.0157	1.043*	0.0138
Dining	1.325*	0.0171	1.185*	0.0202	1.247*	0.0178	1.358*	0.0153
Weekday	1.171*	0.0136	1.157*	0.0153	1.170*	0.0140	1.176*	0.0124
Summer	1.628*	0.0138	1.399*	0.0150	1.448*	0.0140	1.630*	0.0125

Pseudo R^2 = 0.2042; 0.1466; 0.1626; 0.2129 respectively

* indicates significance at 0.05 level

Table 6: Negative binomial regression goodness of fit test

Test	Value			
	Total trips	14-19 years trips	20-24 years rips	25+ years trips
Scaled Deviance / Degree of Freedom	1.144	1.103	1.124	1.105
Scaled Pearson Chi-Square / Degree of Freedom	0.835	1.047	0.875	0.851

The independent variables' influence levels in the analysis varied, with some having relatively less impact on ridership across the age groups. The distance from the bike station to the city centre was negatively associated with bike usage across all users. This impact was relatively high among the 25+ years age bracket, with about a 21% reduction in ridership per kilometre from the city centre to the bike station. Distance had the lowest influence on the 14 – 19 years group, with a 10% decline per kilometre in ridership. This indicates that the further away a station is from the station's city centre, the fewer the bike trips to and from that station.

As expected, the POIs positively influenced bike ridership across the age groups. Shopping facilities around a bike station had the highest impact on ridership demand, with about a 34% increase in the 14 – 19 years model. Similarly, there was about a 28% increase in rides among the 14 – 19 years and 20 – 24 years age models when a leisure facility was located near the bike station. However, this had only a 4% positive effect on bike trip demand for the 25+ years group. Dining services influenced ridership considerably less for young people than for 25+ years users, for whom a 36% increase was visible.

Seasonal changes were associated with substantial changes in ridership among all users. Seasonal change impacted the ridership of the 25+ year group more, with their ridership increasing by about 63% in the summer. Young people recorded a much weaker surge in ridership. Weekdays generally were associated with a marginal increase in ridership demand compared to weekends for the four models, with around a 16% increase in weekday bike trips compared to weekends throughout the model.

The population of eligible users in the coverage area of the bike stations had no substantial influence on ridership demand across all models. Educational facilities in the bike station's coverage area did not have what might have been expected to affect bike share usage positively.

Finally, bike station capacity exhibited a marginally positive influence on ridership demand among all the models, ranging from 0.25% to 1.3%.

5. Discussion

5.1 Bike share usage metrics

The exploratory analysis of bike share data revealed a pattern in which bike trips were used primarily for short trip purposes. This pattern was evident in both the duration and distance frequency distributions, as shown in Figures 6 and 7. Nearly three-quarters of trips were within a duration of 20 minutes. With the city's 38.80 km2 (15 sq. mi) total area, most trips may have been expected to be relatively short. The average duration recorded was approximately 16 minutes, with a median of 10.8 minutes. These values are consistent with findings on bike share systems in Chicago–USA (16 minutes); Washington–USA (18.3 minutes); and Zhongshan–China (16 minutes) (Gebhart & Noland, 2014; Zhang et al., 2018; Zhou, 2015). Approximately 86.3% of the distances covered during bike trips were below 5 km, with an average distance of 2.8 km during the study period. The median bike trip length of 2.18 km further indicates the dominance of short-distance trips.

From further explorations into the distribution of the age of users, it became evident that the frequency of users was concentrated among young people (14 – 24 years). Their 12% share of the city's entire population translated to a much higher proportion of Tartu's bike share membership, total trip count, distances, and durations. Young people accounted for about half of the total bike share users and trips during the study period. Bike share usage among young people equalled approximately 52% and 53.3% of the total duration and distance during the study period. Therefore, it is clear that Tartu's bike share usage is particularly high among young people. While bike share use among young people of university age is high, it is even higher among those of high school age. However, the results of the research do not allow confirmation as to why. This phenomenon might be partly attributed to young people of high school age having many destinations to which they want to travel (i.e., recreational activities, dining, and social activities), with many remaining ineligible to acquire a driver's licence (with 18 being the minimum age for the issue of driving licenses in Estonia).

5.2 Bike share ridership influencing factors

The regression analysis results indicated that the station capacity, distance to the city centre, season, day type and POIs influenced bike share ridership. These findings are consistent with the results of earlier studies on the influencing factors of bike share ridership (Eren & Uz, 2020; Faghih-Imani et al., 2014; Lee et al., 2022; Mattson & Godavarthy, 2017; Scott & Ciuro, 2019).

Additionally, the results from the regression analysis performed in this research further highlighted the variations in the influence of these spatial, temporal, and built-environment factors on bike share ridership across the age groups, making this a significant contribution of this study. Bike share trips are generally expected to decrease when a bike station is further away from the city centre. The phenomenon is supported by the calculated <1 coefficient of the distance variable in the regression results. As reported in other studies, distance to the central business district of cities usually has a negative relationship with bike share ridership (Faghih-Imani et al., 2014; Scott & Ciuro, 2019). In this study, the distance variable influences young people less, who appear more willing to travel long distances than older users. We speculate that this may be at least the result of the younger groups having less access to automobiles, whether due to not having driver's licenses or not being unable to afford them.

Bike share station's capacity had a marginal effect of less than a 2% increase in ridership across all age groups. This effect is possibly related to the higher likelihood of bike availability at larger capacity bike stations at the time of a user's choosing. Proximity plays a crucial role in bike share ridership. This analysis of POI's impact on ridership suggests that they act as magnets, generating and encouraging bike trips to and from nearby stations. Ridership increased by around a quarter with the availability of a shopping facility near the bike station across all age groups. Leisure facilities displayed a varied impact on ridership across age groups. They were associated with a 28% average ridership increase among young people and a minimal rise (4.3%) among older users. These trends suggest that young people are making more trips in connection to shopping and leisure facilities relative to older people. The dining service findings indicate that older users are more inclined to ride bicycles to these facilities than young people. Nearby dining services were associated with a 35.8% increase in ridership among older people and only a 21.6% increase among younger people. In this study, the impact of POIs illustrates that bike share ridership increases when bike stations are closer to these hotspots. These findings relating to POIs are consistent with similar outcomes from other studies (He et al., 2019; Lee et al., 2022).

Temporal variables (summer and weekday) significantly influenced ridership across all age groups. These outcomes align with comparable findings from earlier studies (Lee et al., 2022; Mattson & Godavarthy, 2017; Scott & Ciuro, 2019). Summer was a very active season for bike share ridership, with a surge in bike trips across all ages. However, the change in the season had relatively less effect on young people's ridership, with them apparently more inclined to ride bicycles in less warm seasons than older users. Bike share ridership among young and older people was slightly higher on weekdays than on weekends, with an increase of approximately 15% to 18%. This trend may suggest that the bike share system is particularly popular for utilitarian purposes like commuting (Scott & Ciuro, 2019).

As discussed in the results section, the population of eligible bike users (14+ years) in the coverage area of a bike station had no impact on ridership in this study. A similar effect was observed in a study in Hamilton, Canada, where the population density had no positive influence on ridership (Scott & Ciuro, 2019). In contrast to this finding, the general population's impact on ridership has been established in other studies (El-Assi et al., 2017; Faghih-Imani et al., 2014; He et al., 2019; Lee et al., 2022). This phenomenon in Tartu may be linked to the clustered (i.e., more densely distributed) bike stations within the city centre. Though these stations generally exhibit high use, very few inhabitants are in their coverage area. Consequently, when the bike share data associated with them are factored into overall calculations, this may negate the actual influences of the population density around bike stations in other parts of the city. Additional investigation into the effects of population density on Tartu's bike share ridership will constitute a potentially useful avenue for future research.

Previous studies show educational facilities as positively influencing bike share usage (El-Assi et al., 2017; Faghih-Imani et al., 2014; Mattson & Godavarthy, 2017). In contrast, our findings indicated a 9% to 29% reduction in ridership with the presence of educational facilities. This may be a consequence of the fact that we considered a period of 12 continuous months, including the summer academic break. Since some bike stations are close to educational facilities with few additional POIs, they will likely see reduced activity during the summer break. With summer being the most active season for bike share usage, these influences may thus result in a restrained impact of educational facilities on ridership in the model. A study on bike share in Fargo, North Dakota, USA (120,343 population) discovered a similar phenomenon (Mattson & Godavarthy, 2017). Though most of the bike rides in its system (2015 to 2016) were undertaken on college campuses, overall ridership demand substantially decreased during the summer months.

Conclusion

Bike sharing systems represent a potentially strong addition to public transportation and ridesharing services. According to recent statistics from publicly available open data, substantial percentages of bike-share trips are made by relatively small and distinguishable groups on a demographic basis (Médard de Chardon, 2019). Furthermore, existing literature generally suggests that bike share use is most popular among younger age groups. Most previous studies have been focussed on relatively big cities, while various sources highlight the possibility that strongly popular bike share may be more difficult to achieve in smaller cities. Considering that young people, including university students, may be regarded as a target market for bike share, it is reasonable to suggest that the success of bike share in Tartu might be at least partly attributable to its substantial population of students and young people.

This research sought to investigate young people's use of the Tartu bike share system and examine the effect of seasonal, temporal and built environment factors on bike share ridership across the age groups. The study mainly employed bike share trip data from Tartu's bike share system spanning one year, from July 2021 to June 2022. Exploratory analysis of the pseudonymised data revealed young people's participation level in Tartu's bike share system. The number of check-ins and check-outs at each bike station (on a per day basis) were aggregated. Negative binomial regression analysis was employed on the aggregated data to investigate the influence of seasonal, temporal and some built environmental factors on Tartu's bike share ridership.

The findings revealed a general trend of Tartu's BSS being used mainly for short-trip purposes, with the most active users being young people between the ages of 14 and 24. Within the younger age group, those aged 14 – 19 (high school age) were the most active. Young people appeared willing to ride farther in less favourable seasons, and their ridership was strongly linked to shopping and leisure facilities. The older users (>24 years) seemed to have made relatively more rides connected to dining services. Generally, bike-share in Tartu appears to be a popular, practical, and sustainable transportation option for young people. The fact that Tartu has a high share of students may contribute to its success, with the system being popular for those of university age (20 – 24). On the other hand, the system is even more popular for those of high school age (14 – 19), an age group that has not previously received much attention with respect to its potential for bike share.

Future studies could further explore what made Tartu's bike share system appealing to young people. In particular, additional user information (particularly related to the demography of young people) could allow a deeper exploration of the trends identified in this study.

Bike share use among young people in Tartu: a demographic and spatial analysis

Winnard Semenyo Tutu-Brempong

Summary

Emerging sustainable modes of urban travel are gradually gaining ground as cities become progressively conscious of the impacts of climate change (Rojas-Rueda et al., 2011). In particular, this is on account of their potential to reduce reliance on automobile transport in cities (Machado et al., 2018). Bike share systems in which people subscribe to use privately owned or publicly provided shared bicycles are considered to have the potential to popularise cycling. Bike share has become a sustainable mobility option in many cities for short distances and car trips (Zainuddin et al., 2016). Given that it is rare to find extremely strong performing bike share systems in smaller cities, the great popularity of Tartu, Estonia's bike share system stands out, particularly on account of the city's small population size (less than 100,000). Bike share use is generally higher among younger people, with a small proportion of the population in many cities considered to account for the majority of bike share trips. (Médard de Chardon, 2019). Considering that young people, including university students, may be regarded as a target market for bike share, it is reasonable to suggest that the success of bike share in Tartu might be at least partly attributable to its substantial population of students and young people.

Thus, this master thesis sought to investigate young people's use of Tartu's bike share system via gathering and analysing bike share trip data with pseudonymised user information. The following research questions were asked to achieve the aim of the thesis:

1. How do young people in Tartu use the bike share system relative to older people?
2. How do built environment, seasonal, and temporal factors affect Tartu's bike share ridership across age groups?

The research mainly employed bike share trip data spanning July 2021 to June 2022. The bike share dataset comprised individual trips recorded during the study period. The distribution of the bike trips was analysed according to age in order to determine young people's participation levels. The data were segmented into age groups (14 – 19 years, 20 – 24 years, and >24 years). These segmentations followed a high school aged, university aged, and older aged representation. This procedure was necessary to investigate some of the underlying factors impacting the ridership of young people relative to older users. The number of check-ins and

check-outs per day were aggregated at each bike station, with the aggregated data then being used in a regression analysis. Negative binomial regression was used as it was considered well-suited for overdispersed count data. Independent variables employed in this study included the network distance from each bike station to the city centre; bike station capacity; population and the presence of an educational facility in the coverage area of each bike station, the presence of dining services, leisure and shopping facilities within a 100 m buffer around each bike station; as well as temporal variables including the season and day type (weekend or weekday) which were recorded as dummy variables.

The results showed that young people between 14 and 24 years exhibited a relatively high level of bike share use compared to the older age group. While usage among those of university age is high, it is highest among those of high school age. Although the 14 – 24 years group totals about 12% of the city's population, they accounted for 48% of bike share membership. This high usage among young people further translated into 53% of total bike trips, 52% of the entire trip duration, and 53% of the distance covered from all the bike trips.

The findings from the regression analysis also revealed some of the underlying factors influencing ridership across the age groups. The distance from the city centre to a bike station had a marginally negative impact on bike ridership among younger people, who seem willing to ride farther than the older users. Though summer is usually a busy season for active bike share riders, young people also seem relatively active in other seasons. It was additionally evident that young people rode more in connection with leisure and shopping facilities than the older group, whose ridership was more linked to dining services. The population of eligible users in the coverage area of a bike station did not influence bike rides, and educational facilities recorded no positive impact on ridership among young people. Although these two variables had no positive effect on bike share ridership in the analysis, these results merit further exploration via future study as they contrast with the results of previous research.

The study highlights the importance of investigating ridership influencing factors across age groups, as it was evident that these factors appear to affect overall ridership, with their effects varying across age groups. The findings can inform the improvement of Tartu's bike share system as well as the planning and operation of similar systems, particularly those with characteristics identical to Tartu's.

Rattaringluse kasutus Tartu noorte hulgas: demograafiline ja ruumiline analüüs

Winnard Semenyo Tutu-Brempong

Kokkuvõte

Üha kasvava teadlikkusega kliimamuutuse mõjudest on linnades hoogu kogumas aktiivsete transpordiliikide kasutuselevõtt (Rojas-Rueda et al., 2011) kui potentsiaalne võimalus vähendada eraautode kasutust (Machado et al., 2018). Rattaringlust, kus inimesed kasutavad eraomandis olevaid või avalikult pakutavaid ühisjalgrattaid, peetakse heaks võimaluseks jalgrataste kasutust edendada. Rattaringlus pakub jätkusuutliku transpordialternatiivi autodele juba paljudes linnades lühikeste vahemaade läbimisel (Zainuddin et al., 2016). Rattaringluse süsteemi edukas kasutuselevõtt Tartus paistab silma linna väikese rahvaarvu (alla 100 000 elaniku) poolest – maailmas on vähe edukaid näiteid elujõulisest rattaringluse süsteemist väikestes linnades. Rattaringluse kasutamine on üldiselt populaarsem nooremate inimeste hulgas, kusjuures tihti on vaid väike osa elanikkonnast suure osa kogu rattaringluse kasutuse taga (Médard de Chardon, 2019). Et noori, sealhulgas tudengeid, võib pidada oluliseks rattaringluse sihtrühmaks, võib oletada, et rattaringluse suur kasutatavus Tartus võib olla vähemalt osaliselt seotud tudengite ja noorte kõrge osakaaluga.

Seega on siinse magistritöö eesmärk uurida Tartu rattaringluse süsteemi kasutamist noorte seas võrreldes vanemaealiste kasutajatega, tuginedes pseudonüümitud kasutajainfoga rattaringluse andmete analüüsile. Töö eesmärgi saavutamiseks esitati järgmised uurimisküsimused.

1. Kuidas kasutavad noored Tartu rattaringluse süsteemi võrreldes vanemaealistega?
2. Kuidas hoonestatud linnaruum, hooajalised ja nädalapäevaga seotud tegurid mõjutavad Tartu rattaringluse kasutust vanusgruppide lõikes?

Uurimistöös kasutati peamiselt rattaringluse andmeid 2021. aasta juulist 2022. aasta juunini. Rattaringluse andmestik koosnes individuaalsetest reisidest, mis olid jäädvustatud uuringuperioodi jooksul. Analüüsimaks rattaringluse kasutamist vanusegruppide lõikes visualiseeriti rattaringluse kasutusaktiivsust lähtudes kasutajate vanusest. Andmed jaotati kasutajate järgi vanuserühmadesse (14–19 aastat, 20–24 aastat ja >24 aastat). Rühmad vastavad põhikooli vanema astme ja gümnaasiumiealistele, tudengitele ja täiskasvanutele. Igas rattaparklas summeeriti sisse- ja väljaregistreerimiste arv päevas ja summeeritud andmeid kasutati seejärel regressioonanalüüsis. Kasutati negatiivset binoomregressiooni, sest see sobis paremini antud loendusandmete jaoks. Käesolevas uuringus kasutatud sõltumatud muutujad

hõlmasid sõidukaugust rattaparklast kesklinnani, rattaparkla mahutavust, rahvaarvu, haridusasutuse olemasolu rattaparkla läheduses, söögi-, vabaaja- ja ostuvõimaluste olemasolu 100 m puhvris iga rattaparkla ümber ja ajalisi muutujaid, sealhulgas aastaaega ja päevatüüpi (nädalavahetus või argipäev).

Tulemused näitasid, et 14–24 aastased noored kasutasid rattaringlust rohkem kui vanem kasutajaskond. Rattaringluse kasutus on gümnaasiumiealiste hulgas kõrgem kui ülikoolieealiste hulgas. Kuigi 14–24-aastased noored moodustavad umbes 12% linna elanikest, moodustavad nad 48% jalgrataste kasutajatest. Sealjuures esindab noorte rattaringluse kasutus 53% kogu kasutusest, 52% kogu reisi kestusest ja 53% läbitud vahemaast.

Regressioonanalüüsi tulemused näitavad ka taustategurite mõju rattaringluse kasutamisele vanusrühmade lõikes. Kaugusel rattaparklast kesklinna oli väike negatiivne mõju rattaringluse kasutusele nooremate inimeste hulgas, kes näivad olevat valmis sõitma pikemaid distantse kui vanemad kasutajad. Nooremad grupid olid aktiivsemad ka muul ajal kui suvel. Lisaks ilmnes maakasutuse andmetest rattaringluse jaamade lähikonnas, et noored sõitsid rohkem seoses vaba aja veetmise ja ostlemisega, ent vanem grupp oli rohkem seotud toitlustusteenustega. Rahvaarv ega haridusasutuste olemasolu jaamade lähikonnas ei tõstnud rattaringluse kasutuse sagedust. Rahvaarv ja haridusasutuste olemasolu on tunnused, mis väärivad edasistes uuringutes põhjalikumat tähelepanu, sest käesoleva uuringu tulemused lähevad vastuollu varasemas kirjanduses tooduga.

Uuring rõhutab, kui oluline on uurida rattakasutuse tegureid vanusrühmade lõikes, sest on ilmne, et rattaringluse kasutuspopulaarsust mõjutavate tegurite mõju pole samasugune vanuserühmade lõikes. Käesoleva magistritöö leiud võivad olla heaks informatsiooniallikaks Tartu rattaringluse arendamisel ja üleüldiselt väiksemates linnades rattaringluse süsteemi planeerimisel ja kasutuselevõtul.

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