

COVID-19, From Lockdown to Recovery: Exploring the Dynamics of Bike-Sharing and Public Transport in Tartu, Estonia

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ABSTRACT

The COVID-19 pandemic triggered a seismic shift in global commuting and travel habits, ushering in significant changes in transportation demand. These alterations in travel behavior have proven to be more than transient reactions to the immediate crisis, persisting beyond the pandemic's aftermath. Despite extensive research into contemporary travel pattern changes during and after the pandemic, our understanding of the short-term and long-term repercussions of COVID-19 on travel behavior remains limited.

This research investigates the enduring effects of pandemic-induced lockdowns on bike-sharing and public transport utilization in Tartu, Estonia, a city renowned for its northern climate, evolving cycling infrastructure, low traffic, compact urban layout, high car ownership rates, and walkability. Our empirical analysis reveals the bike-sharing system's rapid and adaptive response to changing circumstances, highlighting the system's ability to navigate crises effectively, contrasting sharply with the protracted recovery observed in public transport demand.

CCS CONCEPTS

• **Applied computing** → *Transportation*.

KEYWORDS

Bike-sharing systems, Public transport, COVID-19, Modal share, Travel behaviour

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1 INTRODUCTION

The COVID-19 pandemic has ushered in a sweeping transformation in various facets of our daily lives, compelling us to reevaluate routines, habits, and priorities. Among the areas most profoundly

affected is the realm of transportation. Stringent regulations, heightened safety concerns, and evolving individual preferences have collectively prompted a thorough reassessment of travel behaviors on a global scale. This transformation has ignited widespread interest and scrutiny, offering profound insights into the future of urban mobility.

Various studies in the literature have explored the impacts of the COVID-19 pandemic on transportation and travel behaviors. Teixeira et al. highlight the resilience of BSSs compared to public transport and recommend expanding BSSs, improving cleaning, subsidizing trips for essential workers, and addressing equity [10].

Chen et al. emphasize the shift towards autonomous travel due to health concerns and the increased use of shared bicycle schemes as a sustainable and socially distanced alternative [2]. Kim et al. examine the impact in Seoul, reporting a decrease in public transit use and increased bike-sharing for longer trips, emphasizing the importance of bike-friendly infrastructure [6]. Teixeira et al. focus on Citi Bike's resilience compared to the subway during disruptions, advocating for bike-sharing promotion and cycling as sustainable alternatives [9]. Bi et al. study spatial-temporal changes in bike-sharing usage patterns and recommend enhanced cleaning, contingency plans, and cycling infrastructure to ease the strain on urban transport networks during outbreaks [1].

These studies indicate a significant shift in transportation behavior during the pandemic, with individuals reducing reliance on public transport, embracing telecommuting, and exploring alternative travel modes. These changes have become lasting habits, underscoring the need for informed decision-making in transportation infrastructure, urban planning, and sustainability. Ongoing research remains crucial, as the full extent of the pandemic's long-term transportation impacts continues to evolve [14].

Tartu, Estonia, like many cities, offers diverse transportation options, including the "Smart Bike" bike-sharing network. During the 2020 lockdowns and social distancing measures, Smart Bike became crucial for urban mobility, promoting outdoor enjoyment, fitness, and social distancing adherence. However, the extent of its pandemic influence remains uncertain due to limited research. Meanwhile, Tartu's public transportation system, mainly buses, faced challenges similar to global trends, with ridership dropping and recovery prospects in question.

This study examines COVID-19's effects on Tartu's Smart Bike system and public buses, analyzing transportation patterns during and after lockdowns. It emphasizes the adaptability of bike-sharing for emergency responses but also raises concerns about the slow recovery of public transport and the growing use of private vehicles, which could undermine sustainability efforts.

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2 CASE STUDY AND DATA ACQUISITION

2.1 An Overview of Tartu City

Tartu is Estonia's second-largest city, with a population of approximately 100,000 inhabitants and an area of 38.8 square kilometers.

The modal share of the city of Tartu is calculated daily based on the data stream received from an Internet of Things (IoT) devices¹ [4, 5, 7]. The share of cycling in daily commuting ranges between 10% and 5%, exhibiting season-dependent variations. Notably, city bikes contribute to approximately 20% to 30% of the overall bicycle traffic, although this proportion undergoes significant fluctuations across different seasons and weekdays [11].

Tartu, situated in a region with proximity to the northern latitudes, experiences a temperate continental climate that significantly influences cycling patterns within the city. These challenging winter weather conditions often deter cycling, leading to a reduction in bike usage.

In addition to the climatic challenges, Tartu's cycling landscape encounters another significant obstacle – the limited availability of designated bike lanes. Currently, a mere 30% of the total length of the city's roads are equipped with dedicated cycling lanes [11], with poor connectivity, impeding the seamless and safe integration of cycling into the urban transportation fabric.

Tartu boasts a dense and walkable urban landscape, a testament to its pedestrian-friendly design. Nevertheless, there has been a noticeable upward trajectory in car ownership and usage in recent years, ushering in newfound challenges related to traffic congestion and urban mobility management [8].

2.2 Tartu Smart Bike

Tartu Smart Bike Share, launched in June 2019, is a self-service BSS for short trips. It started with 750 bikes at 69 stations and has now grown to 100 stations. Most of the fleet has electric-assist motors, but they are temporarily removed in winter for safety. Initially, subscribers enjoyed three free months of membership in June, July, and August 2019, leading to increased user demand.

The salient facet contributing to the utility of contemporary BSSs resides in their comprehensive data collection mechanisms. After each trip, these systems record various information. In Tartu, this data includes bike details, user information, start and end station details, trip duration and length, bike type, and subscription membership. To protect user privacy, only the first three digits of the personal ID code are shared, indicating the subscriber's gender and birth year.

2.3 Public Transport in Tartu

Buses exclusively comprise the public transportation system within the municipality of Tartu. The city boasts a network of 15 distinct bus routes. In September 2015, Tartu introduced an Automated Fare Collection (AFC) system across its bus network, enabling passengers to use contactless chip-based ticketing. The AFC system in Tartu records the bus stop ID, bus line, and the time stamp of ticket validation for each bus passenger.

¹<https://its.cs.ut.ee/modsplit/>

2.4 COVID-19 in Estonia

In Estonia, the first COVID-19 case was confirmed on February 26, 2020, leading to a state of emergency declared on March 12. This initial lockdown aimed to curb the virus's spread, resulting in significant restrictions, including hospital and nursing home visitation prohibitions, the shift to distance learning in educational institutions starting March 16, and the closure of entertainment centers and event cancellations.

The first lockdown, originally set to conclude on May 1, extended until May 17, with gradual easing starting on May 2. During this phase, outdoor events were allowed with social distancing measures, and internal movement restrictions ended on May 8.

In March 2021, Estonia faced a resurgence in COVID-19 cases, ranking highest globally in cases per million people. Consequently, the government reintroduced certain lockdown measures for a second period, including a return to distance learning in educational institutions and strong recommendations for remote work where possible.

3 RESULTS

This section explores the various aspects of changes in BSS and public transport demand during and after the lockdowns.

3.1 Temporal Changes in BSS Demand

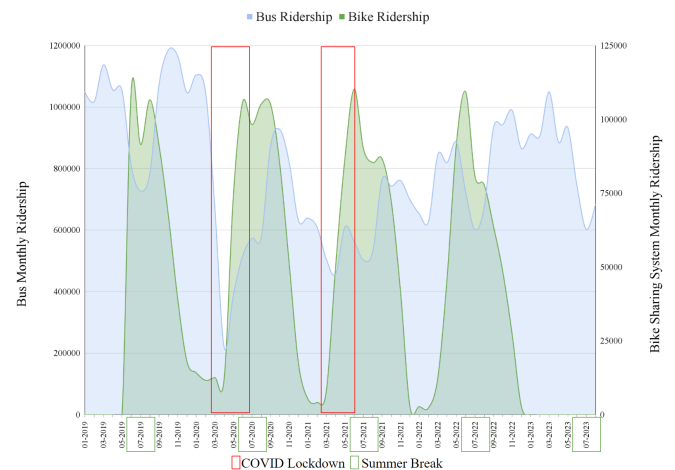


Figure 1: Monthly number of BSS and bus ridership in Tartu.

Fig. 1 provides a longitudinal illustration of the fluctuations in the volume of BSS trips and public transport ridership. As elucidated in Subsection 2.2, the inception of Tartu's BSS occurred in June 2019, resulting in an initial surge in trip numbers during the inaugural three months. This surge can be attributed to the heightened enthusiasm for testing the system out and the complimentary three-month membership provided to all subscribers. Furthermore, it is discernible that demand experiences periodic declines coinciding with school summer breaks, and notably, the temporary withdrawal of electric bikes during the winter months leaves a noticeable mark on the trend.

The Pearson correlation coefficients computed for the relationship between the counts of confirmed COVID-19 cases and the

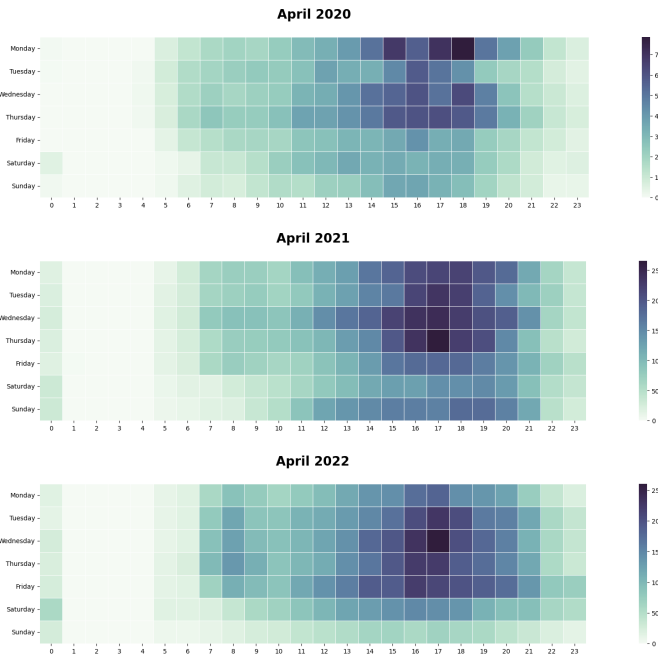


Figure 2: Hourly usage patterns of BSS in Tartu.

volumes of BSS trips in both 2020 and 2021 stand at -0.233 and -0.226 , respectively. These values collectively signify a relatively weak negative linear correlation between these two variables. In simpler terms, the demand for BSS exhibits a limited adverse response to the virus’s prevalence. This observation underscores the resilience of the system, which managed to withstand the challenges posed by the ongoing pandemic crisis.

Nevertheless, the temporal trip patterns of BSS exhibited notable variations throughout the COVID-related restrictions. To illustrate these fluctuations, Fig. 2 provides the hourly heatmaps of bike trip distributions on different hours of weekdays throughout the month of April for the years 2020, 2021, and 2022. In April 2020 and 2021, when restrictions were more stringent, the demand appeared more evenly distributed throughout the day, with relatively quieter weekend nights. In sharp contrast, April 2022 reveals a distinct surge in demand during peak hours and on weekdays, during post-pandemic time.

3.2 Spatial Changes in BSS Demand

A thorough examination of the BSS data reveals a significant disparity in trip length and speed, corroborating earlier research findings. Specifically, during April and May 2020, the average trip length increased by over 30%, while the average trip speed concurrently declined by 18% when compared to a similar timeframe in 2022. This variance may be attributed to a shift in trip purposes, transitioning from home-work commuting to leisurely excursions.

Furthermore, a noticeable shift in the spatial patterns of bike trips is the rise in trips with similar Origins and Destinations (OD).

This trend is particularly pronounced in April and May 2022, accounting for 11.6% and 13% of the total trip count, coinciding with the period of stricter lockdown measures. In contrast, during analogous months in 2020 and 2021, trips with similar ODs constituted a smaller share, representing 5.5% and 5.6% of total trips, signifying a greater prevalence of excursions in these periods.

Another noteworthy transformation involves the spatial distribution of trip flows. Post-pandemic analysis of OD trip distribution reveals a heightened concentration of trips in the central area of the city, aligning with the presence of workplaces, public institutions, and shopping centers (Fig. 3c). In contrast, Figs. 3a and 3b depict a more equitable dispersion of trips throughout the city, with noticeable clusters in densely populated residential areas.

3.3 Demographic Changes in BSS Users

Existing research has noted increased diversity among BSS users [1]. Our data analysis also confirms a significant rise in the average user age during the initial lockdown. However, the reintroduction of electric bikes, primarily in April, resulted in a surge of users and a subsequent decrease in the average age, notably observed in 2021 and 2022.

Regarding the gender gap, while it is narrower in Tartu compared to other regions, we observed an increase in the percentage of women using the BSS during lockdowns compared to the same period in 2022. Notably, the percentage of female users declined slightly from April, May, and June 2020 (41%, 45%, and 42%) to April, May, and June 2022 (38%, 41%, and 40%).

3.4 Changes in Public Transport Demand

While public transport plays a pivotal role as a sustainable transportation mode, the COVID-19 pandemic substantially disrupted public transport usage, primarily due to health concerns. This period witnessed a noticeable shift away from public transport toward alternative modes of transportation [3]. As we navigate the post-pandemic landscape, it remains uncertain whether the impact of COVID-19 on public transport has fully receded. Given the challenges associated with altering travel behavior [13], further research in this domain is imperative [12].

In this study, we explored the ticket validation data of Tartu’s public bus system, the sole public transportation mode in the city, spanning from the start of 2019 to August 2023. The monthly count of passengers is illustrated in Fig. 1. Notably, the number of bus riders exhibits seasonal fluctuations, with lower ridership observed during the summer school break. As depicted in Fig. 1, the COVID-19 outbreak had a profound impact on passenger numbers, with a pronounced decline, particularly during the lockdown periods, as overall commuting to workplaces and schools diminished. However, even after the easing of movement restrictions, while there was an increase in the number of trips, it did not rebound to pre-pandemic levels. While in April 2023, the World Health Organization declared an end to the COVID-19 pandemic as a public health emergency, in the months leading up to this declaration, health concerns had significantly subsided. Nonetheless, it appears that the modal shift among previous bus users persisted as a lasting change in travel behavior. During the first eight months of 2023, which can be considered post-pandemic, the number of bus trips in Tartu registered

