Outpacing the Lanes: Toronto's Bike Share Ridership Surges Ahead of Infrastructure Growth*

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Analysis of Toronto's open data reveals a mismatch between Bike Share ridership growth and cycling infrastructure development from 2017 to 2023. While annual Bike Share rides increased nearly fivefold, bikeway expansion lagged, growing from 539 in 2001 to just over 1,400 by 2023. This study highlights the urgent need for accelerated and strategic expansion of Toronto's cycling network to accommodate the surge in demand. The findings emphasize the importance of data-driven urban planning in ensuring safe, accessible cycling options for a rapidly growing user base.

*Code and data are available at: https://github.com/stevenli-uoft/Toronto_BikeShare_Development

1 Introduction

Cities worldwide are turning to cycling as a sustainable solution to congestion and pollution. Toronto, Canada's largest city, has been at the forefront of this trend with its Bike Share program and expanding cycling infrastructure.

Toronto's Bike Share program, launched in 2011, has become integral to the city's transportation network. Managed by the Toronto Parking Authority, it offers thousands of bicycles at hundreds of stations, providing an affordable option for short trips ("Bike Share Toronto" 2024). The system has grown significantly, recently incorporating e-bikes and integrating with public transit ("Bike Access and Amenities - Toronto Transit Commission" 2024).

Concurrently, Toronto has invested in cycling infrastructure. The Cycling Network Plan outlines expansions to bike lanes, trails, and shared routes ("Cycling Network Plan - City of Toronto" 2024). Key initiatives include the 2016 Bloor-Danforth Pilot project ("Bloor Street Danforth Avenue Pilot Project - City of Toronto" 2024) and the ActiveTO program, which led to some temporary bike lanes becoming permanent (Miller 2020). The city has committed to adding 100 kilometers of new cycling infrastructure between 2022 and 2024, with plans for 500 kilometers by 2030 (Transportation-Services 2024).

Despite these efforts, there is a lack of comprehensive analysis on whether Toronto's cycling infrastructure growth is keeping pace with the increasing popularity of the Bike Share program. This gap in understanding is crucial as it impacts urban planning decisions and the safety and accessibility of cycling in the city.

This paper addresses this gap by analyzing Toronto's Bike Share ridership data and cycling infrastructure development from 2017 to 2023. Our findings reveal a significant mismatch between the rapid growth in Bike Share usage and the slower expansion of cycling infrastructure, highlighting the need for accelerated development of bike lanes and routes.

The remainder of this paper is structured as follows. Section 2 describes the data sources and methodology. Section 3 presents trends in Bike Share ridership and cycling infrastructure evolution. Section 4 addresses the implications of our findings. Section 4.4 concludes with limitations and future research directions.

2 Data

This study utilizes two primary datasets: Toronto's Bike Share ridership data (Toronto Parking Authority 2024) and the city's Cycling Network (Bikeways) data (Transportation Services 2024). Both datasets were obtained from the City of Toronto's Open Data Portal (Gelfand 2022), providing a comprehensive view of cycling infrastructure from 2001 to 2024, and Bike Share ridership in the city from 2017 to 2023.

2.1 Bike Share Ridership Data

The Bike Share ridership data, collected by Bike Share Toronto under the Toronto Parking Authority, contains detailed information about each trip taken. While the original dataset included numerous attributes such as Trip Duration, Start and End Station IDs and Locations, Bike ID, and User Type, our analysis focused on two key variables: Trip ID and Trip Start Time. These were sufficient to determine the unique count of rides, which is the primary metric of interest for this study.

We cleaned the data by downloading all CSV files, extracting the required columns (Trip ID and Start Date), and performing necessary cleaning operations. This process involved standardizing column names across files, standardizing data types, and aggregating the data into monthly total ridership figures. Any incomplete or invalid entries were removed during the cleaning process to ensure data integrity.

Table 1 presents a sample of the processed dataset, showcasing the year and month of observation along with the total number of rides for that month.

Table 1: Sample of Toronto's Bike Share Monthly Ridership Data (2017-2023)

Year & Month	Total Monthly Rides
2017-04-01	9,768
2017-12-01	74,077
2018-08-01	281,219
2020-09-01	440,662
2023-01-01	180,135

To provide an overview of the Bike Share program's growth, we aggregated the monthly data into annual statistics, as shown in Table 2.

Table 2: Annual Bike Share Ridership Summary Statistics

Year	Total Rides	Avg Monthly Rides	Year-on-year Growth (%)
2017	1,190,320	1,190,320	NA
2018	1,922,955	1,922,955	61.55
2019	2,439,517	2,439,517	26.86
2020	2,911,059	2,911,059	19.33
2021	3,575,182	3,575,182	22.81
2022	4,620,469	4,620,469	29.24
2023	5,713,141	5,713,141	23.65

This summary reveals a consistent increase in total annual rides from 1,190,320 in 2017 to 5,713,141 in 2023, representing nearly a fivefold increase over seven years.

2.2 Cycling Network (Bikeways) Data

The Cycling Network data, sourced from the City of Toronto's Transportation Services division, provides detailed information about the city's bikeways. While the original dataset included variables such as street name, starting street, ending street, and surface material, our analysis focused on three key attributes: Route ID, Constructed Year, and Upgraded Year. Notably, information on the total length of each bike route was not available, which presents a limitation in our analysis.

Table 3 offers a sample of this dataset.

Table 3: Sample of Toronto's Cycling Network (Bikeways) Data (2001-2023)

Route ID	Constructed Year	Upgraded Year	Bike Way Type
46	2001	2017	Protected Lanes
6	2001	2012	Protected Lanes
647	2007	NA	Shared Roadways
773	2012	NA	Shared Roadways
978	2018	NA	On-Road Lanes

The raw data contained more detailed specifications for bikeway types, which we grouped into three main categories for ease of understanding and analysis:

1. **Protected Lanes**: Physically separated and protected from motor vehicle traffic (e.g., Bi-Direction Cycle Tracks, Cycle Tracks, Multi-Use Trails).
2. **On-Road Lanes**: Designated lanes on the road, not physically separated (various types of bike lanes).
3. **Shared Roadways**: Roads where cyclists and motor vehicles share the same space (e.g., Sharrows, Signed Routes, Park Roads).

The data cleaning process for the Cycling Network dataset involved:

1. Filtering out Constructed Year and Upgraded Year entries with invalid years or missing data.
2. Standardizing bikeway type classifications into the three main categories.
3. Addressing the limitation that bikeways constructed before 2001 were all labeled with a construction year of 2001 in the original dataset.

2.3 Measurement and Limitations

It's crucial to note that our analysis relies on the count of bikeways rather than their total length. This approach was necessitated by data availability constraints, as information on the

length of each bikeway was not provided in the dataset. Using counts instead of lengths may not provide a fully accurate representation of infrastructure growth, as it doesn't account for variations in bikeway size or capacity. For instance, a short protected lane would be given the same weight in our analysis as a long multi-use trail. This limitation should be considered when interpreting the results, particularly when comparing infrastructure growth to ridership increases.

2.4 Potential Biases and Ethical Considerations

While the data provides valuable insights, it's important to acknowledge potential biases:

- **Spatial Bias:** The uneven distribution of bikeways and bike share stations could skew our understanding of ridership patterns. Areas with more extensive infrastructure or higher station density (often in central or wealthier neighborhoods) may show higher ridership, potentially underrepresenting usage in less-serviced areas.
- **Measurement Bias:** The use of bikeway counts rather than lengths may introduce bias in assessing infrastructure growth, potentially over- or under-representing the actual expansion of the cycling network.

Ethically, it's worth noting that the trip data in the ridership dataset is anonymized, mitigating privacy concerns.

2.5 Data Processing and Analysis

Both datasets were cleaned and processed using R (R Core Team 2023), with additional support from the tidyverse (Wickham et al. 2019), dplyr (Wickham et al. 2023), and lubridate (Grolemund and Wickham 2011) packages. The cleaning process involved removing any incomplete entries, standardizing date formats for consistency across the datasets, and aggregating data where necessary.

These datasets were chosen for their up-to-date and comprehensive nature, offering the most accurate available information on Toronto's cycling infrastructure and Bike Share usage. While other datasets were considered, such as bike lanes measured in kilometers or total bike counts, they were not used due to being outdated or no longer maintained.

When analyzed together, these datasets provide insights into the relationship between infrastructure development and the growing demand for cycling in Toronto, allowing us to assess whether the city's bikeway expansion is keeping pace with increasing ridership.

3 Results

Our analysis of Toronto's Bike Share ridership and cycling infrastructure data from 2017 to 2023 reveals several key trends and patterns, shedding light on the relationship between infrastructure development and cycling adoption in the city.

3.1 Bike Share Ridership Trends

Toronto's Bike Share monthly ridership from 2017 to 2023 is illustrated in Figure 1, showing a clear upward trajectory with pronounced seasonal fluctuations. Peak usage consistently occurs during the summer months, while winter sees a significant reduction in rides. Despite these seasonal variations, the overall trend line demonstrates steady growth in ridership.

The most notable features of this trend include:

1. A consistent year-over-year increase in peak monthly ridership, indicating growing popularity of the program.
2. Gradual expansion of the riding season, with shoulder months (spring and fall) showing increased activity over time, suggesting a broadening user base.
3. A brief dip in ridership during early 2020, likely attributable to initial COVID-19 lockdowns, followed by a robust recovery. This recovery may be partially attributed to the ActiveTO program, which closed major streets to car traffic, creating more space for cyclists (Miller 2020).

3.2 Cycling Infrastructure Development

A breakdown of bikeway types constructed each year from 2002 to 2023 is presented by Figure 2. This graph reveals several interesting patterns in the development of Toronto's cycling infrastructure:

1. A significant spike in bikeway installations occurred between 2005 and 2007, primarily driven by the addition of shared roadways. This surge aligns with the city's efforts to implement its 2001 Bike Plan, which aimed to create 1,000 km of bikeways by 2011. While the city fell short of this ambitious target, the period saw a substantial increase in shared roadways, adding over 145 km by 2007 (Ratchford 2013). As shown in Figure 6, this rapid expansion of shared roadways significantly altered the proportional makeup of Toronto's bikeway network, with shared roadways dominating the infrastructure mix for several years following 2007.
2. After 2007, there's a noticeable shift towards more protected lanes and on-road lanes, reflecting growing concerns about cyclist safety and calls for more separated cycling infrastructure.

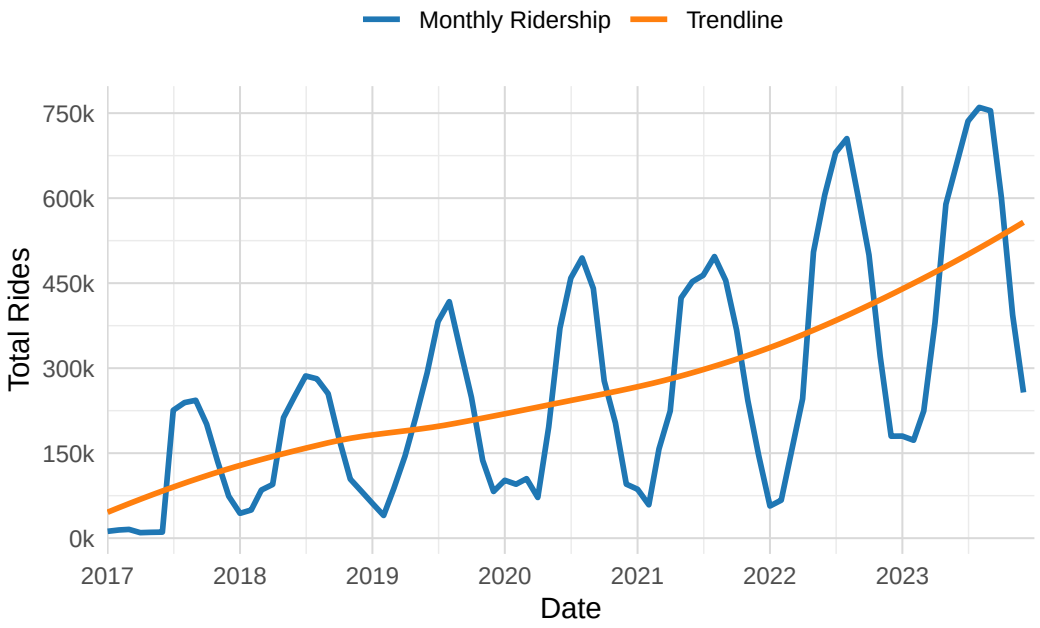

Figure 1: Toronto Bike Share Monthly Ridership Trend (2017-2023)

3. The installation of new bikeways has been relatively consistent from 2010 onwards, with a mix of all three types (shared roadways, on-road lanes, and protected lanes) being added each year.

Bikeways were also upgraded throughout the years to improve the quality and safety for bikers. Figure 3 shows the breakdown of bikeway upgrades by year from 2002 to 2023. Notable observations include:

1. A significant spike in upgrades around 2015, primarily focused on converting existing bikeways to protected lanes. This likely reflects the city's response to increasing demands for safer cycling infrastructure and aligns with several initiatives that began development around that time.
2. After 2015, upgrades have continued at a lower but steady rate, with a focus on improving existing infrastructure rather than just adding new bikeways.

3.3 Cumulative Growth of Cycling Infrastructure

To provide a complete understanding of Toronto's entire Cycling network, Figure 4 presents the cumulative growth of different bikeway types from 2001 to 2023, demonstrating:

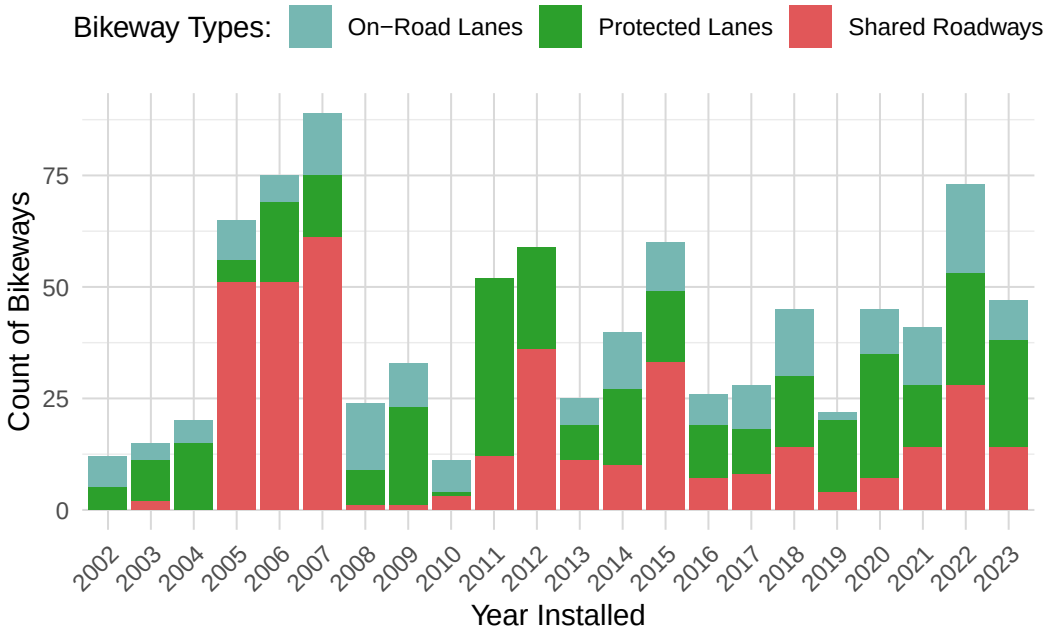

Figure 2: Breakdown of Bikeway Types by Installation Year (2002-2023)

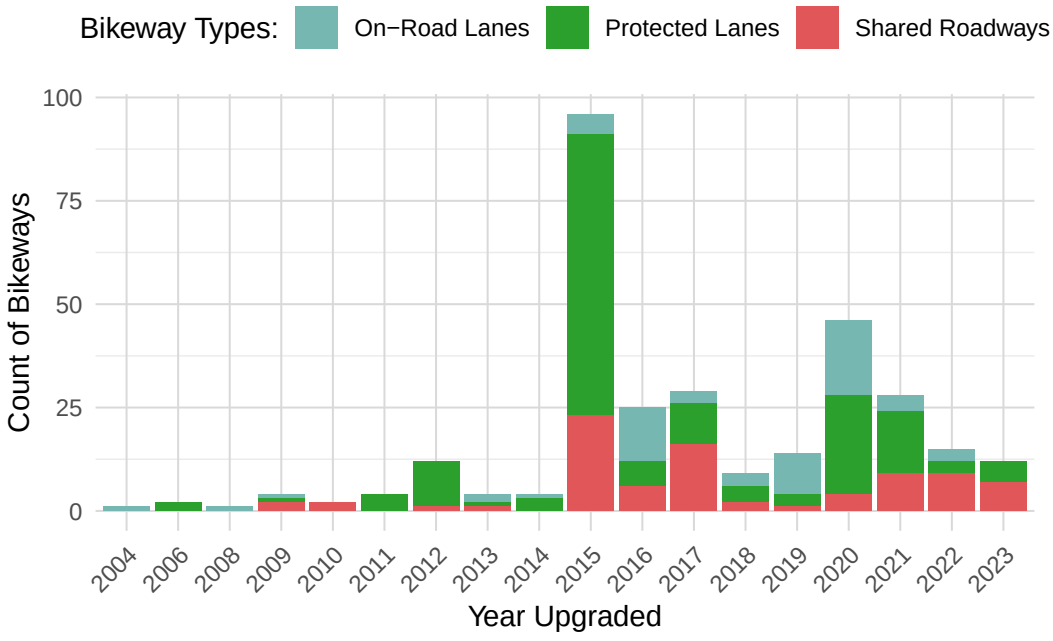

Figure 3: Breakdown of Bikeway Types by Upgraded Year (2002-2023)

1. A steady increase in the total number of bikeways over the two decades, from 539 in 2001 to 1,446 by 2023.
2. The rapid growth of shared roadways in the mid-2000s, which has since stabilized as a proportion of total infrastructure.
3. A consistent growth in protected lanes, particularly accelerating in recent years, aligning with the city's commitment to add 100 kilometers of new cycling infrastructure between 2022 and 2024, and 500 kilometers by 2030 (Transportation-Services 2024).

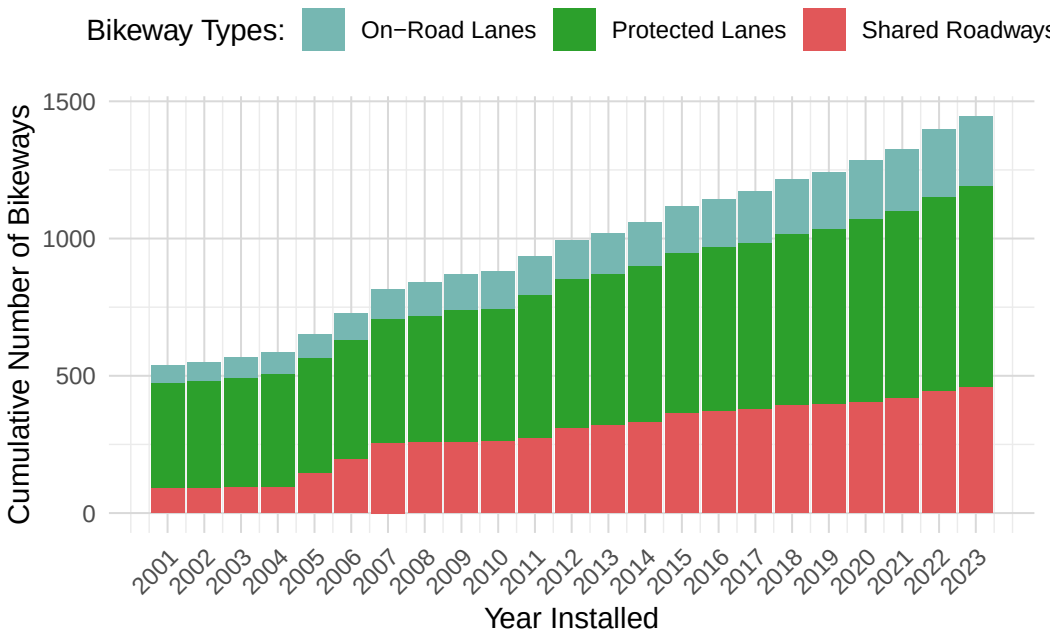

Figure 4: Cumulative Bikeway types by Installed Year (2001-2023)

3.4 Comparison of Ridership and Infrastructure Growth

To directly compare the ridership and infrastructure growth, Figure 5 provides a comparative view of annual Bike Share ridership and the cumulative number of bikeways from 2017 to 2023. This graph reveals:

1. A strong positive correlation between the growth in Bike Share ridership and the expansion of cycling infrastructure.
2. Bike Share ridership has grown at a faster rate than the expansion of bikeways. However, it's important to note that this comparison is limited by the use of bikeway count rather than total length, which might provide a more accurate representation of infrastructure growth.

3. Despite the apparent slower growth of bikeways compared to ridership, the continuous increase in infrastructure likely supports and encourages the growing popularity of cycling in Toronto.

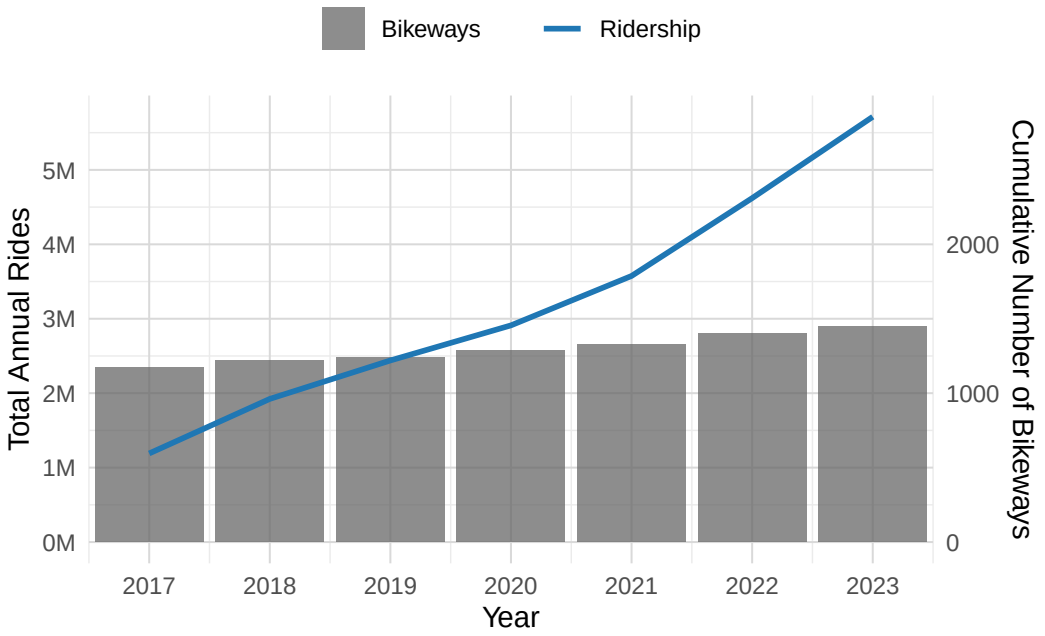

Figure 5: Comparison of Annual Bike Share Ridership and Cumulative Bikeways (2017-2023)

These results suggest that while Toronto has made significant strides in expanding its cycling infrastructure, the growth in Bike Share ridership may be outpacing the development of new bikeways. This trend underscores the importance of continued investment in cycling infrastructure to meet the growing demand for safe and accessible cycling options in the city.

4 Discussion

The analysis reveals a complex interplay between infrastructure investment and cycling adoption in Toronto from 2017 to 2023. This discussion will explore the implications of our findings, addressing the central question of whether Toronto's bikeway infrastructure is keeping pace with the growth in Bike Share ridership.

4.1 Rapid Growth in Bike Share Utilization

The most striking finding from our analysis is the dramatic increase in Bike Share ridership over the study period. The nearly fivefold increase in annual rides from 2017 to 2023 demonstrates

a significant shift in urban mobility patterns and a growing acceptance of cycling as a viable transportation option in Toronto. This trend aligns with global movements towards more sustainable and active transportation modes in urban areas.

The consistent year-over-year growth, even in the face of the COVID-19 pandemic, suggests a resilient and potentially permanent change in transportation habits among Toronto residents. This rapid adoption of Bike Share presents both opportunities and challenges for urban planners and policymakers.

4.2 Infrastructure Development: Progress and Challenges

Our analysis of cycling infrastructure development reveals a more nuanced picture. While there has been steady growth in the total number of bikeways, from approximately 600 in 2001 to over 1,400 by 2023, the rate of infrastructure expansion has not matched the pace of Bike Share ridership growth. This disparity raises questions about the capacity of the current infrastructure to safely and efficiently accommodate the increasing number of cyclists.

The shift in focus from shared roadways to more protected lanes, particularly evident after 2007, reflects an evolving understanding of cyclist safety needs. This aligns with the city's commitment to Vision Zero and Complete Streets policies, which prioritize safety for all road users ("Cycling Network Plan - City of Toronto" 2024). However, the data suggests that there may be a need for accelerated implementation of these safer infrastructure options to meet the growing demand.

4.3 Policy Implications and Future Directions

The rapid growth in Bike Share ridership, outpacing infrastructure development, underscores the need for more aggressive expansion of Toronto's cycling network. The city's recent commitment to adding 100 kilometers of new cycling infrastructure between 2022 and 2024, with plans to complete 500 kilometers by 2030 (Transportation-Services 2024), is a step in the right direction. However, our findings suggest that even this ambitious plan may need to be accelerated or expanded to meet the growing demand. Several policy implications emerge from our analysis:

1. Prioritizing Protected Infrastructure: Given the clear preference for safer cycling options, future infrastructure development should prioritize protected lanes over shared roadways where feasible.
2. Strategic Expansion: The city should consider strategically expanding the Bike Share program in tandem with new infrastructure development to ensure a balanced growth of both supply and demand.
3. Integration with Public Transit: The success of the Bike Share program suggests opportunities for further integration with other forms of public transportation, potentially addressing last-mile connectivity issues.

4.4 Limitations and Future Research

While our study provides valuable insights into the relationship between cycling infrastructure and Bike Share usage in Toronto, it has several limitations that suggest avenues for future research:

1. **Geographic Distribution**: This study did not examine the spatial distribution of Bike Share usage and infrastructure. Future research could employ geographic information to map these distributions, revealing patterns of usage and infrastructure gaps.
2. **Quality of Infrastructure**: Our analysis focused on infrastructure quantity rather than quality or connectivity. Future studies could incorporate these measures for a more comprehensive understanding of Toronto's cycling landscape.
3. **Infrastructure Measurement**: Due to data limitations, our analysis relied on the count of bikeways rather than their length. Future studies with access to length data could offer a more precise comparison between infrastructure development and ridership growth, potentially creating a weighted index that accounts for factors such as bikeway type, length, and connectivity.
4. **Comparative Analysis**: A study comparing Toronto with cities of similar climate and urban structure could help identify best practices in balancing infrastructure development with growing cycling demand.

These research directions could significantly enhance our understanding of the complex relationship between cycling infrastructure development and ridership growth in urban environments.

In conclusion, while Toronto has made significant strides in expanding its cycling infrastructure and Bike Share program, our analysis suggests that infrastructure development is lagging behind the rapid growth in cycling demand. As the city continues to invest in sustainable transportation options, a data-driven, strategic approach to cycling infrastructure development will be crucial in supporting and encouraging the growing cycling culture in Toronto.

Appendix

The following graph shows how the composition of Toronto's bikeway network has evolved over time, taking into account the cumulative additions of different bikeway types.

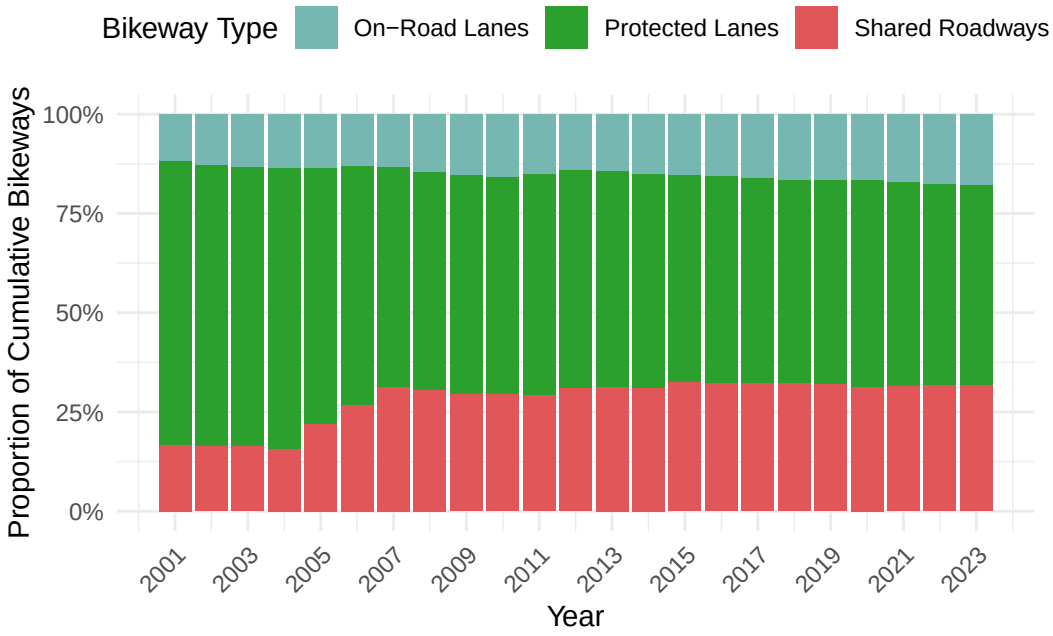

Figure 6: Proportional Breakdown of Cumulative Bikeways by Type and Year (2001-2023)

This graph provides additional context to the absolute numbers shown in the main text. It illustrates how the relative proportions of different bikeway types have changed as the network has grown, which may reflect shifts in urban planning priorities or infrastructure strategies over the years.

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