Prevent Bicycle Thefts: Analyzing the time and location of the thefts*

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This study investigates the patterns and contributing factors of bicycle theft in Toronto, Canada. Although fewer bicycle thefts have occurred in recent years, the recovery rate of stolen bicycles remains consistently low. Bicycle thefts are more likely to occur during the summer months, on Fridays, in the afternoon and evening, and in apartment. The analysis highlights the need to improve recovery strategies and implement effective bicycle theft prevention measures to address the ongoing issue of bicycle theft in Toronto, thereby fostering a safer and more secure city for cyclists.

1 Introduction

Cycling has emerged as a sustainable mode of transportation, offering significant environmental, social, and economic benefits. It reduces reliance on non-renewable resources, promotes physical health, and provides a cost-effective alternative to driving (Pucher and Buehler (2008)). Particularly for short- and medium-length trips in urban areas, cycling is a viable and attractive choice for many (Tabascio et al. (2023)). Recognizing these advantages, the City of Toronto has actively implemented initiatives to create a safer and more welcoming environment for cyclists.

However, bicycle theft remains a persistent challenge worldwide (Johnson, Sidebottom, and Thorpe (2008)). In Montreal, approximately 20% of cyclists have expressed concerns about inadequate parking facilities and the risk of theft (Bachand-Marleau, Larsen, and El-Geneidy (2011)). Studies show that a significant number of cyclists reduce or stop cycling altogether following a theft, illustrating the detrimental impact this crime has on the cycling community (Cohen et al. (2024)). Although many studies have explored the behavioral effects of bicycle theft and ways to improve infrastructure to promote a better cycling environment, few have

*Code and data are available at: https://github.com/Isazhou13/Bicycle_Thefts_Analysis.git

delved into the specific patterns of bicycle theft itself, analyzing its occurrences and identifying commonalities among theft incidents. Therefore, this study addresses the gap by offering empirical evidence on patterns of theft occurrences, specially focusing on high-risk times and places of bicycle theft. This information is not only can help cyclists to avoid theft, but also helpful for governments to implement more effective prevention strategies that enhance cycling safety.

This study utilized open-source data from OpenDataToronto to investigate the patterns and underlying causes of bicycle theft in the city. By cleaning and analyzing the data, the study identified a low recovery rate for stolen bicycles, underscoring the need for more robust theft prevention measures. Additionally, the analysis shows that bicycle thefts are more likely to occur during the summer season, on Fridays, between 12:00 PM and 6:00 PM, and in apartment, highlighting the importance of prevention strategies in these times and areas.

The remainder of this paper is structured as follows: Section 2 covers the data, and Section 3 presents the discussion. The Data section provides context and visualization for the dataset. Section 3 critically examines the results, discusses the limitations of the study, and proposes areas for future exploration.

2 Data

This study uses R packages (R Core Team 2023) to clean and analyz the dataset , including libraries from tidyverse (Wickham et al. 2019), ggplot2(Wickham 2016), readr (Wickham, Hester, and Bryan 2024), dplyr (Wickham et al. 2023), here (2 2020), knitr(Xie 2023), tidyr(Wickham, Vaughan, and Girlich 2023) and modelsummary(Arel-Bundock 2022) .

2.1 Data Measurement and Considerations

The dataset for this analysis on Bicycle Thefts in Toronto was obtained from OpenDataToronto (Gelfand 2022). This dataset on bicycle thefts includes incidents reported to the Toronto Police Service (Services 2024), which update annually, contains information starting from 2014, with the most recent update on July 24, 2024. The raw data originally consisted of 36,125 observations across 28 variables.

After removing missing values, selecting relevant variables, and improving readability through formatting and renaming, the final cleaned dataset contains 32,991 observations and focuses on the following seven variables: Year, Month, Day of the Week, Hour, Location Type, Status, and Day Part. These represent the year, month, day of the week, and hour of the bicycle being stolen, the location where bicycle theft occurred, and the bicycle theft status(Stolen, Recovered and Unknown).

The Day Part variable was constructed based on hour of the bicycle theft occurrence, recognizing that bicycle thefts correlate more closely with general timeframes rather than specific

hours. Therefore, the day is divided into four time segments as showed in Day Part Variables: Morning (6:00 AM - 11:59 AM), Afternoon (12:00 PM - 5:59 PM), Evening (6:00 PM - 11:59 PM), and Overnight (12:00 AM - 5:59 AM).

Even though the dataset was last updated in 2024, the bicycle theft information is current up to June 2024. Therefore, only bicycle thefts from 2014 to 2023 were included in the analysis, as they provide full-year data on bicycle theft occurrences.The top five rows of the dataset are displayed in Table 1.

Table 1: Sample of Cleaned Data of Bicycle Thefts in Toronto

Year	Month	Day of the Week	Hour	Location Type	Status	Day Part
2014	January	Wednesday	7	Apartment	Stolen	Morning
2014	January	Wednesday	18	Single Home, House	Recovered	Evening
2014	January	Wednesday	12	Apartment	Stolen	Afternoon
2014	January	Friday	8	Private Property Structure	Stolen	Morning
2014	January	Saturday	18	Apartment	Stolen	Evening

2.2 Offense Trends by Year

Figure 1 shows the status of bicycle offenses from 2014 to 2023. The peak occurred in 2018, with a total of 3,768 occurrences.The data indicate increases in the total number of offenses from 2014 to 2020. Following 2020, it is noticeable that the occurrence of bicycle thefts declined, suggesting a potential improvement in public safety.

However,the recovery of reported bicycle thefts remains concerningly low. As depicted in Figure 1, among the total number of occurrences, only a small portion of the bicycles are being recovered and returned to their owners. Figure 2 provides a detailed examination of the bicycle recovery rate over the years, calculated by dividing the total number of recovered bicycles in a specific year by the total number of bicycle thefts in that year. In 2014, the recovery rate was approximately 1.57%, and in 2022, only 0.21% of bicycles were recovered (Table 2). This downtrend raises questions about the efficiency of bike recovery in Toronto.

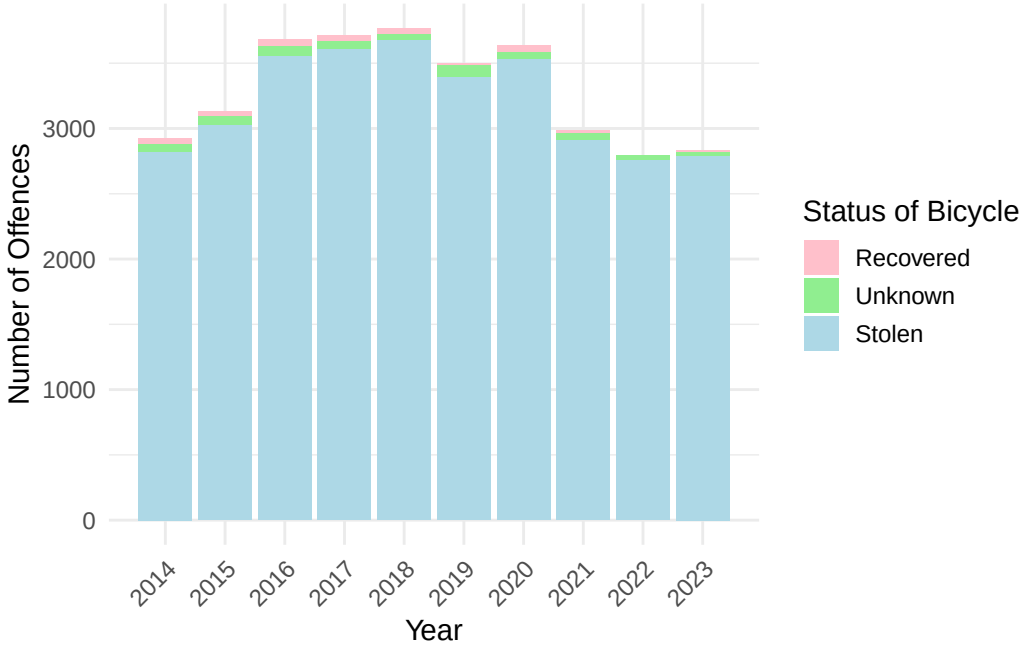


Figure 1: Bicycle Status Over the Years

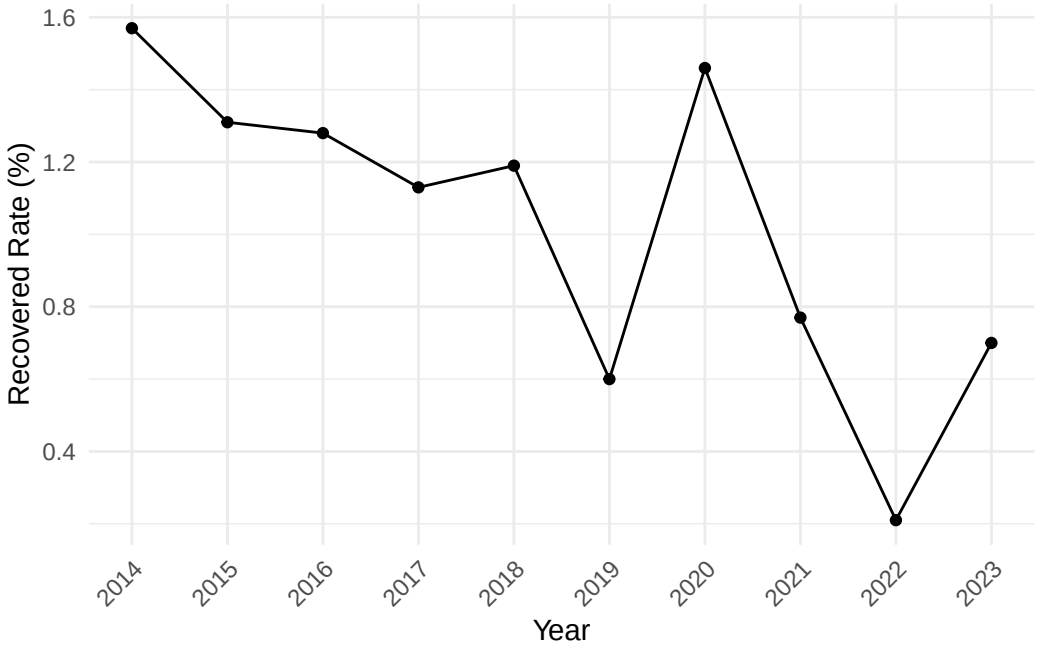


Figure 2: Recovered Rate Over the Years

2.3 Offense Trends by Month

Figure 3 shows the offenses of bicycle theft by month for each year from 2014 to 2023. The data reveals that the number of occurrences is lowest in February. It then steadily increases in the following months, reaching its peak around July, before showing a declining pattern again. This indicates a seasonal trend in bicycle thefts, where bicycle thefts tend to occur more frequently during the summer and are less wlikely to happen during the winter.

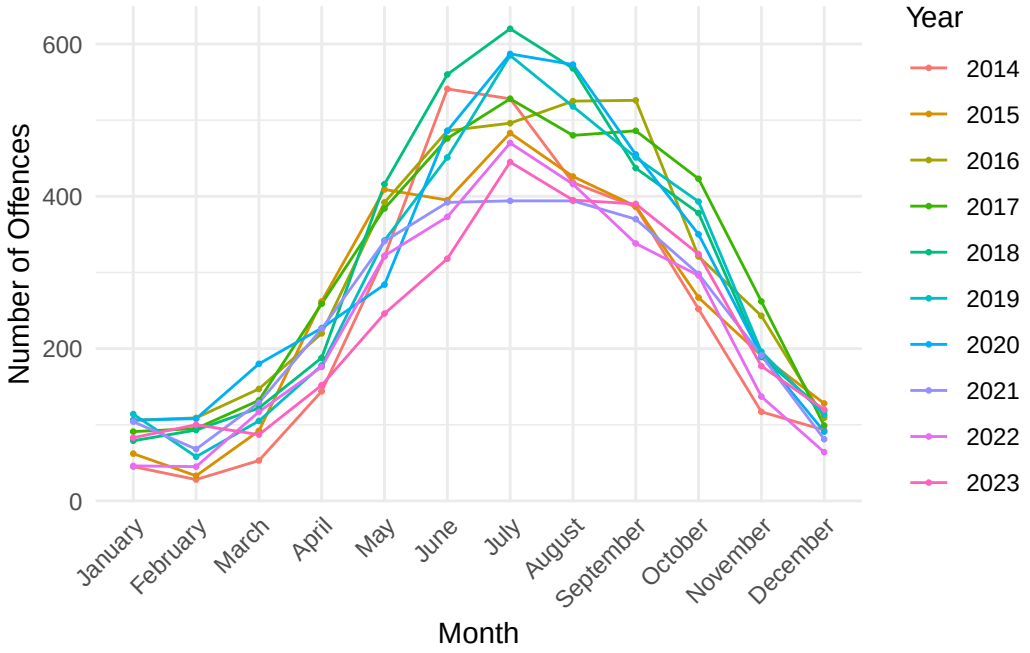


Figure 3: Number of Offences by Month

2.4 Offense Trends by Day of the Week

Figure 4 illustrates the number of bicycle thefts by day of the week. The data indicates a relatively consistent pattern of thefts throughout the week, with difference between weekdays and weekends. Number of offences of bicycle thefts are generally lower on weekends compared to weekdays. Among the weekdays, Friday stands out as having the highest number of offences, making up 15.4% of the total bicycle thefts(Table 3) .

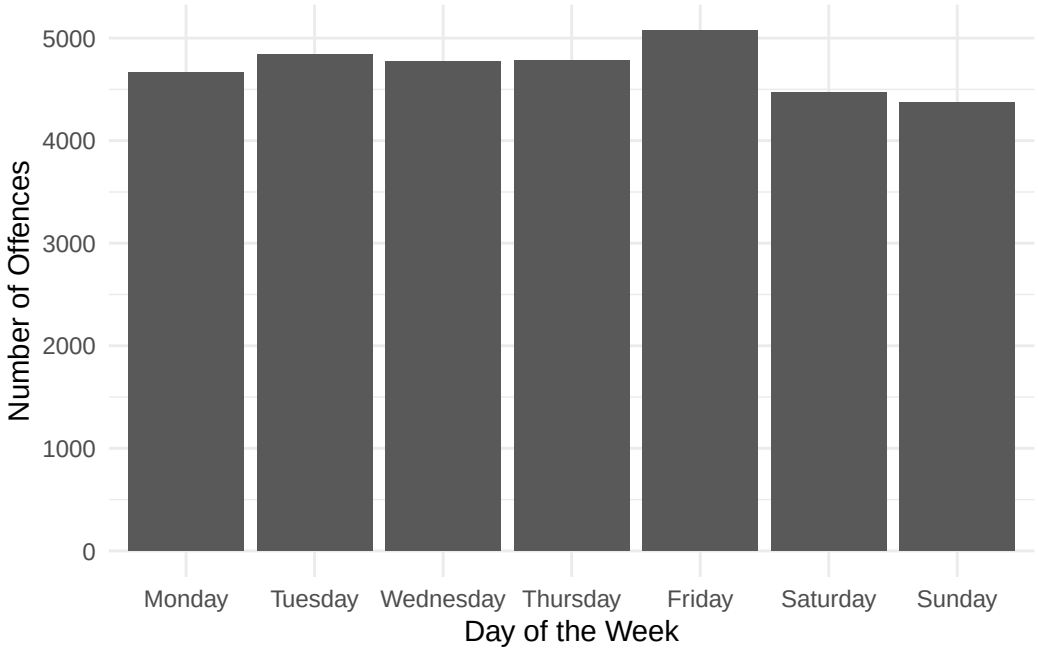


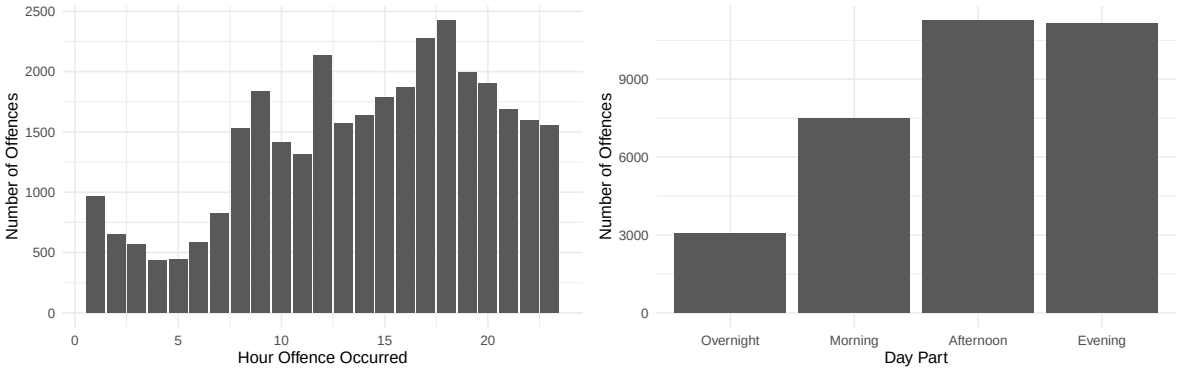
Figure 4: Number of Offences by Day of the Week

2.5 Offense by Hour

Figure 5 illustrates the distribution of bicycle thefts by hour and by day part. The data shows that the fewest thefts occurred around 5:00, followed by minor peacks around 9:00 and 12:00.The most significant peak was observed at 18:00. When considering the broader day part categories, it is evident that majority bicycle theft offences happened during the afternoon and everning, accounting for 67.9% of total thefts. Fewest incidents occurring overnight,acounting for only 9.3% of the overall bicycle thefts (Table 4).

2.6 Offense by Location Type

Figure 6 depicts top four locations where bicycle thefts are most likely to occur, which are Apartment, Streets/Roads/ Highways and Single Home/House and Parking lots. These areas have a high concentration of bicycle parking and often limited security measures, which results in a high occurrence of bicycle thefts



(a) Number of Offences by Hour

(b) Number of Offences by Dat Part

Figure 5: Number of Offences by Time

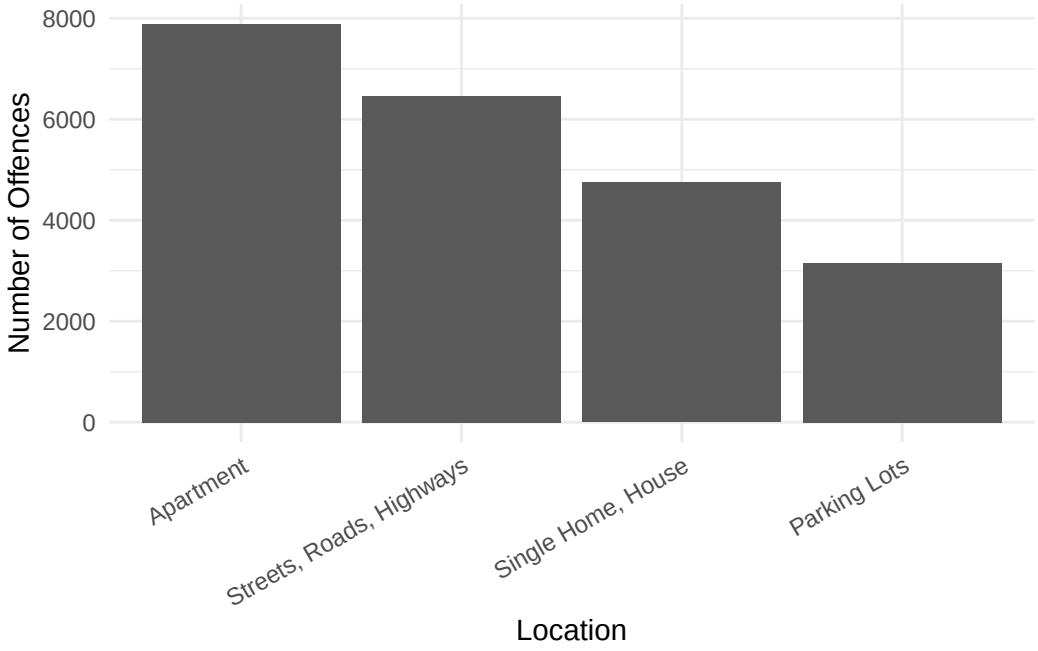


Figure 6: Number of Offences by Location Type

3 Discussion

3.1 Summary of Findings

This study analyzed trends and patterns of bicycle theft occurrences in Toronto using a dataset from the Toronto Police Service covering 2014 to 2023. After data cleaning, the analysis focused on key variables such as bicycle status, offenses by year, month, day of the week, hour, and location type. The research identifies when and where bicycles are more likely to be stolen. These findings can not only help Toronto residents know where and when they need to pay more attention to their bicycles, but they can also help policymakers understand theft patterns and develop better prevention strategies. The research can also be applied to similar issues in other regions to enhance preventive measures.

3.2 Essential to Prevent Bicycle Theft

Figure 1 shows an increase in bicycle thefts from 2014 to 2020, followed by a decline in 2021 and 2022. This is attribute to the COVID-19 pandemic accelerated the planning and completion of the cycling infrastructure in Toronto (Lin, Chan, and Saxe (2021)). This expansion and improvement make the cycling safter and provided with more secure spaces for bicycle parking.

The recovery rates for stolen bicycles, as depicted in Figure 2, remain consistently low, dropping from 1.57% in 2014 to a mere 0.21% in 2022. These findings align with previous research, such as Van Lierop et al. (2015), which reported that only 2.5% of survey respondents recovered their stolen bicycles. The low recovery rate is linked with the proof of the ownership problem The majority of cyclists are unable to provide their bike's serial number or any legal documentation, like a purchase receipt, to prove ownership of the bicycle. (Johnson et al., 2008). Therefore, it become even harder for police to give back the correct bicycles to the right owner. Thus, as the cyclist, it is important to keep relevant information about the bicycle, which is helpful for future recovering if the bicycle being stolen.

Moreover, some offenders steal bicycles for financial gain(Johnson, Sidebottom, and Thorpe (2008)). It can be helpful for bicycle owners who have lost their bikes to search through various second-hand selling websites, such as Facebook Marketplace, Kijiji, or similar platforms, to see if anyone nearby is selling a bike that looks like theirs.

To improve recovery rates, police departments could adopt strategies such as photographing and registering bicycles (Van Lierop et al., 2015). Despite the City of Toronto's efforts to provide guidelines for bicycle theft prevention, including advice on proper locking techniques, selecting safe parking spots, and encouraging bicycle registration, the recovery rate remains low. This raises concerns about the effectiveness of current police recovery strategies and the challenges of tracing and identifying stolen bicycles. It is therefore crucial for cyclists to be more vigilant and cautious when parking their bicycles to reduce theft risk.

3.3 Seasonal, Weekly, and Daily Patterns

Figure 3 demonstrates the seasonal trend of bicycle thefts, with thefts peaking in summer and declining in winter. The findings of this paper align with existing research indicating that bicycle theft is more frequent in the summer, correlating with higher cycling activity during warmer months (Van Lierop, Grimsrud, and El-Geneidy (2015)). According to the research, the likelihood of cycling is related to temperature and wind speed. Specifically, the probability of cycling increases by 3% for each 1°F rise in morning temperature and decreases by 5% for each 1 mph increase in wind speed (Sears et al. (2012)). In addition, darkness will result people cycling less (Heinen, Van Wee, and Maat (2010)). Consequently, more cyclists on the road during the summer due to the higher weather, less wind, and shorter darkness, which create more opportunities for thieves, making it easier for offenders to find the types of bicycles they are targeting.

Moreover, not all offenders steal bicycles for financial gain; some do so for personal transportation or joyrides (Johnson, Sidebottom, and Thorpe (2008)). As a result, during the summer, offenders also tend to need bicycles more than in winter, leading to an increase in thefts during this season. Therefore, cyclists need to pay closer attention to securing their bicycles and choosing parking locations, especially during the summer months.

When examining weekly patterns,as shown in Figure 4 bicycle thefts are more common on weekdays, particularly on Fridays, than on weekends. This trend is likely due to the increased presence of bicycles on the streets during the week as people commute, which contributes to higher theft rates. Additionally, commuters may be rushed or distracted, especially during the early morning hours, leading them to pay less attention to securing their bicycles properly. Consequently, this creates more opportunities for theft. Moreover, bicycles are often stolen in densely populated areas (Chen, Liu, and Sun (2018)). On weekdays, many bicycles are parked near workplaces, schools, and transit stations, which creates opportunities for offenders to steal the bicycles. Furthermore, people tend to leave their bicycles parked for longer periods during workdays compared to weekends, further increasing the likelihood of theft.

Figure 5 shows that most bicycle thefts occur at 9:00, 12:00, and 18:00, which are peak commuting times when people typically arrive at work, take lunch breaks, and leave the office. Additionally, a significant proportion of bicycle thefts happen during the afternoon and evening, accounting for 34.1% and 33.8% of all occurrences, respectively. This finding matches with the study, which reported that 32.3% of thefts occur in the afternoon (Van Lierop, Grimsrud, and El-Geneidy (2015)). However, the study also highlights overnight as another peak time for bicycle thefts. This discrepancy might be due to the difference in sample sizes, as that research only received 1,922 useful responses, significantly fewer than the dataset used for this research. The increased risk of bicycle thefts during the afternoon and evening can be explained by the higher number of bicycles parked in public areas, providing greater opportunities for theft. Therefore, the analysis suggests that bicycle owners need to be especially vigilant during these peak hours.

3.4 Location Type Patterns

Figure 6 indicates that the majority of bicycle thefts occur at apartments, making them the most common location for these crimes. The second highest occurrence of bicycle thefts is found on streets, roads, and highways. Research shows that bicycles are more frequently stolen in places where parking racks are installed (Chen, Liu, and Sun (2018)), which aligns with our findings. Apartments typically do not allow residents to bring bicycles into their units, as doing so can cause inconvenience in common areas, such as elevators, for other residents. Moreover, storing bicycles on balconies can create safety issues. Therefore, many apartments provide residents with bicycle racks where they can securely lock their bicycles. However, the management of these facilities is not always effective, leading to a high probability of theft in the apartments. Similarly, streets, roads, and highways also have bicycle racks for parking bicycles.

3.5 Weaknesses and Next Steps

The dataset currently lacks critical information related to bicycle thefts. For example, it does not specify whether the stolen bicycles were locked and, if so, what type of lock was used. Research indicates that 10% of victims did not lock their bicycles at the time of theft, leaving them more likely to be stolen (Van Lierop, Grimsrud, and El-Geneidy (2015)). Additionally, different locks require varying amounts of time and effort to unlock, directly influencing the success rate of thefts. Detailed information about the location is also relevant, as bicycle thefts are more likely to occur mid-block than at intersections (Chen, Liu, and Sun (2018))

Moreover, the dataset is based on police reports and does not have information about unreported bicycle thefts, potentially providing an incomplete picture of theft incidents in Toronto. On average, only 56% of bicycle thefts are reported to the police (Johnson, Sidebottom, and Thorpe (2008)). This indicates that a huge proportion of cyclists do not report bicycle thefts to the police.

Furthermore, the dataset lacks data on the total number of bicycles in Toronto, as well as yearly and monthly bicycle usage patterns. Without this information, analyzing theft trends over time is less precise, as increased bicycle use correlates with a higher likelihood of theft. OpenDataToronto offered information on bicycle counts and locations, which can be helpful for this study and can help solve the problem of lacking ridership information. However, the bicycle count dataset only contains information about ridership in 2010, and it does not provide the necessary information on recent trends and patterns in bicycle ridership, so it is not included in this analysis.

Future studies would benefit from conducting surveys to understand cyclist behaviors related to bicycle theft and parking habits. Additionally, gathering relevant information and incorporating bicycle usage data would allow for a more accurate analysis through the calculation of the bicycle theft percentage in relation to the total number of bicycles in use.

Table 3: Summary Statistics for Day of the Week

Day of the Week	N	%
Monday	4667	14.1
Tuesday	4842	14.7
Wednesday	4776	14.5
Thursday	4785	14.5
Friday	5073	15.4
Saturday	4473	13.6
Sunday	4375	13.3

Table 4: Summary Statistics for Day Part

Day Part	N	%
Overnight	3072	9.3
Morning	7498	22.7
Afternoon	11264	34.1
Evening	11157	33.8

Appendix

Table 2: Recovered Rate of Bicycle Theft Incidents by Year

Year	Total Occurrences	Recovered	Recovered Rate(%)
2014	2926	46	1.57
2015	3135	41	1.31
2016	3680	47	1.28
2017	3715	42	1.13
2018	3768	45	1.19
2019	3504	21	0.60
2020	3638	53	1.46
2021	2988	23	0.77
2022	2800	6	0.21
2023	2837	20	0.70

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