

The Highs and Lows of Transit Safety: Analyzing Crime Patterns in Toronto's Subway Stations Pre- and Post-Covid-19

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The Highs and Lows of Transit Safety: Analyzing Crime Patterns in Toronto's Subway Stations

Pre- and Post-Covid-19

Master of Spatial Analysis, 2024

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Spatial Analysis, Toronto Metropolitan University

Abstract

This study examines the impact of Covid-19 on crime rates within the Toronto Transit Commission's (TTC) subway system. Using data from 2016 to 2022, this research analyzes crime patterns before and after the pandemic, drawing on different sources such as social services and the Ontario Marginalized Index to understand the socioeconomic factors surrounding each station. The study finds that crime tends to be concentrated in low to medium-ridership zones, a trend intensified by the pandemic. High-use stations, in contrast, showed a plateau in crime rates, suggesting a correlation between high passenger volumes and a reduction in criminal activity. The results demonstrate the TTC's challenges in attracting choice riders to low-ridership stations as they continue to experience high crime rates and increasing safety concerns. The study suggests an immediate, feasible action plan that can help increase ridership levels, choice riders, and safety near concerning subway stations. This research contributes to the broader discourse on public transit safety by highlighting the importance of addressing both actual and perceived threats to ridership. By implementing measures that adopt a safer environment across all stations, the TTC can work towards providing a more equitable and reliable transit system to all Torontonians.

Keywords: TTC, Crime, Crime Rates, Safety, Count Index, Trade Area Index, Social Services, Ontario Marginalized Index, Ridership,

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CHAPTER ONE: INTRODUCTION

1.1. Introduction

Public transit has become an ever-important necessity since its earliest introduction into society. This public system has helped people of all races and economic classes travel from one location to another. Transit systems consist of different modes, the three most predominant being subways, street cars, and buses. These public transportation systems vary greatly in their success across various regions. For instance, a comparison between the Los Angeles County Metropolitan Transportation Authority and Transport for London can be drawn. The latter, serving a larger population, is widely acclaimed as one of the world's most successful systems, renowned for its efficiency and extensive coverage. In contrast, despite serving a smaller population, Los Angeles has faced criticism for substantial deficiencies and the need for substantial improvements in customer service and overall effectiveness.

In Canada, the Toronto Transit Commission (TTC) has, over the years, gained a reputation for being one of North America's best public transit systems. From 2016 to 2021, the TTC has won numerous awards, the most prestigious being the American Public 'Transportation Association's award for Transit System of the Year (TTC, 2017). This award recognizes the TTC as a clean, punctual, safe, and continuously growing system. It demonstrates its commitment to renewing and adding new vehicles to the system promptly and supporting its clients as best as possible while introducing PRESTO, a new form of payment that makes the experience more user-friendly. This can be seen when comparing 2016 to 2022. In 2016, there were 69 subway stations, 146 bus routes (excluding night bus services and community buses), 11 streetcar routes, and four subway lines (TTC, 2016). In 2022, the TTC saw an increase in subway stations to 75

stations, and bus routes increased to 162 routes (excluding night bus service and community busses) (TTC, 2022). Streetcar routes decreased to 9 to better handle congestion within the city, but this did not come at any other cost as there were four subway lines.

Beyond efficiency and coverage, safety stands as a critical pillar of any successful public transit system, and the TTC has historically embodied all three characteristics. However, in recent years, challenges, such as the global pandemic Covid-19, have posed considerable obstacles to maintaining its safety standards. After the implementation of lockdown measures, ridership declined substantially on the TTC due to restrictions on movement. Despite these measures and the decrease in ridership, safety concerns heightened as incidents of violence arose across the system (Toronto Star, 2022). When further analyzing the intricate relationship between the TTC, Covid-19, and criminal cases pre-and-post Covid-19 eras, a complex relationship exists. Although one affects another, it is not a closed ecosystem, as various factors are involved.

Crime on the TTC is not unique to this system but can be seen as a microcosm of Toronto, reflecting large issues the city has faced for decades (Harvey, 2022; Clarke, 2023). These issues range from mental health problems to drug addiction and poverty (Harvey, 2022). Covid-19 can be seen as a tipping point, accelerating crime rates on the TTC, with some crimes described as 'random attacks' (Chong, 2023). Even though crime is a substantial factor, it is also essential to understand that the fear of a crime is as important as a crime. If individuals fear stations through hearsay, it can have the same effect as crimes occurring at a station, making riders want to avoid the station if possible. The TTC has been trying to lure riders back into the system, but this effort has not gone as planned, as customers continue to feel unsafe (Harvey, 2022; Chong, 2023; Clarke, 2023). By increasing ridership, not only will revenue rise to at least

pre-Covid-19 levels, but it will also help with security. This is due to crime prevention through environmental theory (CPTED). CPTED aims to increase safety through natural surveillance, which increases law-abiding people in an area, thereby deteriorating criminal behaviour.

Although the ecosystem is not closed, there is evidence that the relationship between societal issues and crime on the TTC is substantial when analyzed through the effect that Covid-19 has had. Before the offset of Covid-19, an estimated 1.4 million individuals used the TTC daily in 2018; post-Covid-19, this number decreased to an estimated average of 872,000 individuals in 2022 (TTC, 2022). This represents a decrease of approximately 38%. In 2022, there were 1,068 incidents of reported violence, a substantial increase from the 679 incidents reported in 2018 (CBC, 2023).

1.2. Research Objectives and Questions

This study seeks to primarily answer the following question: How has the Covid-19 pandemic affected the TTC subway stations' crime rate? The results of this question will determine whether the TTC subway stations have become more unsafe, as perceived by many local Torontonians. The study will also seek to answer three additional questions.

Q1. What is the change in the spatial distribution of the five safest and most unsafe subway stations from 2016 to 2022?

Q2. Is there a correlation between the stations and community services based on any shifts that may have occurred between 2016 and 2022?

Q3. Does a correlation exist between the Ontario Marginalized Index and the safest and most unsafe stations?

The first sub-question will provide a visual aid as to which subway stations are most prevalent in crime. The second and third questions will build on the outputs produced by the first results. The second question will use different social variables, such as community centers, health services, and financial help centers, to name a few, and will see if the five most and least unsafe subway stations share a correlation through a count index. A similar analysis will be conducted to answer the third question using the Ontario Marginalized Index and a trade area index instead.

1.3.Study Area

The study area for this research paper is the City of Toronto in Ontario, Canada. Toronto, the largest city in the country, has a population of 3 million people as of 2022 (City of Toronto, 2023). Although the city is not growing at the national rate of 5.2%, it is steadily increasing at 2.3% (Statistics Canada, 2022). The city's boundaries span north to Steeles Avenue, south to Lake Ontario, east to Rouge River and Rouge Park, and west to Etobicoke Creek and Highway 427. Toronto is home to a diverse population, with half identifying as a minority, immigrant, or both. The city has become a hub for various businesses, consumers, and public services, making it Canada's most noteworthy concentration point.



Figure 1. Map of the City of Toronto with Major Transit Routes

As Canada's largest city, Toronto offers its residents various forms of transportation. Despite having “the highest average commute times of any major city in the country and the worst commutes for any city in North America” (Toronto Foundation, 2023), public transit remains a vital component of daily life. Toronto's most common modes of transport include private vehicles, public transit such as the TTC, walking, cycling, and being a passenger through ride-sharing apps or carpooling. According to the Transportation Tomorrow Survey (2016), 74% of households have access to at least one or two vehicles. The same report indicates that 55% of trips made on public transit are for leisure activities, with 34% commuting from home to work and back. Overall, 64% of people choose to drive, 13% are passengers through carpooling or rideshare apps, 11% use public transit, and 8% walk or cycle when mobilizing from one location to another (Transportation Tomorrow Survey 2016, 2018).

CHAPTER TWO: LITERATURE REVIEW

2.1. Importance of Public Transit

Public transportation is vital for transporting people from one location to another. It is the most beneficial in large cities as it is more cost-efficient, energy-efficient, less polluting, and can move more people in less space than private motorized vehicles (Rubenstein et al., 2012). In addition to these benefits, improving existing conditions helps relieve traffic congestion (Adler et al., 2020), vital in supporting the most low-income urban residents who rely on this service (Plano, 2015).

The research conducted by Adler et al. shows that improving public transit is vital for a city in numerous ways. Adding dedicated bus lanes on street level would increase the speed at which buses can flow through an area as they move from one stop to the next (Adler et al., 2020). This would reduce congestion and lower operating costs in high-frequency zones originating in a city's centralized business district (Adler et al., 2020; Rubenstein et al., 2012). With faster frequencies of buses passing by, people who rely on these services the most for everyday activities, such as low-income individuals, would seek to benefit the most. A more reliable transit system would allow these people access to better healthcare systems, education systems, and grocery stores that provide better food quality (Plano, 2015). All these benefits would help lower unemployment rates, lower travel time, and increase overall health (Plano, 2015; Adler et al., 2020).

2.2. Covid-19 and its Effects on Public Transit

Covid-19 has had a long-lasting and adverse effect on public transit, having a negative correlation extensively decreasing ridership (Palm et al., 2022; Qi et al., 2023; Mashrur et al.,

2022; Kar et al., 2022). Covid-19 has reshaped the public perception of public transit viability as their preferred method of travel, seeking to use alternative options when possible (Palm et al., 2022; Qi et al., 2023; Mashrur et al., 2022; Kar et al., 2022). Although there are people who use alternative methods where possible, there is a vulnerable population of low-income, diverse, recent migrants who are forced to continue to take public transit (Palm et al., 2022; Qi et al., 2023; Mashrur et al., 2022; Kar et al., 2022). However, the decline in public transit ridership in major Canadian and American cities has forced public transit agencies to face budget cuts, harshening the conditions for the vulnerable population that relies on this service (Kar et al., 2022).

The negative correlation between Covid-19 and public transit was initially observed in the first wave of the pandemic, with ridership dropping by 80% (Mashrur et al., 2022). After the initial wave of Covid-19, public transit started to resurface more frequently, albeit there were substantial policies for health concerns limiting the capacity to which it returned. When the first wave passed, the TTC found itself in an irregular influx where it saw ridership drift between dropping by 21% to 71% daily (Mashrur et al., 2022). Substantial contributions to this were the rise of telecommuting and people switching back to personal vehicles when possible.

Many companies and schools went virtual, offering a safer environment and limiting the spread of Covid-19, thereby reducing the need to use public transport to travel. As the pandemic started to subside and returning to the workplace became a viable option, 80% of new telecommuters expressed their desire to continue telecommuting permanently. The educational system had also stayed virtual for approximately two years since the lockdown commenced. With the workforce and educational sectors being virtual for at least two years and many still

being virtual, it produces hundreds of millions of missed revenues from potential customers for public transit agencies.

The TTC continues to be subject to poor ridership as the pandemic has increased motivation among individuals and families to purchase personal vehicles, impacting public transit usage (Palm et al., 2022). According to Palm et al. (2022), a focus group was formed, and people from Toronto and Vancouver voiced their opinions based on pre-pandemic and post-pandemic public transit. 32% of pre-pandemic transit riders planned on riding public transit less (Palm et al., 2022). From the focus group, those who did not have a personal vehicle were asked questions about buying a vehicle. 54% of the people stated that purchasing a vehicle had become more appealing, with 26% reporting looking into buying a vehicle and 11% purchasing one (Palm et al., 2022).

While some individuals may be privileged to take alternative transportation methods, a large demographic of low-income earners, recent immigrants, and diverse communities rely heavily on public transportation, especially during the pandemic (Palm et al., 2022; Qi et al., 2023; Mashrur et al., 2022; Kar et al., 2022). ‘Choice riders,’ defined by Palm et al. (2022), are individuals with private vehicles who opt to take public transit. Previously, many public transit agencies had generated a growing number of choice riders to add to their customer base. However, post-pandemic, these agencies face difficulties in tempting choice riders to take public transit, leaving these agencies with predominantly low-income individuals or those without access to a private vehicle (Qi et al., 2023). This vulnerable population taking public transit is also accompanied typically by blue-collar and essential healthcare workers (Palm et al., 2022). The pandemic has caused major equity concerns, putting an already vulnerable population into high-risk exposure spaces without any alternatives. Knowing the risk of catching Covid-19, this

population did not change the duration or distance of their trip (Palm et al., 2022), further demonstrating their reliance on the system. All these varying factors indicate how different demographics were affected by Covid-19, from the more affluent reducing their public transit use to those who rely heavily on this service still riding the service like pre-pandemic conditions although knowingly being put at far greater risk.

2.3. Identifying Crime

A criminal offence can be defined as deviant behaviour violating local laws of a geographical location (Sikorski et al., 2024). Crime is highly correlated to the geography of an area, meaning that depending on one's location, the likelihood of being involved in an incident may vary considerably as they offer different variables. Although geography plays a vital role in understanding where crime is committed, crime as a concept is studied through a sociological perspective (Sikorski et al., 2024). The overlapping intersection between geography and sociology helps unravel deeper social dynamics that can influence crime patterns in an area. Crime has proven to show patterns and create hotspots in a geographic context. Repetition of crime events in a given area over a set period will develop hotspots (Hajela et al., 2020). This implies that once a location starts to have high crime counts with frequency, the area's geography will likely become increasingly unfavourable and remain in this state for the foreseeable future, allowing crime to flourish. Analyzing crime through a sociological aspect adds another layer of complexity as diverse types of crime, additional variables, and psychological levels motivate an individual (Sikorski et al., 2024). The psychological level of an individual will heavily determine the severity of the crime they choose to commit (Sikorski et al., 2024). It is widely accepted

through literature that crime is most prevalent in larger cities as they are highly dense, offering more opportunities (Sikorski et al., 2024).

When further exploring the concept of the influencing factors leading an individual to commit a crime, it is essential to understand the broader concept of criminality. Criminality is the total crime committed in an area over a specific time (Sikorski et al., 2024). Socioeconomic variables such as age, sex of the offender, population, labour market, educational level, living conditions, and an individual's economic position all heavily influence how and which type of crime is committed (Sikorski et al., 2024; Mitra et al., 2023). These socioeconomic variables together create what is often referred to as a "crime-prone demographic" (Abedin et al., 2022). The refugee population tends to be well-represented in the crime-prone demographic due to the characteristics they overperform in (Abedin et al., 2022). When refugees arrive at their host nation, stress from extreme hardships upon arrival can cause social disaffection, a sense of abandonment, depression, and posttraumatic stress disorder, which are all behaviours that increase the likelihood of engaging in criminal activities (Abedin et al., 2022). While the listed socioeconomic variables demonstrate the demographics most susceptible to criminal behaviour, their motivation can be divided into three key elements. As Sikorski et al. (2024) state, the first element is having an offender motivated enough to commit the crime, followed by having a target that is attractive enough to motivate the criminal to commit the crime, and finally, an unsupervised location providing an opportunity for the criminal.

The risk-gain analysis further supports the three elements of committing a crime. A criminal is likely to commit a crime only when the risk and effort are marginal while the potential gain is considerably greater (Xu et al., 2021). This would greatly vary as to what is considered a gain depending on everyone's condition of living. As criminals seek to reduce their

risk factors, they tend to lure around locations that are most optimal for them, further emphasizing the importance of location (Sikorski et al., 2024). Additionally, the risk-gain analysis highlights the fluctuating tendencies of crime rates in response to socioeconomic policies put in place by governments.

2.4. Crime on Public Transit

As mentioned, public transit is vital for all cities, especially as the population grows. However, public transit is not immune to the effects of criminal activities and is also highly influenced by crime, which affects its ridership. It is widely accepted that ridership and crime are linearly correlated, particularly between lower or medium ridership levels where crime rates tend to be higher (Li et al., 2019; Xu et al., 2021). This correlation between ridership and crime causes public transit agencies difficulty attracting choice riders. Although choice riders know the benefits of taking public transit (Li et al., 2019), such as reduced chances of accidents and reduced traffic, the sense of feeling safe is far greater. Crime variables show minimal variation between public transit users and the general public, indicating that both environments are identified as low-risk opportunities, whether on public transit or the general public. The pandemic triggering a decline in ridership due to health regulations and people's concern about avoiding public transit further demonstrated the relationship between crime occurrence in low to medium ridership zones (Li et al., 2019).

From an overarching perspective, crime is most likely to happen at subway stations along low to medium-ridership zones as they have high foot traffic and low surveillance (Xu et al., 2021). New subway stations and those located close together provide offenders with advantageous locations, increasing the number of thefts in the area (Xu et al., 2021). This is because individuals waiting at stations become targets, and motivated offenders use the public

transit system as a quick escape route, taking advantage of the nearby population as a distraction (Xu et al., 2021). Phillips and Sandler (2015) offer a solution to reducing crime rates in subway stations by temporally closing a line or a specific set of subway stations. The proposed solution provides a short-term fix but cannot be relied upon as congestion builds up, making the system unreliable. Li et al. (2019) study indicates that crimes tend to plateau in high ridership zones, although this poses challenges for public agencies seeking to attract choice rider's post-pandemic. Jacobs' (1992) book refers to "eyes on the street" as another solution to increasing safety. The eyes on the street concept was the foundation of CTEP, which seeks to increase people's activity in an area by natural surveillance. Having more active and busy neighbourhoods where people travel from one place to another creates a self-governing environment where criminal activities are more likely to be noticed, thereby deterring potential criminals from committing acts of violence as they know multiple people are watching them.

While various solutions exist to ensure customer safety, one must recognize the types of criminal offences one may encounter. The three main types of criminal offences encountered in subway stations due to their condition of high foot traffic and low surveillance are drug offences, public nuisance, and theft (Zhang et al., 2022). These offences happen at different rates depending on whether on a weekday, weekend, or public holiday. On weekdays, criminal activity tends to be based on theft as more targets offer offenders various targets (Zhang et al., 2022). One is less likely to witness drug offences and public nuisance as there is more foot traffic, and the surrounding customers act as informal guardians, discouraging the offender from committing any crime (Zhang et al., 2022). In conclusion, understanding all the dynamics of public transit is essential for implementing effective safety measures for choice and everyday riders. Public

transit agencies can better service their respective cities by addressing these issues and creating a safer environment.

2.5. Youth Crime

One group of people that increases the complexity of criminology is youth crime, as they are a fluid group with complex factors. Various age ranges are considered in youth crime studies. This review focuses on the age range of 8 to 21 years, based on the studies by Krzysztof Pękala et al. (2021) and Long & Liu (2022). According to Krzysztof Pękala et al. (2021), youth offenders can commit offences from age 8 to age 17 or 18. These findings are consistent with Long & Liu's (2022) paper, including individuals a few years older. Understanding that these years are vital to one's development, being raised in less-than-ideal circumstances can lead to adverse outcomes. For these reasons, there is no single definition of what leads to youth crime. However, scholars agree on several consistent factors that lead to a life of criminal offences. These factors include being raised in abusive homes, lack of parental supervision and support, the presence of illegal drugs at home or in the neighbourhood, reliance on social services, failure to complete primary or secondary education, and low social cohesion (Krzysztof Pękala et al., 2021; Long & Liu, 2022; Jha, 2021; Rotger & Galster, 2018).

Understanding the main variables that contribute to youth crime can help explain patterns in where these crimes are committed. Due to the young nature of the offender, they tend to commit crimes in known areas where they have a spatial awareness of the area (Long & Liu, 2022). For these reasons, young offenders target areas near their homes, schools, neighbourhoods, and high-traffic areas they frequently pass by (Long & Liu, 2022). Since these young offenders often live in poor conditions, low social cohesion tends to persist in their neighbourhoods. This allows them to act promptly and swiftly and grants them ideal conditions

to commit the crime continuously. It is commonly known that once a person commits a crime and can get away without penalty, they are likely to commit a crime again, leading them to a cycle into which they will continue to commit crimes into adulthood (Long & Liu, 2022).

Considering all these factors and adding additional hurdles that new refugee families and children face, this only creates more opportunities for young refugees to commit a crime (Rotger & Galster, 2018).

While the factors mentioned above do contribute heavily to youth crime, it is vital to consider three overarching socio-economic factors: inadequate housing and financial instability, substance abuse issues, and health issues, both physical and mental. These issues influence young offenders' immediate decisions and play a substantial role in their personal development and opportunities. Deshpande & Mueller-Smith (2022) state that when youth are on financial assistance from the government and no longer living with family, they often lose these benefits once they turn 18 if they have an employer and no longer seek to study. They are expected to cover all their cost and support themselves with their income from their formal job. However, the monthly revenue often does not cover expenses they may incur, forcing some individuals to engage in illicit income-generating activities. For some, these activities may be new, while others may return to old criminal habits, leading to an increase in youth crime as they seek ways to survive.

Substance abuse is another critical factor. Youth who start using alcohol and other drugs at an early age are at an increased risk of continuing a path of delinquency as they grow older and enter early adulthood (Jenson et al., 2024). Many of these factors are tied to an individual's health status. While physical health is essential, various professionals have noted a strong relationship between mental health issues and acts of violence (Jenson et al., 2024). Additionally,

professionals believe that many delinquents tend to have both mental health issues and substance abuse problems simultaneously (Jenson et al., 2024), indicating the complexity of youth crime.

CHAPTER THREE: DATA AND METHODS

3.1. Introduction

Various comprehensive datasets were gathered from multiple sources to address the primary research question of what effect the Covid-19 pandemic has had on the crime rate per 10,000 daily commuters at TTC subway stations. The sources used included Toronto's Open Data Portal, TTC crime reports, TTC ridership statistics, and the Ontario Marginalized Index for 2016 and 2021. The data collected was refined to include only the necessary characteristics for two primary analyses: a count index and a trade area index.

3.2. Data

3.2.1. Data Collection

Toronto's Open Data Portal houses numerous information on various topics. The database is composed of both privately collected data and government-funded public data. This data undergoes a review process to ensure its accuracy and relevance before being uploaded to the server. The City of Toronto regularly maintains and updates the public data, ensuring its accessibility and reliability. This study used the Open Data Portal data to introduce various factors into the analysis, such as public services, recreational centers, and health facilities. Analyzing the collected data helps understand how different correlations may exist between crime and social services, providing a holistic view of the factors contributing to crime on the TTC.

The TTC crime report database, created and maintained by the TTC, provides detailed information on crime incidents within the transit system. This includes the location, time, type of

crime, and a brief description of each incident. Data is gathered each time a crime occurs on the TTC, and a report is created. The report is then categorized and added to the existing crime database. This information was made available through Freedom of Information (FOI) requests and is continuously updated. For this study, FOI requests were made for the years 2016 and 2022. The TTC crime report data is foundational to this study, offering an initial outlook on where crime is occurring, how crime is changing on the TTC, and the types of crimes most prevalent. This detailed crime data allows for a robust analysis of trends and patterns over time.

Like the TTC crime reports, the TTC also keeps statistical information on their ridership levels. The introduction of Presto in the TTC was to help and encourage users to pay their fair price while riding public transit. The TTC has taken the opportunity to collect other valuable information, such as the busiest routes and average ridership. When a user enters or switches public transit vehicles, the system records each transaction and uploads it to a database. With this information, the TTC can produce various statistics, such as daily ridership. Using these statistics and the TTC crime report allows one to create the crime rate per ridership, which is the critical question this project seeks to answer.

The final dataset used for the study was the Ontario Marginalization Index for 2016 and 2021. This data set is a comprehensive tool that “combines a wide range of demographic indicators into four distinct dimensions of marginalization: economic, ethno-racial, age-based, and social marginalization” (Public Health Ontario, 2021). Developed by St. Michael's Hospital using the 2016 and 2021 Canadian Census, the index provides a spatial understanding of where inequities may exist across Ontario. It is available at different geographic scales, allowing for detailed comparisons. This data set is critical for answering the paper's third sub-question, which aims to determine if there is a spatial correlation between the Ontario Marginalization Index and

crime hotspots on the TTC. By integrating this index, the study can explore the broader socio-economic and demographic context in which TTC crime occurs, identifying areas of marginalization that may be associated with higher crime rates. This approach ensures a thorough understanding of the interplay between marginalization and crime on public transit.

Together, these various datasets provide a foundation for analyzing crime trends in the TTC subway stations, enabling a comprehensive analysis of how crime rates have changed in response to Covid-19 and socioeconomic factors.

3.2.2. Data Preprocessing

To ensure the reliability and validity of the analysis, the collected data underwent a cleaning and preparation process. This step was crucial for eliminating inconsistencies, inaccuracies, and irrelevant information that could skew the results.

The cleaning process for the data from Toronto's Open Data Portal primarily required only selecting the necessary variables and grouping similar attributes. As there are various forms of data on the portal, the requirement when using the database was to select variables that were deemed necessary. This was determined by cross-referencing the literature review and the data that previous academics have used when conducting similar studies. This offered a holistic view of what data would align with the study. The data that shared relevance with the study was then used for further analysis. This portal collected all the variables, such as public services, recreational centers, and health facilities. The data was divided into different categories, with the initial division being whether certain services were available to people of all ages or youth only. The division was created as the literature revealed a gap in how older offenders are likely to react and think compared to younger offenders. Within the first division, which split services between

the general public and youth, a new division was created to group services with similar characteristics. It is important to note that as Covid-19 started in 2019 when comparing the data from 2016 to 2022, Covid-19 testing centers were only included for the latter as they would not have existed prior.

Working with both the TTC crime and average daily ridership data required cleaning to be usable. The first dataset utilized was the TTC crime report, encompassing various crimes committed across different transit modes, such as buses, streetcars, and subways. As this research solely looks at crime on TTC subway stations, an initial selection within that data was created to select only the relevant cases to the study. For this research paper, a crime committed on a subway station platform, entrance, lobby, or outside the immediate building or entrance is considered a crime committed on a subway station. There were 69 subway stations in 2016 and 75 in 2022. As the study compares 2016 to 2022 data, the six new stations added between the given dates were excluded from the project when answering the primary research and sub-questions; therefore, only 69 unique addresses were included in the results. Given this, each crime case belonged to one of the 69 subway stations; thus, a new field was added indicating which line the subway station is located on for comparison. The X and Y coordinates for each crime location were added for the selected cases, enabling future geocoding in ArcPro.

From the initial table, a new table was produced where it had a count of all 75 subway stations with their respective X and Y coordinates, each subway station's respective line, the number of criminal cases at each station for 2016 and 2022, and the average daily ridership for 2016 and 2022. This new table used two formulas to determine the number of crimes per 10,000 daily riders and the percentage change between 2016 and 2022 for each subway station.

The first formula to determine the number of yearly crimes per 10,000 daily riders at each TTC subway station in 2016 and 2022 is as follows, with the only difference between 2016 and 2022 being changing the respective years:

Number of Yearly Crimes per 10,000 Daily Riders

$$= \frac{\text{Total Crime Committed in 2016}}{\text{Total Average Daily Ridership}} \times 10,000$$

The second formula to determine the percentage change between each subway station from 2016 to 2022 is as follows:

Percentage Change =

$$\frac{\text{2022 Number of Yearly Crimes per 10,000 Daily Riders} - \text{2016 Number of Yearly Crimes per 10,000 Daily Riders}}{\text{2016 Number of Yearly Crimes per 10,000 Daily Riders}} \times 100$$

These two formulas introduce three new variables: the number of yearly crimes per 10,000 daily riders in 2016, the number of yearly crimes per 10,000 daily riders in 2022, and the percentage change.

The Ontario Marginalized Index was the last dataset, requiring partial data reconstruction. The Ontario Marginalized Index is divided into four distinct categories per dissemination area. To determine overall marginalization per dissemination area, the four categories were added and then divided by 20 to give an overall marginalization score. The number of 20 was chosen, as each category ranges from 1-5. The overall marginalization score ranged from 1-5, with 1 indicating the least marginalized dissemination area and 5 the most, similar to the existing ranking system the index already uses.

3.3. Methods

The two methods used for the study were a count index and a trade area index, both valuable tools for analysis that can uncover crime patterns differently. The count index measures the number of crimes in relation to specific socioeconomic buildings across the city. This index will help identify whether certain types of buildings are associated with higher crime rate stations. In comparison, the trade area index and Ontario Marginalization Index can assess how crime rates compare to expected socioeconomic factors in a particular area to the rest of the study area. This can reveal whether certain areas experience more or less crime than predicted and highlight the potential influence of marginalization on crime. While both indexes indicate areas of concern, the first method offers insights into the relationship between crime and expected performance, where the count index correlates crime incidents with specific physical spaces.

3.3.1. Count Index

The results from Q1 and the data collected from Toronto's Open Data Portal were used as the base layer for the map. From Toronto's Open Data Portal data, 15 variables were chosen for the 2016 and 16 for the 2022 maps. A new variable for 2022 is added because the Covid-19 testing station did not exist in 2016. The variables were then grouped into one of six clusters and placed on the map as point data. A 1-kilometre buffer was constructed around the five safest stations in 2016, the five safest stations in 2022, the five most unsafe stations in 2016, and the five most unsafe stations in 2022. The 1-kilometre buffer was chosen as the average person takes about 15 minutes to walk that distance, which is a reasonable time a person would be willing to walk to arrive at a subway station. Each point in a 1-kilometre buffer of a subway station was

tallied. The total count of each cluster point in a buffer was then compared to how many cluster points were in the city to complete the count index and allow for analysis.

3.3.2. Trade Area Index

Once the Ontario Marginalized Index has been reconstructed and each dissemination area has been assigned to one of the 5 clusters, it will be used as a base layer for the trade area index along with the results from Q1. A 1-kilometre buffer was constructed around the five safest stations in 2016, the five safest stations in 2022, the five most unsafe stations in 2016, and the five most unsafe stations in 2022. The 1-kilometre distance was chosen using the same rationale of walking distance as in the count index. Each dissemination area with its centroid in the 1-kilometre buffer of the subway station participated in being included in the buffer. The clusters in each trade area were tallied together to create the trade area index and produce scores. These scores were then compared to the scores of the rest of the cities to delineate if any correlations exist between the two variables.

CHAPTER FOUR: RESULTS

4.1. Introduction

The results will answer the primary research question and the three sub-questions. The primary research question will be answered with statistics using two formulas to determine two key variables. The first sub-question will portray where the ten most noteworthy subway stations are in 2016 and 2022. The ten most noteworthy subway stations are the five most concerning and safest stations aggregated together. The second and third sub-questions will use the ten most noteworthy subway stations of 2016 and 2022 to determine whether a correlation exists between social service buildings using a count index or between the marginalization index using a trade area index.

4.2. Primary Research Question

Table 1 reveals that insecurity has increased in the TTC. Through the 69 stations, average ridership has decreased by approximately 11.46% from 2016 to 2022. The exact decline is 2,221,320 average daily riders to 1,966,817 average daily riders. When analyzing crime counts, they have increased from 2016 to 2022. In 2016, there were 1,005 incidents; in 2022, there were 1,798 cases. The increase is better illustrated when comparing crimes committed per 10,000 people in 2016 to 2022. In 2016, it was 398, and in 2022, 615. Crime percentage change was calculated using these numbers, indicating that criminal cases increased by approximately 54.54%.

Table 1: TTC Subway Stations Crime Data

Subway Station	Subway Line Located On	Average Subway Ridership in 2016	Average Subway Ridership in 2022	Ridership Percentage Change	Crimes Committed in 2016	Crimes Committed in 2022	Crimes Committed per 10,000 People in 2016	Crimes Committed per 10,000 People in 2022	Crime Percentage Change
Bathurst	2	29,320	26,234	-10.5	27	38	9.2	11.4	24.2
Bay	2	27,090	24,260	-10.4	17	30	6.3	6.2	-1.5
Bayview	4	8,410	8,149	-3.1	1	5	1.2	8.6	622.4
Bessarion	4	2,880	4,269	48.2	1	1	3.5	7.0	102.4
Bloor-Yonge	1 & 2	204,630	155,186	-24.2	70	163	3.4	7.0	105.3
Broadview	2	29,800	25,057	-15.9	25	32	8.4	10.8	28.4
Castle Frank	2	8,520	12,470	46.4	15	18	17.6	20.0	13.9
Chester	2	6,690	9,995	49.4	6	10	9.0	3.0	-66.5
Christie	2	14,740	15,179	3.0	5	11	3.4	7.2	113.6
College	1	47,600	42,883	-9.9	19	38	4.0	7.0	75.3
Coxwell	2	15,620	19,148	22.6	15	16	9.6	14.6	52.3
Davisville	1	24,300	13,973	-42.5	11	23	4.5	15.0	232.0
Don Mills	4	32,310	26,093	-19.2	14	24	4.3	8.4	94.6
Donlands	2	10,080	11,481	13.9	6	15	6.0	6.1	2.4
Dufferin	2	31,220	27,837	-10.8	14	26	4.5	6.5	44.2
Dundas	1	77,200	72,637	-5.9	37	79	4.8	6.5	35.0
Dundas West	2	28,680	21,509	-25.0	22	21	7.7	16.3	112.1
Dupont	1	14,770	22,327	51.2	3	11	2.0	4.0	98.5
Eglinton	1	75,050	59,802	-20.3	26	46	3.5	6.7	93.1
Eglinton West	1	16,210	6,569	-59.5	8	7	4.9	13.7	177.6
Ellesmere	3	1,760	1,068	-39.3	6	1	34.1	28.1	-17.6
Finch	1	85,720	59,364	-30.7	35	69	4.1	9.9	143.4
Glencairn	1	6,040	16,118	166.9	1	4	1.7	1.2	-25.1
Greenwood	2	10,390	13,568	30.6	6	6	5.8	6.6	14.9
High Park	2	10,510	11,802	12.3	1	17	1.0	6.8	612.4

Islington	2	40,250	21,331	-47.0	19	13	4.7	7.0	49.0
Jane	2	19,860	15,349	-22.7	8	12	4.0	10.4	158.8
Keele	2	14,670	17,108	16.6	21	14	14.3	9.9	-30.6
Kennedy	2 & 3	68,940	31,249	-54.7	32	95	4.6	20.2	334.3
King	1	60,930	40,664	-33.3	11	19	1.8	4.9	172.4
Kipling	2	49,870	31,220	-37.4	24	53	4.8	14.1	192.9
Lansdowne	2	17,590	19,541	11.1	9	19	5.1	4.1	-20.0
Lawrence	1	22,340	27,847	24.7	10	19	4.5	6.5	44.4
Lawrence East	3	7,850	8,968	14.2	3	9	3.8	4.5	16.7
Lawrence West	1	17,630	22,975	30.3	15	16	8.5	3.9	-54.0
Leslie	4	6,200	5,920	-4.5	4	4	6.5	1.7	-73.8
Main Street	2	20,930	24,918	19.1	25	47	11.9	13.2	10.9
McCowan	3	3,710	2,331	-37.2	1	4	2.7	4.3	59.2
Midland	3	2,370	1,293	-45.4	1	1	4.2	15.5	266.6
Museum	1	9,680	14,399	48.8	4	6	4.1	4.2	0.8
North York Centre	1	29,120	23,768	-18.4	4	7	1.4	8.8	543.2
Old Mill	2	7,350	9,319	26.8	4	5	5.4	7.5	38.0
Osgoode	1	25,580	27,396	7.1	1	10	0.4	1.8	366.9
Ossington	2	25,920	25,828	-0.4	22	24	8.5	10.1	18.6
Pape	2	26,280	24,708	-6.0	17	15	6.5	6.1	-6.2
Queen	1	45,260	38,827	-14.2	15	26	3.3	6.4	94.3
Queen's Park	1	45,460	39,543	-13.0	2	9	0.4	1.8	302.4
Rosedale	1	6,010	4,787	-20.3	6	18	10.0	35.5	255.7
Royal York	2	23,050	18,568	-19.4	13	14	5.6	6.5	14.6
Runnymede	2	19,530	15,374	-21.3	5	15	2.6	7.8	204.9
Scarborough Centre	3	22,830	24,399	6.9	4	28	1.8	7.0	297.7
Sheppard West	1	40,640	22,694	-44.2	18	22	4.4	8.8	99.0

Sheppard Yonge	1 & 4	74,750	61,349	-17.9	23	36	3.1	4.9	58.9
Sherbourne	2	25,030	28,870	15.3	16	27	6.4	7.3	13.8
Spadina	1 & 2	42,300	117,958	178.9	51	96	12.1	5.9	-50.8
St. Andrew	1	60,900	39,775	-34.7	11	13	1.8	0.8	-58.2
St. Clair	1	34,610	33,574	-3.0	16	34	4.6	3.6	-22.7
St. Clair West	1	25,820	38,700	49.9	7	22	2.7	5.4	100.2
St. George	1 & 2	132,380	108,290	-18.2	31	75	2.3	3.1	34.1
St. Patrick	1	29,700	27,617	-7.0	5	7	1.7	1.4	-14.0
Summerhill	1	6,280	16,269	159.1	5	13	8.0	6.1	-22.8
Union	1	118,450	91,601	-22.7	21	50	1.8	4.4	146.3
Victoria Park	2	31,460	13,611	-56.7	34	31	10.8	20.6	90.3
Warden	2	29,500	12,635	-57.2	29	35	9.8	31.7	222.0
Wellesley	1	22,280	26,152	17.4	13	47	5.8	15.7	168.7
Wilson	1	23,510	25,511	8.5	18	35	7.7	7.1	-7.8
Woodbine	2	15,250	18,615	22.1	16	16	10.5	9.7	-7.8
York Mills	1	21,780	30,088	38.1	13	19	6.0	8.0	33.6
Yorkdale	1	27,930	8,900	-68.1	7	7	2.5	7.9	213.8
Total	N/A	2,221,320	1,966,817	-11.5	1,005	1,798	398	615	54.5

4.3. Spatial Distribution Changes

4.3.1. 2016 Results

Analyzing Figure 2, key statistics stand out when identifying the five safest and most concerning subway stations. The most concerning stations have a crime rate of 12 – 34 incidents per 10,000 people, while the safest have a crime rate of 0.4 – 1.4 per 10,000 people. When comparing the two most contrasting stations, the crime rate increases by 33.6 incidents. Four of the five most concerning stations are located on Line 2. This is the opposite of the safest stations, as four of the five safest stations tend to be on Line 1.

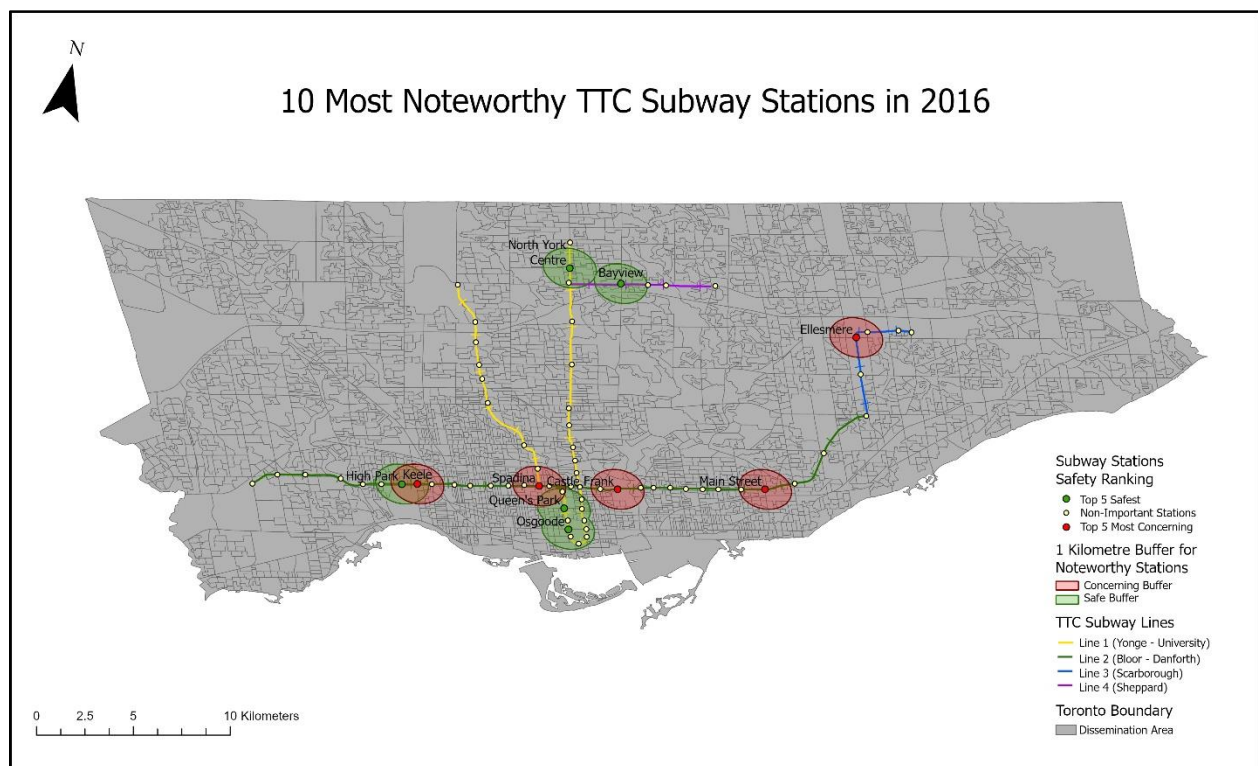


Figure 2. Map of the Safest and Most Concerning TTC Subway Stations in 2016

4.3.2 2022 Results

When contrasting the 2016 results to those of 2022, there are changes in the statistics and locations. The five most concerning stations tend to be closely clustered at the point where Line 2 and Line 3 merge. The five safest stations continue to show clustering characteristics. The most concerning stations have a crime rate of 20-35, and the safest stations have a crime rate of 0.7 – 1.8 per 10,000 people.

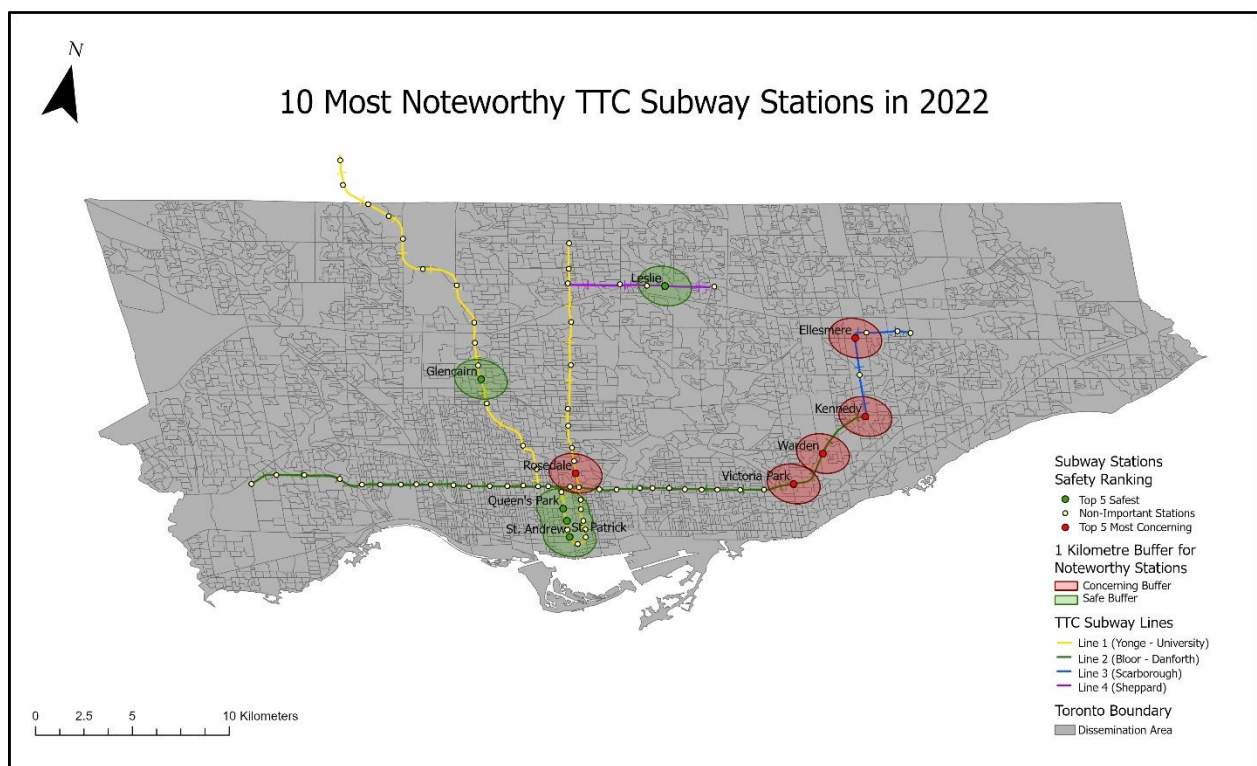


Figure 3. Map of the Safest and Most Concerning TTC Subway Stations in 2022

4.3.3. Percentage Change

Figure 4 depicts which stations saw the largest increase and decrease in crime percentage change. The most concerning and safest stations do not show many clustering characteristics in any location as they are spread out. The five safest stations had a decreased crime rate, which equated between -73% to -50%, whereas the most concerning stations saw an increase ranging from 334% to 622%.

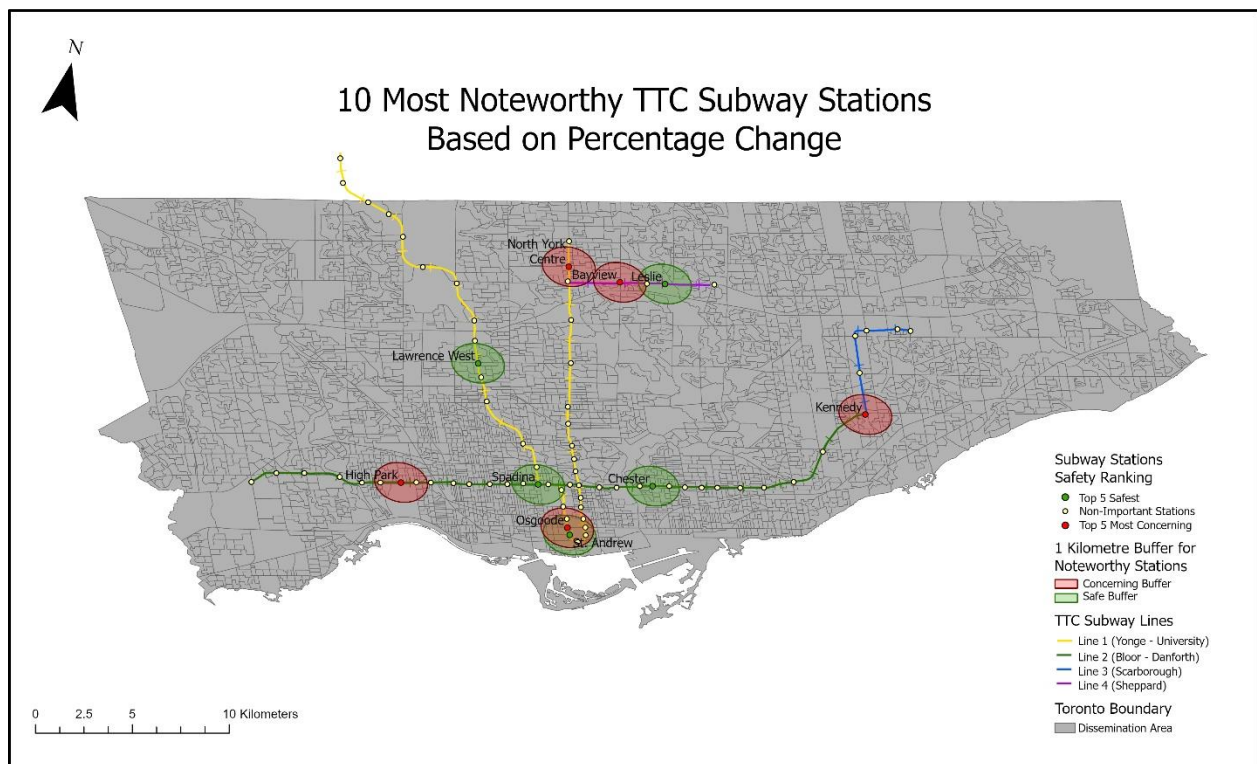


Figure 4. Map of the TTC Subway Stations that Became Noteworthy

4.4 Community Services Correlation

The count index produced six cluster groups: Cluster 1 – Youth Financial & Employment Services, Cluster 2 – Youth Health & Wellness Services, Cluster 3 – Youth Housing & Settlement Services, Cluster 4 – Housing & Shelter Services, Cluster 5 – Health & Wellness Services, Cluster 6 – Community & Educational Services. Using the buffers created, the concerning and safest stations either overperformed or underperformed compared to the rest of the city in 2016 and 2022.

4.4.1 Count Index 2016

Using the buffers in Figure 5 for the subway stations, two separate count indexes were created for 2016: one for the five most concerning stations, Figure 6, and one for the safest five subway stations, Figure 7. The concerning count index notably overperformed in Cluster 2 and 5 while underperforming in Cluster 1. The safest stations count index notably overperformed in Cluster 1, 2, 3, and 5, underperforming in Cluster 4.

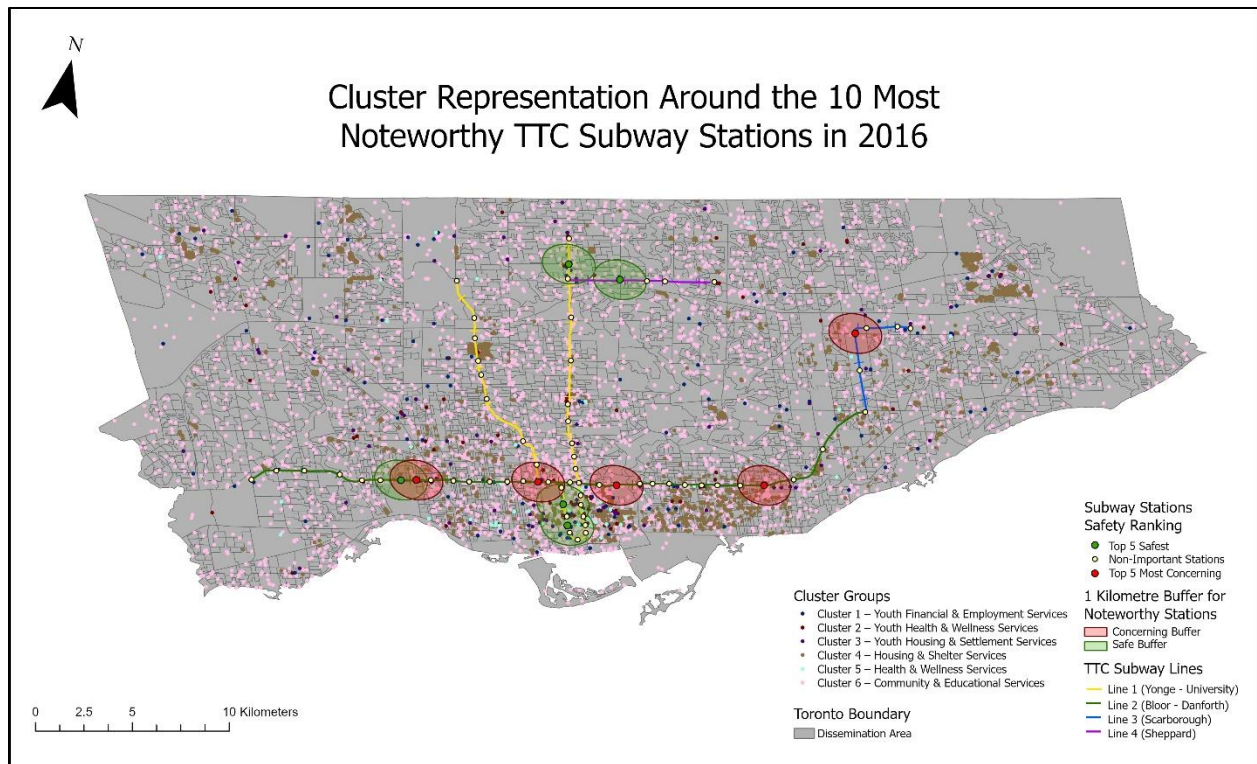


Figure 5. Map of the TTC Subway Stations in Relation with the 6 Cluster Groups in 2016

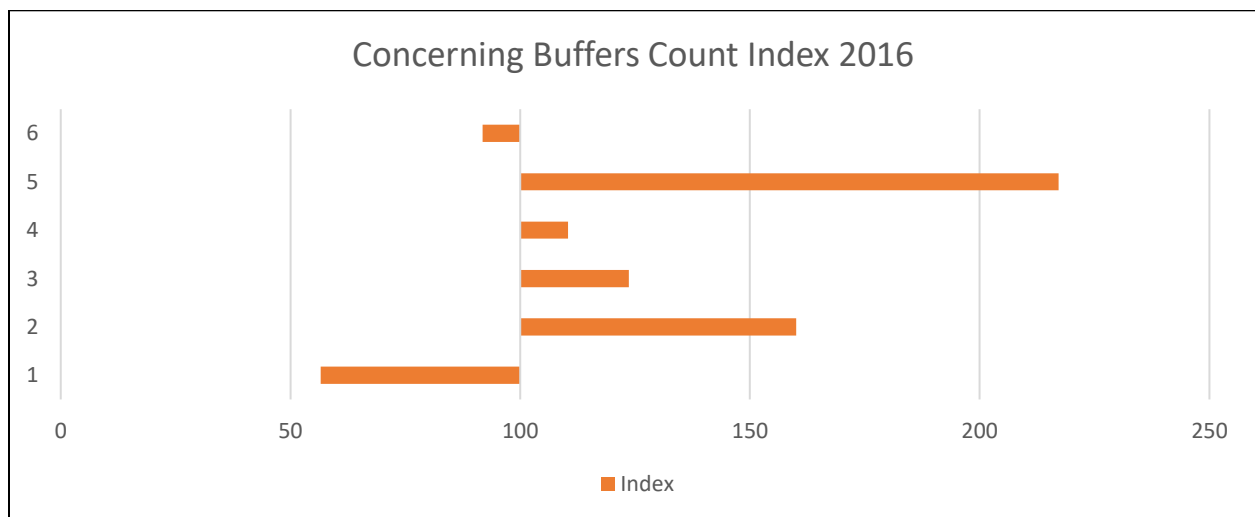


Figure 6. Count Index for the Most Concerning Subway Stations Buffers in 2016

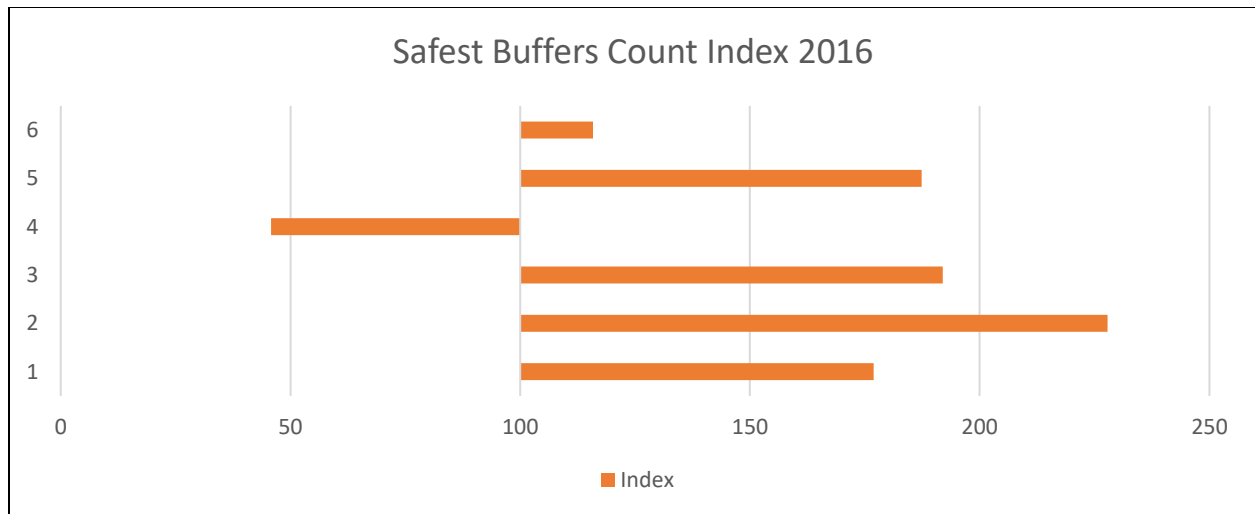


Figure 7. Count Index for the Safest Subway Stations Buffers in 2016

4.4.2. Count Index 2022

Continuing with the same method, using the buffers in Figure 8, two count indexes were created, one for the most concerning, Figure 9, and the safest, Figure 10, subway stations in 2022. The concerning index overperformed in Clusters 3 and 5. The safest index overperformed in Clusters 1, 2, 3, and 5, underperforming in Cluster 4.

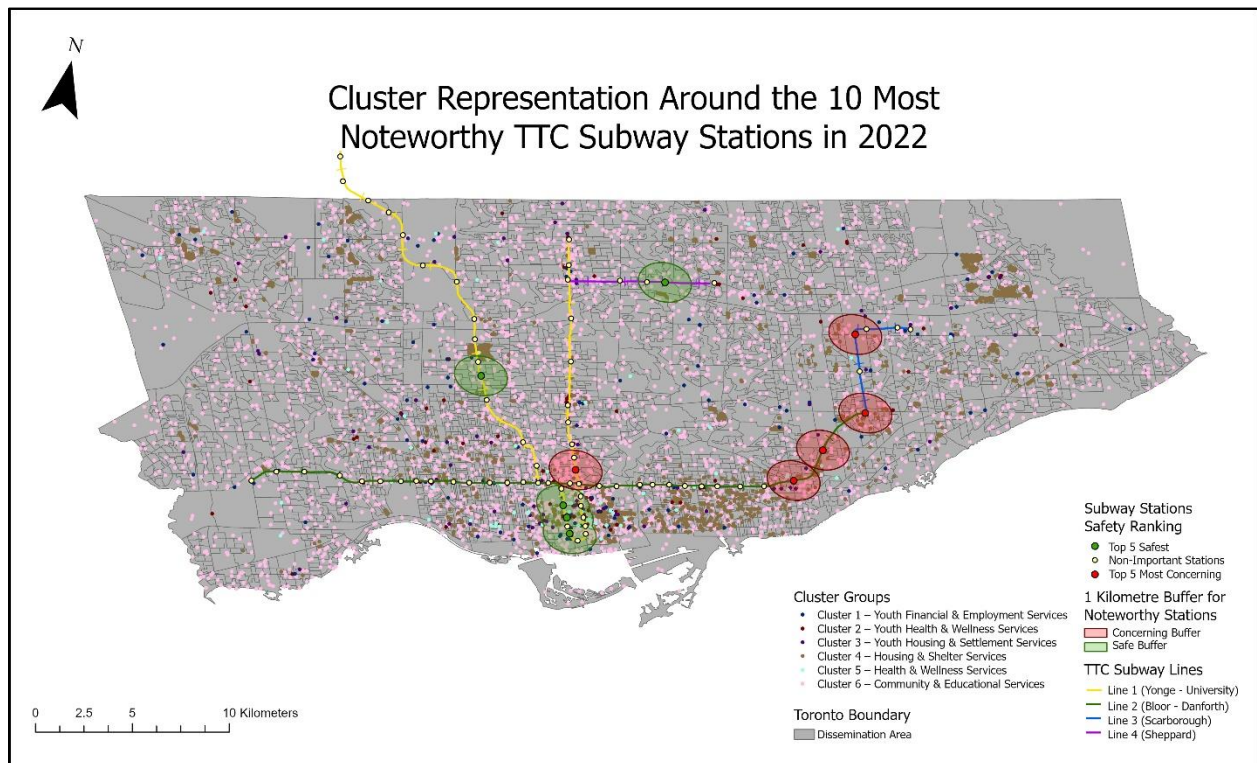


Figure 8. Map of the TTC Subway Stations in Relation with the 6 Cluster Groups in 2022

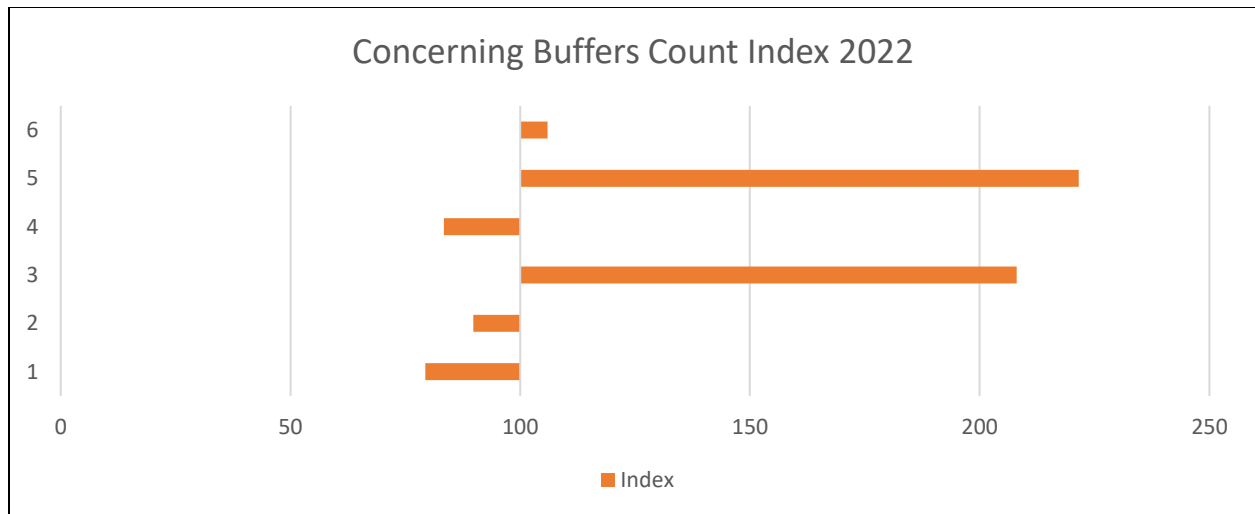


Figure 9. Count Index for the Most Concerning Subway Stations Buffers in 2022

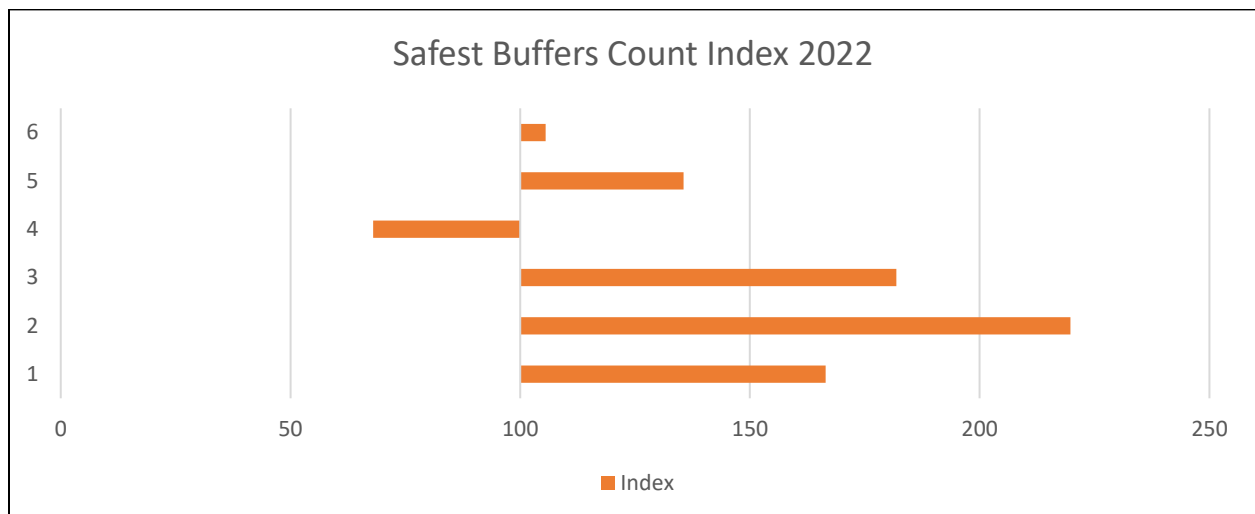


Figure 10. Count Index for the Safest Subway Stations Buffers in 2016

4.5 Marginalization Index Analysis

The trade area index consists of five cluster groups: Cluster 1 – least marginalized, Cluster 2 – somewhat marginalized, Cluster 3 – moderately marginalized, Cluster 4 – notably marginalized, and Cluster 5 – most marginalized. The composition of marginalization will be determined using the two buffers created, one for the most concerning and another for the safest subway stations in 2016 and 2021.

4.5.1. Trade Area Index 2016

The composition of the most concerning subway stations tends to overperform in Cluster 3 while underperforming in Cluster 1, 4, and 5. Cluster 3 tends to overperform for the safest subway stations, with Clusters 1 and 4 underperforming.

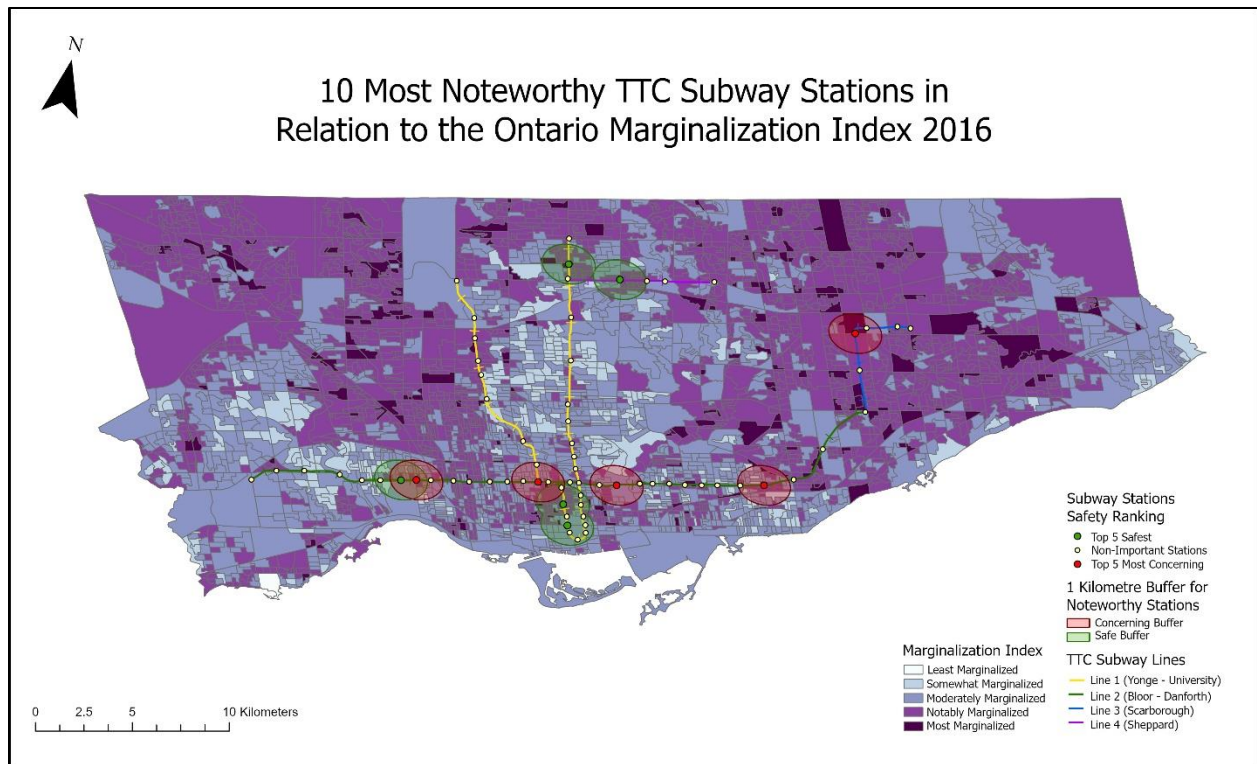


Figure 11. Map of the TTC Subway Stations in Relation to the Ontario Marginalized Index 2016

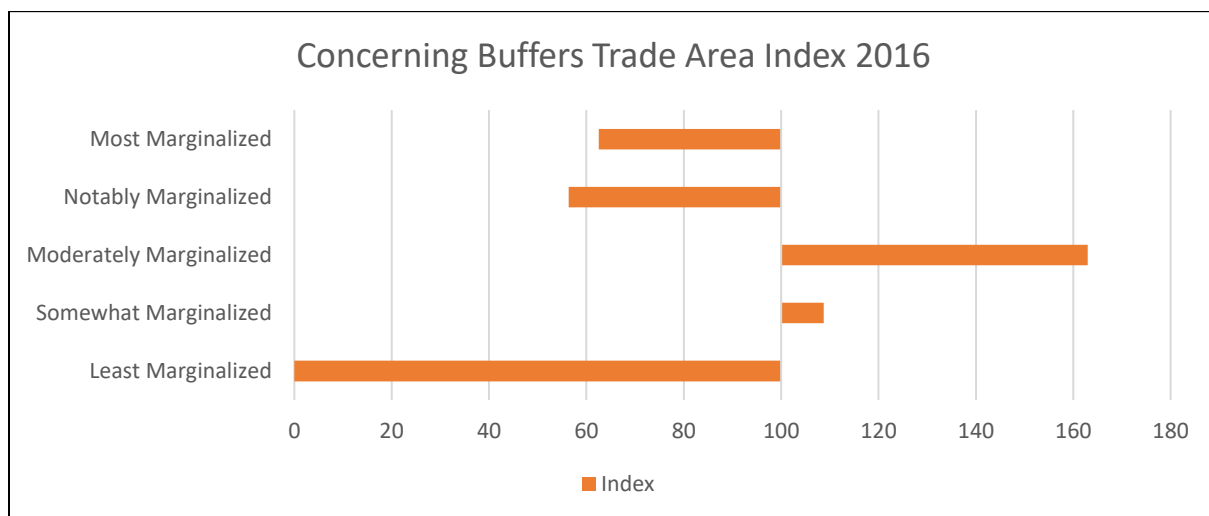


Figure 12. Trade Area Index for the Most Concerning Subway Stations Buffers in 2016

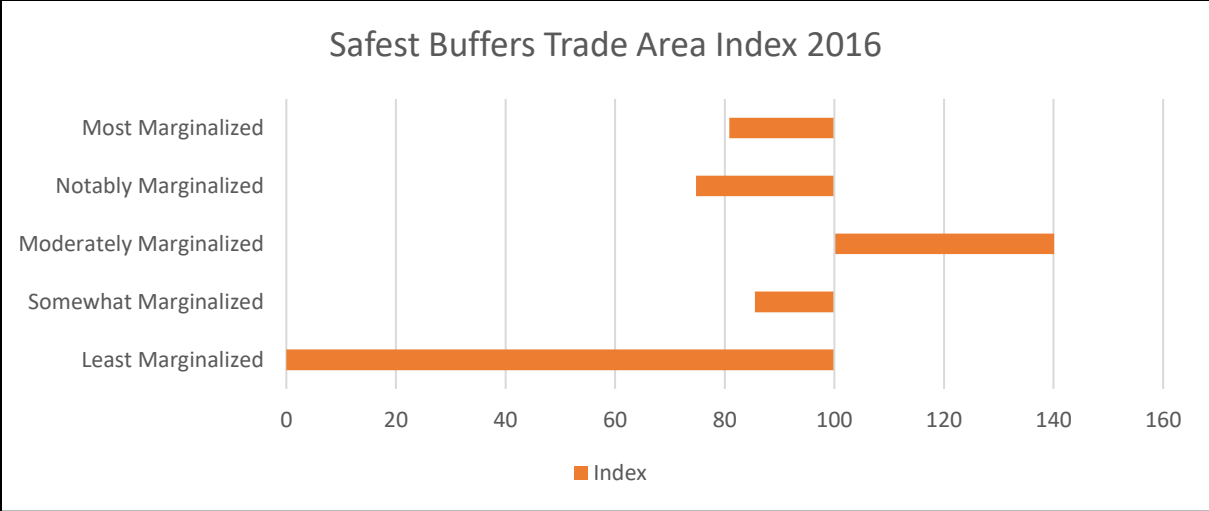


Figure 13. Trade Area Index for the Safest Subway Stations Buffers in 2016

4.5.2. Trade Area Index 2021

Trends can be detected when analyzing the consistency of the most concerning and safest subway stations. The most concerning index tends to overperform in Clusters 4 and 5 while underperforming in Clusters 1, 2, and 3. The safest index notably overperforms in Clusters 1 and 3, underperforming in Cluster 2.

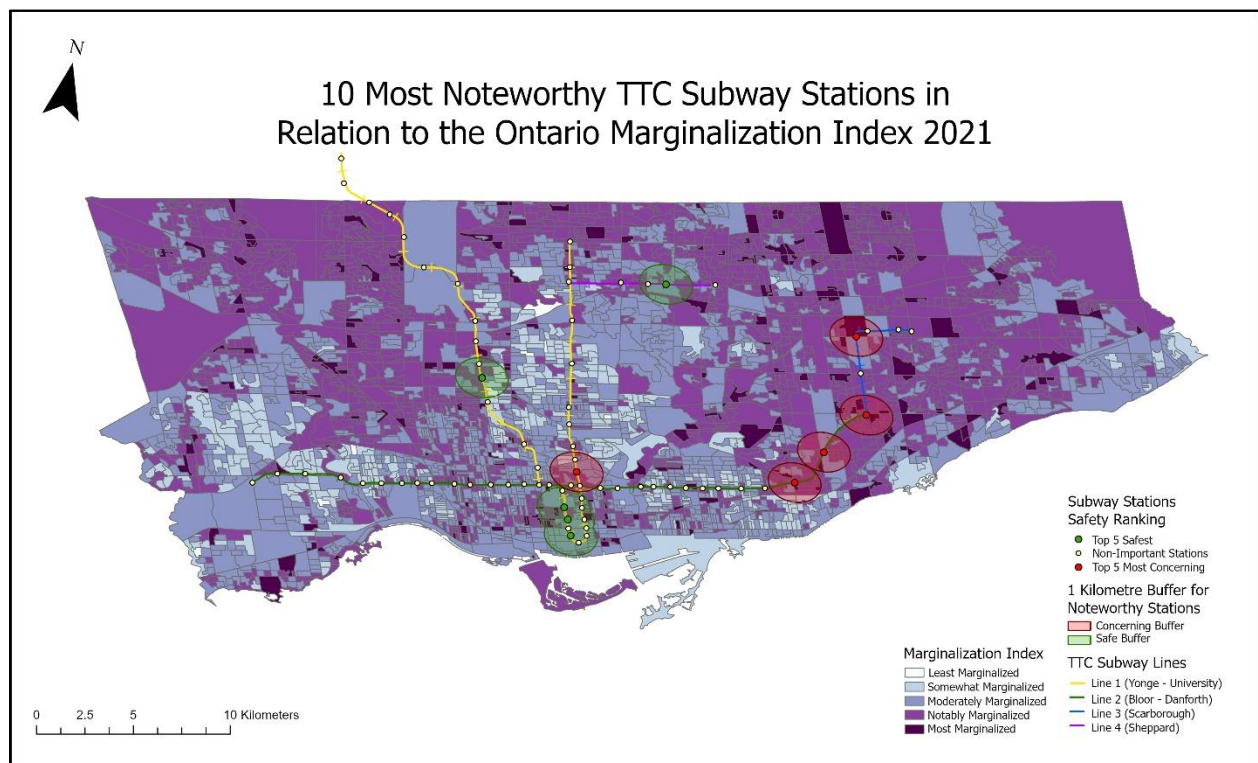


Figure 14. Map of the TTC Subway Stations in Relation to the Ontario Marginalized Index 2022

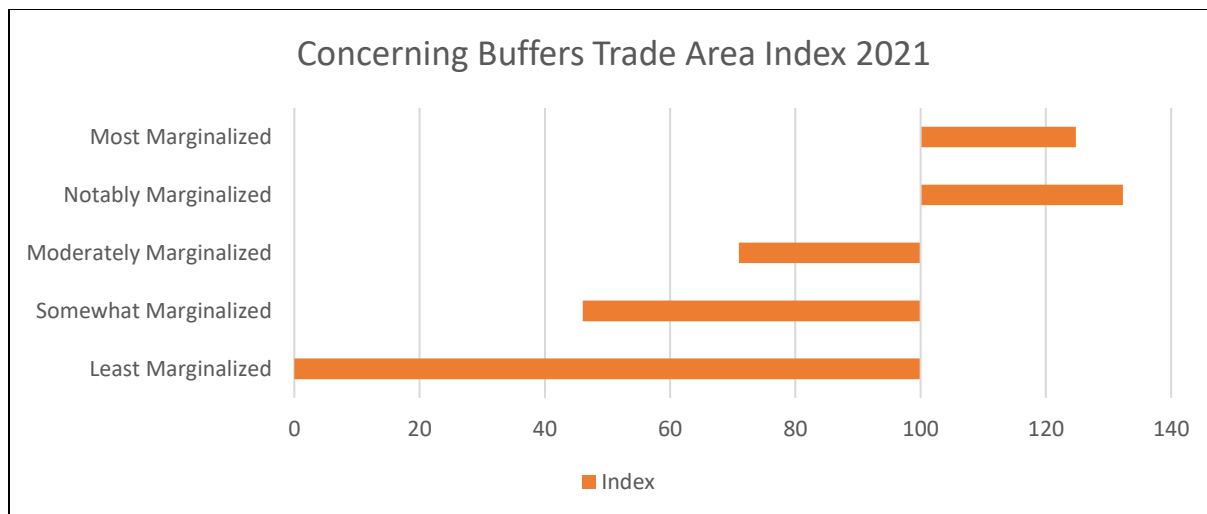


Figure 15. Trade Area Index for the Most Concerning Subway Stations Buffers in 2021

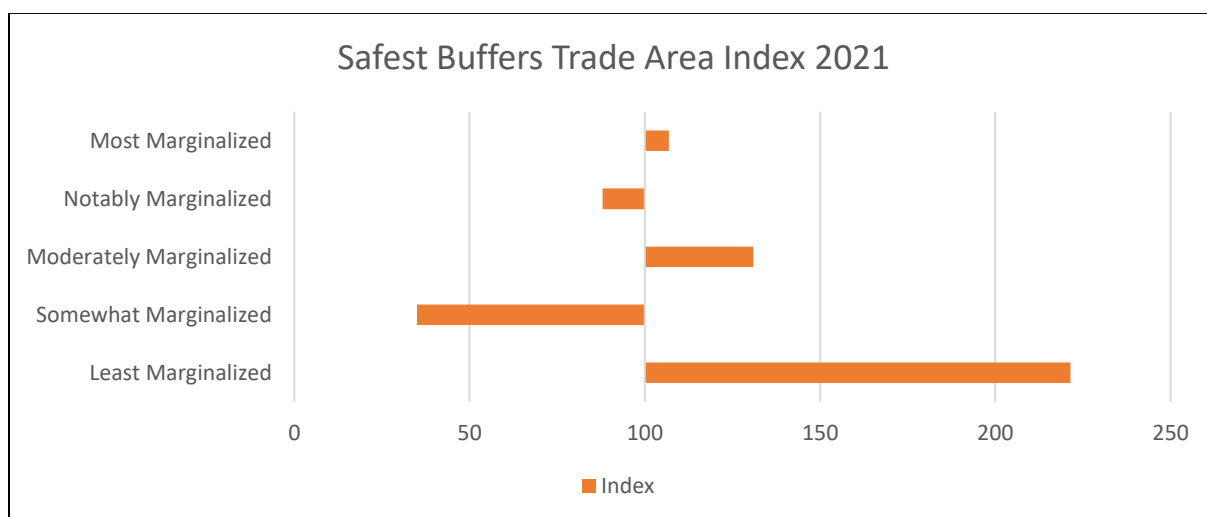


Figure 16. Trade Area Index for the Safest Subway Stations Buffers in 2021

CHAPTER FIVE: DISCUSSION AND CONCLUSION

5.1. Revisiting the Research Questions

The research sought to understand the effects that Covid-19 may have had on the crime rate in the TTC subway stations. An analysis was conducted to answer the primary research question to see if crime counts, crime percentage or both increased from 2016 to 2022 partly due to the Covid-19 global pandemic. Using the change detected, the five subway stations that were most unsafe and safest in 2016 and 2022 were mapped to determine where they were located and whether they were correlated to social services buildings or the Ontario Marginalized Index.

5.2. Discussion

5.2.1. Primary Research Question

The study found that crime had increased in every aspect throughout the TTC, warranting people's feelings of uneasiness. The crime percentage increased by 54.53%, and ridership decreased by 11.46%. This means that the average subway rider found themselves in a safer position in 2016 than in 2022, as their likelihood of involvement in an incident has severely increased. Only 15% percent of the stations on the TTC have gotten safer and saw an increase in ridership.

5.2.2. Spatial Distribution Changes

When analyzing the spatial distribution patterns of the ten most noteworthy subway stations in 2016 and 2022, there are trends in the locations of the subway stations. For the 2016 results, four of the five most concerning stations tend to be located on Line 2 (Bloor - Danforth).

Three of the five stations also tend to be on the further ends of the TTC, both east and west. They are sporadically placed along the line and do not tend to cluster together. This can be seen as the opposite of the safest stations. The safest stations tend to be located on Line 1 (Yonge - University) and clustered together. The areas clustered together are high-use stations with constant riders using the subway. These ridership numbers can be correlated with the risk gain theory. As ridership decreases, the likelihood of crime increases as the perpetrators' risk is reduced, while the opposite occurs in high ridership use stations. These results align with Li et al. (2019) and Xu et al. (2021), indicating that perpetrators are likelier to commit a crime with low to medium ridership.

Although most of the results for 2016 follow Li et al. (2019) and Xu et al. (2021) concept of crime and ridership correlation, two stations can be found as outliers: Keele and High Park. Keele is the third most concerning station, whereas High Park is the third safest station, yet both stations are located beside each other and share similar market areas using the 1-kilometre buffer. An explanation of why the discrepancy exists can be linked to the rationale that the TTC, crime, and Covid-19 do not share a closed ecosystem, allowing unaccounted factors to be included in the outcome. Although the two stations are relatively close, the immediate makeup of neighbourhoods surrounding the stations can be juristically different. Policing of the station can also be another reason why the difference in safety occurs. With High Park station beside the municipal park High Park, one of the city's main attractions, the area will likely be patrolled more frequently to continue to attract tourists and Torontonians alike. Another reason for the difference can be the design of the subway stations. Although all subway stations aim to meet safety goals for maximum security, discrepancies can still exist within the designs to allow for more opportunities for offenders to commit crimes in certain stations compared to others. This

could be why Keele and High Park stations may be beside each other yet on different ends regarding safety.

When contrasting the results of 2016 with those of 2022 and including the variable that people had travel restrictions, the result aligns with that of Hajela et al.'s (2020) research. With the added travel restrictions, areas that already had high crime rates further intensified, and as Hajela et al. (2020) state, once a hotspot is defined, it will continue to remain. This can indicate why four of the five most concerning stations tend to be clustered between Line 2 and Line 3 (Scarborough), as crime was allowed to grow. Three of the five stations safest stations are clustered together around the downtown core. For the remaining safest stations, one station remained relatively in the same area between Lines 1 and 4 (Sheppard), with the last station moving from High Park to Glencairn Station. Given the travel restrictions enacted to reduce the spread of Covid-19, it is reasonable to assume that most perpetrators are either most comfortable, live within the area, or know where the concentration of concerning stations exists. Given the results from 2016, it should be noted that this area has an existing tendency to have safety concerns and should be taken as an area of interest for further studies.

The ten most noteworthy subway stations based on percentage change best reflect which stations have seen the most change between 2016 and 2022. An area of interest that should be further studied is the stations surrounding Lines 1 and 4. This is because two stations saw a big increase in crime, North York Centre and Bayview, while Leslie station got considerably safer. An explanation for this is the effects of Covid-19 and its influence on people's daily life routines, drastically limiting what a person can do because of travel restrictions or health concerns. As travel restrictions were applied on all levels of public transit, stations with higher ridership

numbers tended to show the biggest decrease count-wise, making the percentage change more considerable.

5.2.3. Community Services Correlation

When analyzing the second sub-question, the 2016 count index for the safest stations must be compared to that of the 2022 safest stations and the same for the most concerning station indexes. The safest indexes display a consistent trend. They tend to overperform in all youth clusterings and health and wellness services while underperforming in housing and shelter services. In contrast, between 2016 and 2022, different clusters overperformed and underperformed during that period, with only one cluster, health and wellness services, constantly overperforming.

Although there may appear to be no trends, a few can be delineated. When looking at the social services and their placements, many tend to considerably overperform in the safest stations indexes, which tend to be high-use stations. The opposite is true when looking at the most concerning station indexes. The trend for these indexes is that they tend to overperform in two cluster groups, with one of them usually being health and wellness services. The stations in both 2016 and 2022 also tend to be low-use stations. One can infer from the results that the correlation best exists between social services and ridership levels. If crime continues to plateau due to ridership levels, it is best to put social services in these more trafficked areas to help as many people as possible. The sense of security should not discourage people around these subway stations, and they should continue to feel safe. This is because the literature suggests that people will not commit crimes if the ideal environment does not exist, as Sikorski et al. (2024) indicate. Instead, the most concerning station indexes portray the type of service most prevalent in the

area, which, in turn, means what is most needed for the neighbouring communities. This can be assumed because they are not highly frequented stations, and if the city feels that a specific population is most at risk or in need of a service, they will add it strategically where it can help the most people in need. Overall, the results for these indexes revealed that the relationship between crime and social services fluctuates heavily and is most useful for the most concerning stations as they will indicate which issues in the area are of most concern and need immediate action.

5.2.4. Marginalization Index Analysis

The Ontario Marginalized Index provides a unique insight into how the relationship between Covid-19 and TTC crime has developed. The 2016 data illustrates that no meaningful relationship can be delineated. The most concerning and safest subway stations share similar characteristics; their trade areas tend to overperform with moderately marginalized dissemination areas, and the rest of the different levels of marginalization underperform in the trade areas. When Covid-19 is introduced as a variable, the differences appear in marginalization. The most concerning stations trade market considerably overperformed in most marginalized and notably marginalized categories while underperforming in the moderately, somewhat, and least marginalized categories. As for the safest subway stations, they considerably overperformed in the least marginalized and underperformed in the somewhat marginalized. The remaining groups neither over nor underperform to any distinction in the trade area. These results tell us that when people are restricted to where they are allowed to travel and must stay in one location and only go where it is deemed necessary, marginalized neighbourhoods tend to be more unsafe than those not. This can further relate to what drives a person to commit a crime. As discussed, when

a person needs a particular service or resource and cannot achieve it through the wages they earn at work, if they are employed, they will go to extraordinary methods to acquire them.

5.3. Strengths of the Study

The paper's main strengths are its comprehensive data and geospatial analysis from 2016 to 2022, covering the period before and after Covid-19, which notably influenced the TTC. The data analysis allows for different trends to be detected and suggests possible rationalities as to why they may occur due to various social constructs and services. The study also relies on past literature to further illustrate why specific trends may occur. It uses the effects of Covid-19 to either further tie the concepts together or find where the literature does not align anymore. The geospatial aspect expands on the results of which subway stations are safer or more concerning, adding different levels of interactions within the city.

5.4. Limitations, Suggestions, and Future Research

As the nature of the paper is exploratory, some limitations exist. Although the paper relies heavily on a wide range of extensive datasets, there are issues with availability and quality. One of the major concerns is that not all crime cases may be reported, which can heavily influence the outcome if enough cases go unreported. This change can either further align with past studies or deviate. Another limitation of the dataset is the consistency provided. Through the paper, the study compares 2016 ridership levels to 2022, although there is an issue in 2022: Scarborough Town Center did not have a ridership level reported; therefore, 2021 data was used, causing minor discrepancies. Additionally, the study omitted the six new stations added between 2016 and 2022 as they did not have a base number for 2016. Regarding the dataset provided by

the Ontario Marginalization Index, a housing variable was one of the four subcategories used when aggregated together to create an overall level of marginalization. The housing variable does not accurately account for the downtown lifestyle in which it is more common to have renters and young individuals than compared to the rest of the province. This lifestyle skews the results, as these attributes typically indicate marginalization outside Toronto's downtown core. The last primary concern with the data is that the Ontario Marginalization Index is constructed for every census year. 2022 was not a census year, so 2021 data had to be used. Another limitation is the temporal scope of the study. As the paper's results illustrate immediate changes that have occurred on the TTC, it does not indicate how future long-term effects will develop due to Covid-19. The final major limitation is the influence of any other external factor that was not accounted for; as described, crime is a complex theory involving many different factors; therefore, not all can be analyzed.

Based on the findings and limitations, some suggestions can be made to improve safety and well-being while riding the TTC. A more feasible approach the TTC can take to better deal with the most concerning stations is by improving natural surveillance while attempting to boost choice riders and accessibility at the same time. Adding more bus routes and improving frequency around the most concerning stations will discourage people from committing crimes as bystanders act as informal security for other riders. This goes with the theory that crime will only be committed in low-use areas and when the risk to gain factor is in the proper condition. Adding these new suggestions will oppose low ridership and create a safer environment.

Future research should seek to add a variety of methods to expand on the exploratory results further. The first of three suggestions is to conduct a similar study again with the next Canadian census and the one that follows to see if the results found have had long-term effects

on crime in the TTC. The next suggestion would be to employ different statistical methods to understand better the causal relationship between the TTC and crime rates. The final suggestion would be to conduct a behavioural analysis to understand the exact type of crime most prevalent at TTC subway stations.

5.5. Conclusion

These results further illustrate that previous literature correctly predicted that crime is more likely to be committed in low- to medium-ridership zones rather than high-ridership areas. The impact of COVID-19 has further emphasized this trend, with the most concerning and safest clusters corresponding to the least and most busy stations, respectively. Covid-19 has highlighted the TTC's challenges in attracting choice riders to low-ridership stations as these areas continue to face high crime rates. On the other hand, Covid-19 did not force high-use stations to experience the same challenges as the low-use stations, demonstrating their resilience to consciously plateau crime rates. This study highlights the need for targeted interventions in low to medium-ridership zones to mitigate crime and improve safety substantially as public transit systems recover from the effects of the pandemic. The TTC must focus on enhancing security measures, increasing public engagement, and improving the overall transit experience.

Overall, the study found that Covid-19 harmed the TTC between 2016 and 2022, increasing crime rates and crime counts, warranting people's feelings of unease when riding the subway. It also found consistent hotspots within the city where crime is more prevalent, which tends to be closely related to ridership levels. Although these negative impacts were discovered, key takeaways were also uncovered, indicating that an area's social services and social constructs play a vital role in the TTC and should be considered when building a safer TTC for the future.

APPENDIX A

Table A1: Crime Data for New Subway Stations Added Post 2016

Subway Station	Subway Line Located On	Year Implemented	Average Subway Ridership in 2022	Crimes Committed in 2022	Crimes Committed per 10,000 People in 2022
Downsview Park	1	2017	8,845	4	5.7
Finch West	1	2017	20,950	19	4.3
Highway 407	1	2017	9,042	0	4.4
Pioneer Village	1	2017	14,789	9	8.8
Vaughan Metropolitan	1	2017	21,186	11	6.1
York University	1	2017	30,112	3	0.7

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