TTC Delay Data Analysis

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Introduction

The purpose of this report is to gain high level understanding of service delay trends for the Toronto Transit Commission (TTC) – A public transport agency serving population of over 3 million residents in Toronto, Ontario, Canada. We will also investigate the causes for these delays and discuss potential solutions to improve punctuality. TTC currently operates almost **200 bus routes, 14 streetcar routes and 4 subway lines** with **75 Subway Stations**. Toronto is one of the fastest growing cities in North America but even with new projects in recent years and more to come in the future, many critics claim the public transport system is finding it difficult to cope with population growth. Our analysis report will make recommendations based on the year over year trends as well as a general trend to the following key questions:

1. What is the daily and monthly delay trend? Does it follow a pattern year over year?
2. What are the leading causes for these delays? How does it change yearly?
3. How do we measure the magnitude of delay?
4. How does leading causes relate to the magnitude of delays?
5. What locations and routes were most affected by these delays?
6. How can we improve the services?

Data

The data was sourced from City of Toronto Open Data Portal starting from January 2017 to December 2019. Data can be accessed here. The data was cleaned to ensure bad data is discarded. The location/station names had free-text fields at the data collection source so most similar entries for the location columns were grouped together in the cleaning process but due to the large amount of unique values some low-frequency values may have been left out when analyzing the locations. Hence, this analysis report will be relative rather than absolute for any location-based analysis. Data cleaning Jupyter notebooks can be accessed on my GitHub account.

Analysis

1. Daily and Annual Trend

In fig 1.1, the daily trend shows that TTC experiences a relatively higher number of delays in the morning when their regular services begin around 6:00 am. However, buses and streetcars perform better during the morning rush hour; the subway experiences the highest number of delays. The bus service experiences another peak in the late afternoon around 3 pm, while Subway service experience a slight rise in the number of delays in the afternoon rush hour around 5 pm. Streetcars tend to perform much better after the early morning delays and has a downward trend for the most part except around 3 pm, similar to bus service.

Year over year comparison indicates that subway service followed the hourly trend very closely throughout the three years used for the analysis, with 2018 being the worst performing year for the most part. On the other hand, buses showed a significant improvement in the service in 2019 during peak times. The morning and afternoon rush hours recorded 40% and 30% fewer delays than the preceding year. The streetcars also reflected a similar trend. To understand this significant improvement in services, we will look into the reasons behind bus and subway service delays.

The fig. 1.2 displays the monthly trends for all TTC services. The monthly graph indicates no specific movement, as all lines lay mostly flat. In the year-over-year comparison, the bus service shows significant improvement in the second half of 201. Though the graph stays flat primarily, the streetcars and bus service observed fewer delays in December for 2018 and 2019 but showed a significant spike for the January of the following year.

Fig 1.1 Hourly Trend

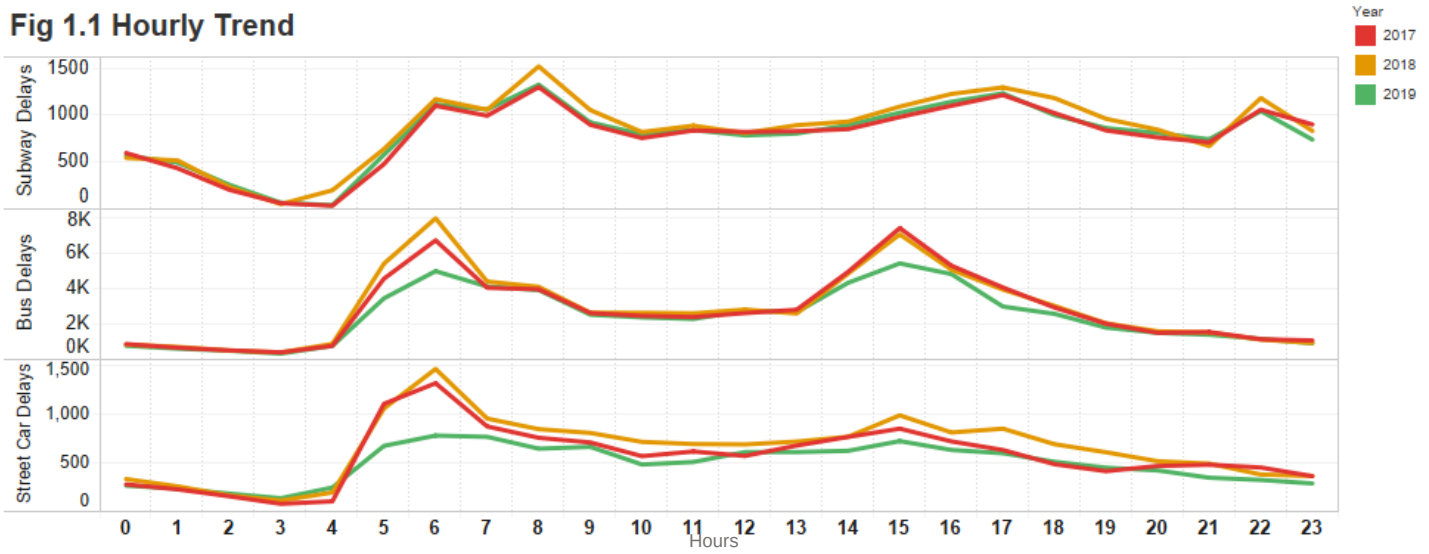


Fig 1.2 Annual Trend

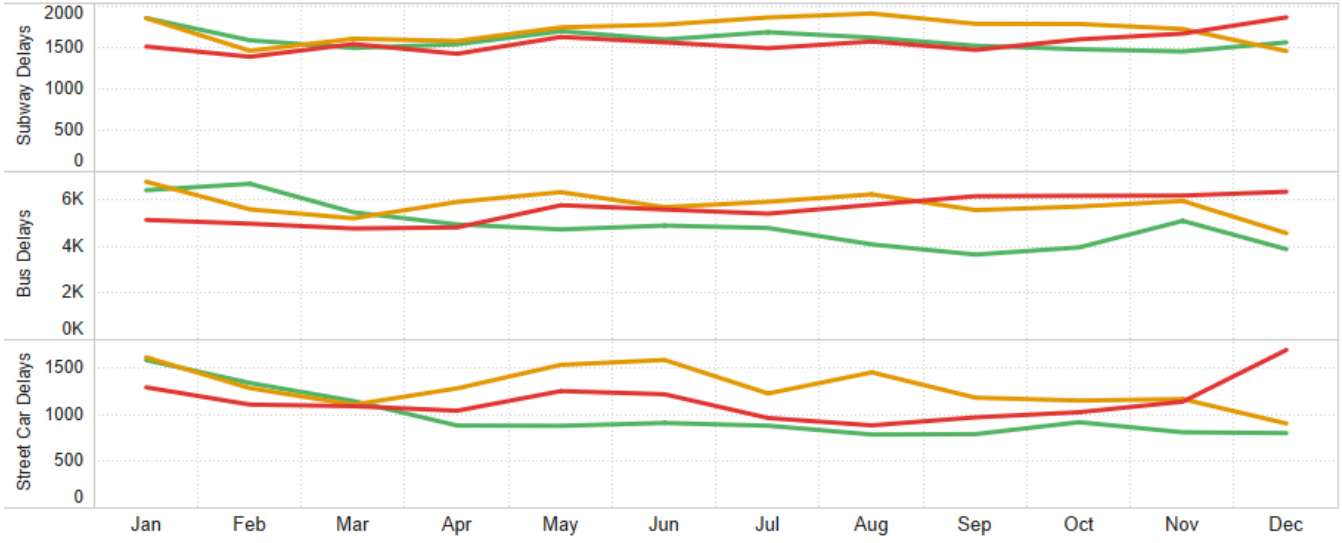


Fig 1.3 Total Annual Delays

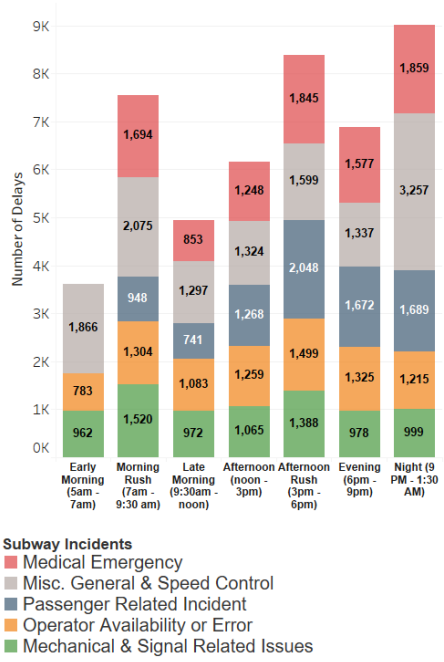
Subway Delays		Bus Delays		Streetcar Delays	
2017	18,798	2017	67,563	2017	13,709
2018	20,633	2018	69,884	2018	15,519
2019	19,170	2019	59,175	2019	11,760

2. Causes for delays

Fig 2.1 and 2.2 compares causes throughout the day for Bus and Subway service, respectively. *Mechanical issues* stayed consistent throughout the day for both services. *Operator Availability or Error / Late Leaving Garage,* also contributed significantly, especially in the morning and afternoons. The timing of such delays indicates the start of working shifts for vehicle operators had a visible role in both services.

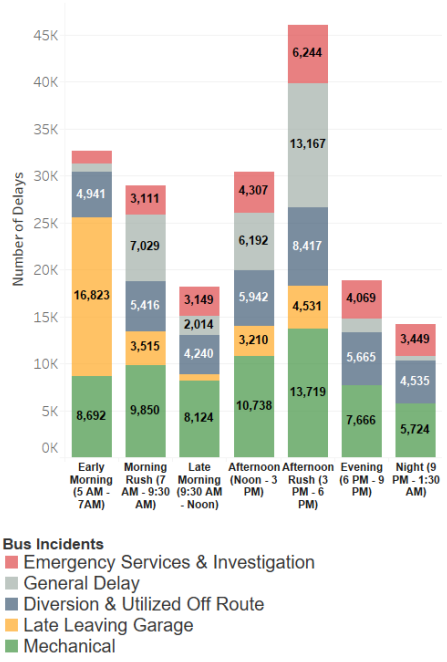
For Subway service, *medical emergencies* and *passenger related incidents* (assistance alarm activation without reason, door blocking, and disorderly conduct) accounted for substantial delays throughout the day. We will dig into the magnitude of these delays later in section 3 of this analysis to suggest any recommendations.

Fig 2.1 Daily Causes for Delays - Subway Service



Subway Incidents
- Medical Emergency
- Misc. General & Speed Control
- Passenger Related Incident
- Operator Availability or Error
- Mechanical & Signal Related Issues

Fig 2.2 Daily Causes for Delays - Bus Service



Bus Incidents
- Emergency Services & Investigation
- General Delay
- Diversion & Utilized Off Route
- Late Leaving Garage
- Mechanical

Though mechanical issues led to almost one-third of the delays, Bus service *utilized off routes* and *general delays* due to roadblocks, and traffic also contributed significantly during day time as well.

Since *Mechanical issues* were common between Bus and Subway service, my analysis dig deeper into the mechanical failures and cross-checks them against vehicle IDs in the datasets to compare how these mechanical delays fared for the vehicles that had the most number of delays over three years. The Buses showed significant improvement with an often lesser number of mechanical delays recorded in the following year for most vehicle IDs. In comparison, the Subway service reflected the opposite trend. Subway vehicles often had more mechanical failure related delays than the preceding year.

Due to a vague assumption that all data was accurate and missing Vehicle IDs in the original dataset, this analysis can not be deemed conclusive, but we can observe that buses were maintained relatively better than the subway trains during this period.

Fig 2.3 Number of Mechanical delays by Vehicle ID

Subway

	2017	2018	2019
5421	17	14	13
5566	2	32	12
5571	7	18	5
5576	9	9	3
5591	4	7	9
5631	8	16	1
5666	8	11	8
5676	9	5	12
5696	8	11	11
5731	11	9	8
5741	8	9	7
5751	5	25	4
5761	1	8	7
5801	8	5	13
5906	6	9	10
5976	4	12	6
6001	6	7	5
6041	5	2	7
6051	4	5	22
6061	13	13	4

Bus

	2017	2018	2019
9034	36	34	16
9037	39	20	16
9047	32	29	11
9022	23	30	17
9006	15	36	18
9042	28	32	8
9021	27	20	18
1132	28	18	19
9044	15	27	18
9052	9	27	22
1096	24	14	14
1098	20	18	12
1091	22	14	14
8163	13	9	26
1402	16	10	21
1707	15	12	19
1397	17	16	12
1106	18	12	14
8125	10	19	14
1129	14	8	11

*** Green indicates drop in yearly count while red shows an increase compared to last year*

3. Magnitude of delay

To analyze the magnitude of the delay without any bias, I will use the “gap-to-delay ratio” instead of absolute minutes delayed. This ratio will serve as a standardized metric for the analysis of delay magnitude. Since 2 mins delay on a route that runs every 30 mins is not as significant as 2 mins delay for a route that runs every 5 mins.

The Gap-to-delay ratio will have an inverse relationship with the magnitude of the delay. Where a value below 1.0 will indicate, the bus was delayed by more than its gap to the next bus. A value between 1.0 and 2.0 reflects the delay was more than half of the gap e.g., a 6 mins delay on a 10 mins gap. We will consider any ratio value above 4.0 as a ‘short delay’, meaning it is insignificant and acceptable for daily operation for a public transport service affected by road traffic i.e., Bus and Street Cars.

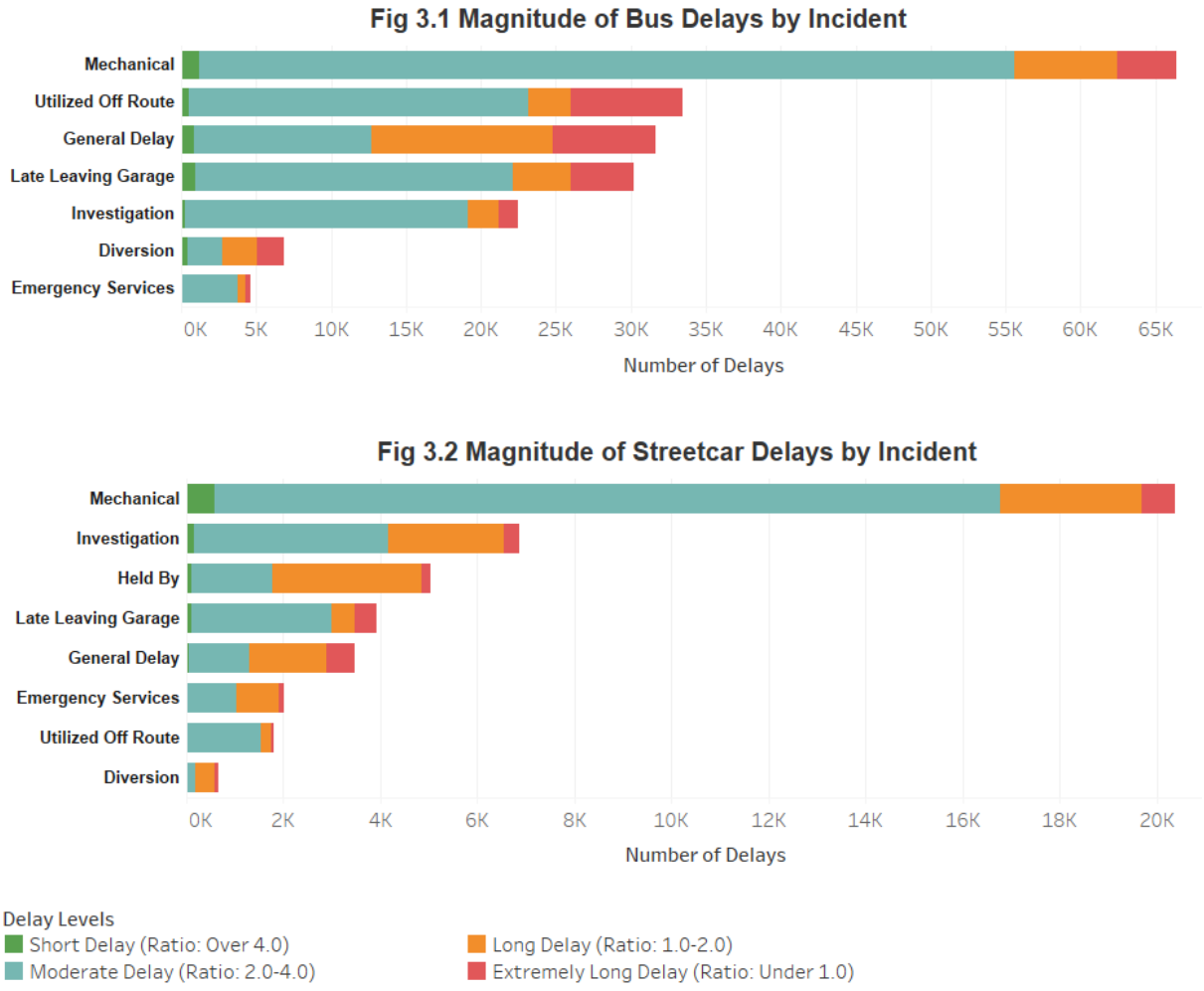
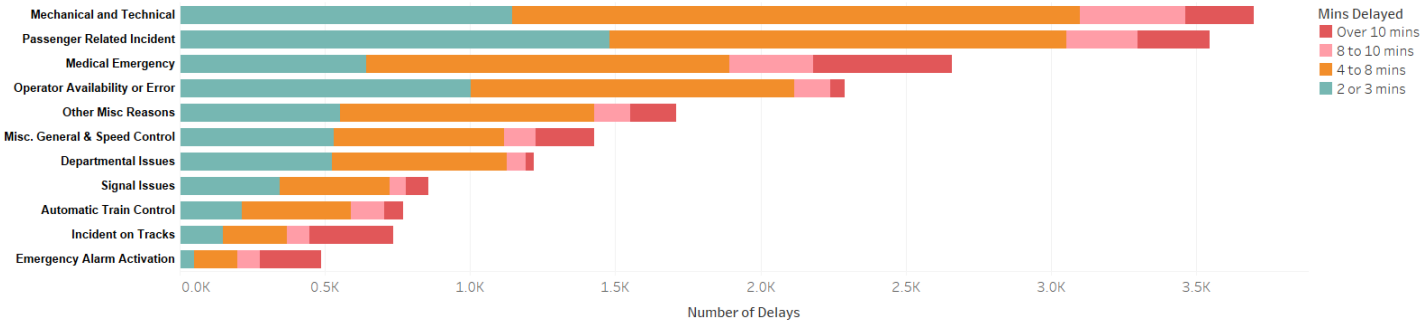


Fig 3.1 and 3.2 compare the causes with the magnitude of delay. Both road services experienced the highest number of delays due to mechanical reasons, with over 75% of these delays fell into the moderate category. Overall a very short percentage were short delay while *utilizing off-routes*, and the *general delay* had the highest number of long and extremely long delays for the bus service. Proportionately, Streetcars experienced a smaller ratio of extremely long delays or short delays. A significant proportion of higher ratio delays in the 'late leaving garage' category for both services should be thoroughly examined to suggest improvements in punctuality of employees or general operations.

For Subway service, since the '*gap_mins*' information was not available for more than half of the data, I will use the absolute delay mins as the key metric. We will exclude under 2 mins category for Subway service as it is an acceptable delay for daily operations. Please note, subway service on primary lines (Line 1 and Line 2) is as frequent as every 5-7 mins during regular hours and every 2-4 mins during rush hours.

Fig 3.3 Minutes Delayed by Incident - Subway



Subway service also observed the highest number of delays due to *Mechanical and Technical* issues, it led to higher than acceptable delays (2-3 mins) for the subway service. My biggest concern would be passengers related incidents where passenger behavior led to, on average, over 3 delays per day for 3 years, and more than half of these delays were more than 3 mins. Medical emergencies understandably led to longer delays, with over 25% taking 8 mins or higher. It is closely followed by Operator availability or error, which led to over 2 delays per day in this period. Considering the scale of operation for TTC, single-digit delays per day may not seem a lot, but these delays disrupt the schedules and become basis for mistrust between TTC and its clientele.

Fig 3.4 Subway Minutes Delay - Frequency Distribution

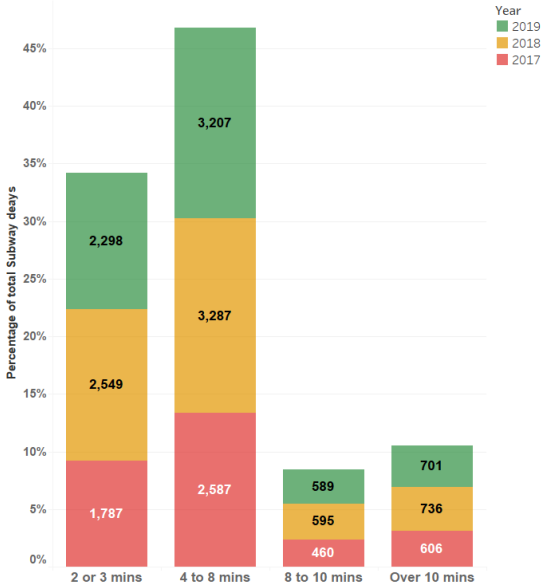


Fig 3.4 indicates 65% of subway delays were over 4 mins. 2018 was the worst year in all categories as the number delays rose significantly from 2017 in all delay groups. Though service improved relatively in 2019 but it did not fall close to 2017 levels.

4. Top Locations and Bus Routes

Fig 4.1 Top 10 Bus Locations with Average Delay and Gap-Delay Ratio

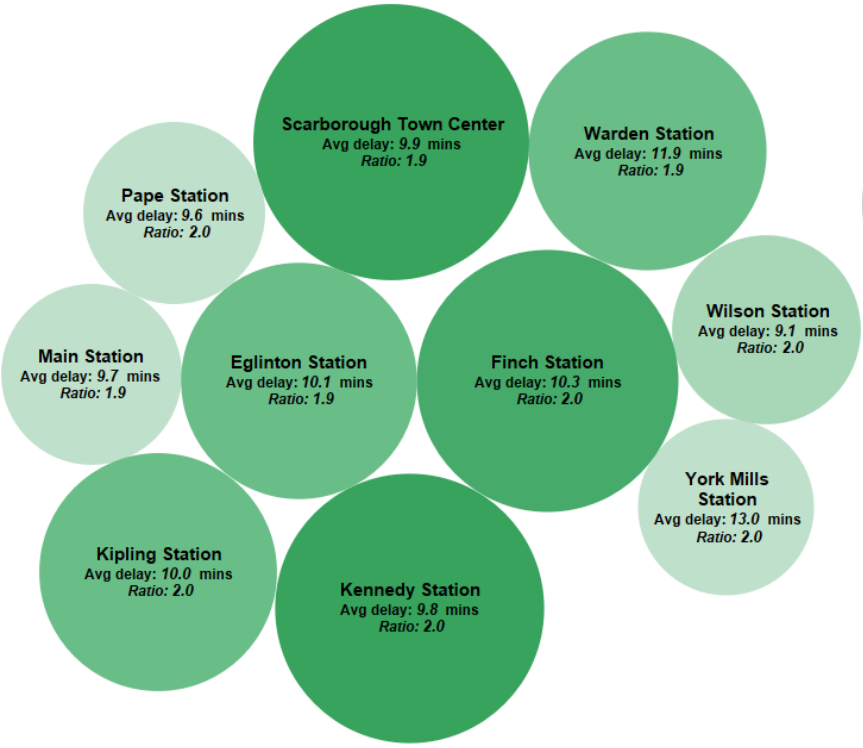


Fig 4.2 Top 10 Bus Routes with Average Delay & Gap-Delay Ratio

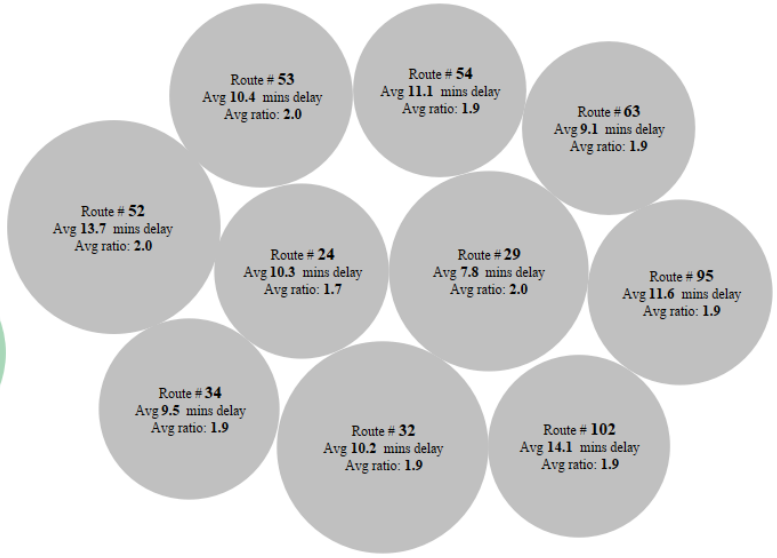


Fig 4.3 Top 10 Street Car Locations & Average Delay

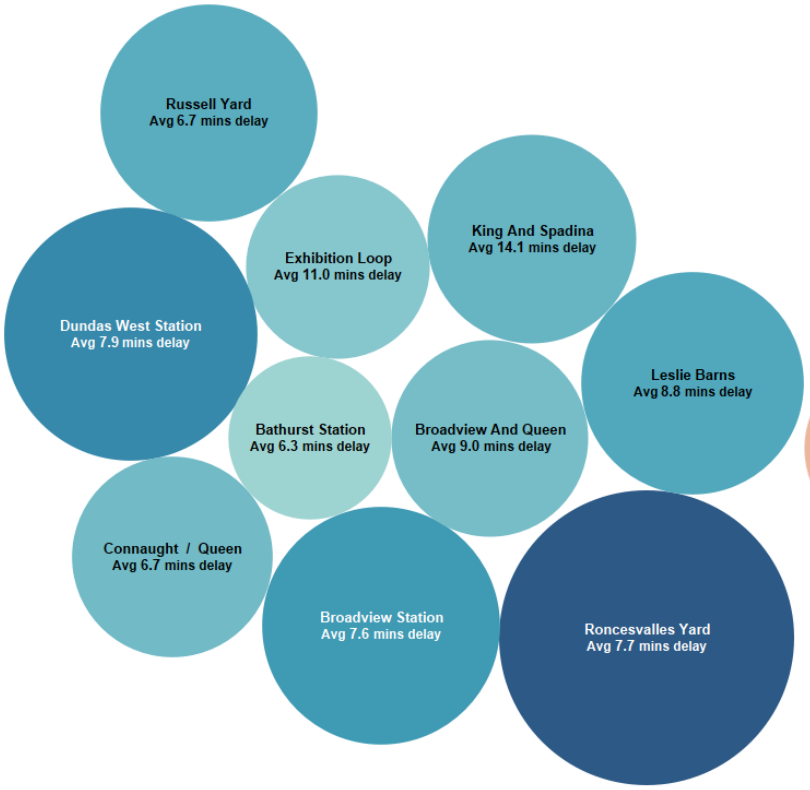
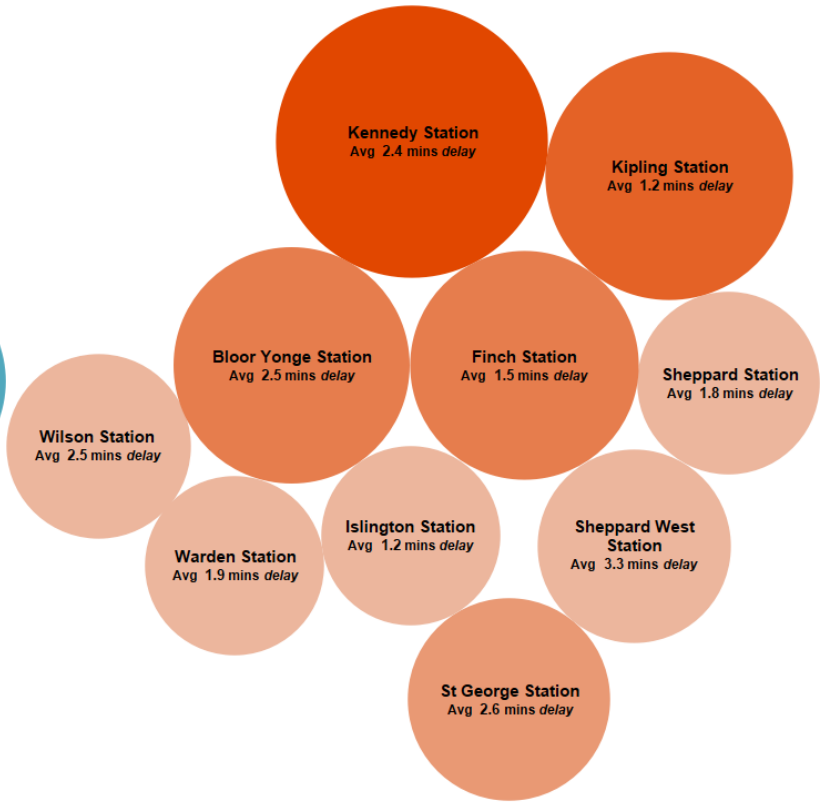


Fig 4.4 Top 10 Subway Stations & Average Delay



***Size and Colors positively correlates to the number of total delays at each location*

The bubble charts above in all four figures show the worst-performing locations for each of the TTC services and the bus routes with the highest number of delays with their average delayed time over three years.

Fig 4.1 and 4.2 reflects the worst-performing bus stops and routes, respectively. 5 out of these 10 locations are on the east end of the city, followed by north with 4. An in-depth analysis can also be performed based on the regions to understand any geographical inclinations and the leading causes behind these delays. The average delay time for these bus locations and routes was over 9 minutes with an average gap-delay ratio of around 2.0(i.e., a bus with a 10 mins gap to the next scheduled bus was, on average, 5 mins late). Such long delays are alarming for these routes and the locations.

As shown in Fig 4.4, top subway train stations experienced around an average of 2 mins delay. Comparing these stations with the worst-performing bus locations, we can notice a significant intersection. Kipling, Kennedy, Finch, Warden, and Wilson stations were among the top 10 worst performing services. These stations should be investigated further for determining the root causes behind such poor performances.

Conclusion And Recommendations

Overall, TTC services showed a mixed trend on a year over year comparison. Mechanical and Technical issues caused a significant amount of delays. TTC claims it has been updating its systems, especially on the subway tracks, to improve performance, but an extraordinarily high number of mechanical failures in all services may indicate that the fleet is aging or over-used. A thorough assessment of the maintenance methods would help TTC avoid such issues. Vehicle Operators also led to substantial delays either with availability issues or by misoperating the vehicles. Better training programs, performance evaluations, and employee scheduling checks can help TTC eliminate unnecessary delays.

General delays and off-route utilization for road-based services combined led to over 35% of the delays during these three years. Typically, such delays are expected for road-based services, but our analysis indicates that most of these delays fell into moderate delays. Given the worst 10 routes had an average delay time of over 9 mins, rescheduling, revised route plan, or additional buses on these routes are some of the TTC administration's options to improve the customers' reliability.

Some stations were consistent locations for both bus and subway services. An in-depth investigation into these locations may reveal some of the challenges TTC faces. Sites that experienced a higher number of delays also experienced a substantially higher average delay time. The delay-gap ratio was around 2.0 for almost all the high delay frequency bus locations; this does not translate into a reliable service a TTC user would expect.

To conclude, TTC is known to be actively working towards automation of its subway trains, eliminating a substantial portion of the delays in the future. In the last couple of years, TTC has overhauled its fleet with new streetcars and continuously added many more modern buses, that echoes through a fall in delay count for buses and streetcars in 2019. With a 5th subway line coming to Toronto and the conclusion of other TTC led construction projects in 2021, all services aim to improve significantly in the future. Though TTC users and critics currently have a lot to complain about, TTC riders have a lot to look forward to with new projects coming into action.