What Drives Emergency Medical Services (EMS) Demand?*

Community-based paramedic service strategies that focus on medical emergencies, emergency transfers, and vehicle accidents may help to effectively manage EMS demand

Julia Lee

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By examining Paramedic Services Incident Data (2017-2022) provided by Toronto Paramedic Services, the following anaylsis aims to identify the key drivers of Emergency Medical Services (EMS) demand to help inform demand-management strategies. Through data visualization, this analysis finds that medical emergencies, incidents requiring emergency transfers, and vehicle accidents are overall drivers of EMS demand. This suggests that centering strategies around these drivers may enhance the overall efficiency of paramedic services. Additionally, this analysis emphasizes that thoughtful consideration for the unique needs of those who require EMS is important to build practical EMS-demand-management strategies.

1 Introduction

"In case of an emergency, please call 911." From building walls to road signs, this is a message that appears almost everywhere, and it instills the idea that no matter the circumstance, there will always be emergency services available to help. However, research shows that this is not the case. A report on Toronto's paramedic services highlights that there were no ambulances available for over 1,000 calls in 2023 (Draaisma 2024). With drastically increasing wait times for those who required Emergency Medical Services (EMS), it is necessary to understand why paramedic services are unable to keep up with a seemingly growing demand for EMS.

In response to this rising challenge, the report posits that in order to elevate the "efficiency and effectiveness" (Draaisma 2024) of Toronto's paramedic services, further research on how

*Code and data are available at: https://github.com/JuliaJLee/Toronto_Paramedic_Services.git

to manage EMS demand is needed. Thus, by using Paramedic Services Incident Data offered by Toronto Paramedic Services, this analysis seeks to identify which types of emergencies (e.g. medical emergencies, vehicle accidents, etc.) drive EMS demand. Knowing the drivers of EMS demand can help inform paramedic service strategies that allow for better EMS demand management.

With this, this analysis first examines the total number of emergency calls made from 2017 to 2022 to better understand how EMS demand has changed over time. Then, it looks at EMS demand through five different incident types as outlined by Toronto Paramedic Services to identify the drivers that push EMS demand. Lastly, this analysis considers whether drivers of EMS demand differ across different communities. As a result, the present analysis finds that overall, medical emergencies, incidents requiring emergency transfers, and vehicle accidents are the key drivers of EMS demand. However, not all communities are found to have the same drivers. So, while strategies that target medical emergencies, incidents requiring emergency transfers, and vehicle accidents may enhance the overall efficiency of paramedic services, it is important to consider the unique needs of various communities to shape stronger EMS-demand-management strategies.

In what follows, a description of the data that was used within this analysis (Section 2), a detailed account of the results (Section 3), and a brief discussion of the analysis (Section 4) is provided.

2 Data

2.1 Toronto Paramedic Services Data

Paramedic Services Incident Data (2017-2022) is provided by Toronto Paramedic Services (Toronto Paramedic Services 2023). The records of when a paramedic was dispatched having received a call, the type of incident, the priority level of each incident, the number of paramedic units that arrived at the scene, and the general location of each incident are all periodically updated to the city of Toronto's Open Data portal (City of Toronto 2024).

To simulate, test, download, and clean the Paramedic Services Incident Data (2017-2022), the statistical programming language R was used (R Core Team 2023). Specific libraries that assisted the analysis include `tidyverse` (Wickham et al. 2019), `dplyr` (Wickham et al. 2023), `opendatatoronto` (Gelfand 2022), `tinytex` (Xie 2019), `ggplot2` (Wickham 2016), `knitr` (Xie 2015), `maps` (Becker et al. 2023), and `sf` (Pebesma 2018).

The Paramedic Services Incident Data is refreshed annually and contains information on every single incident paramedics have responded to since January 1, 2017 to December 31, 2022. For every day of each year, there are multiple records of incidents that have occurred. For every record, there is an ID number, the date and time when a paramedic unit was dispatched, the type of incident, the severity of the incident (priority), the number of paramedic units at the

scene, and the general location of the incident. Table 1 below previews this information for recorded incidents in 2022.

Table 1: Paramedic Services Incident Data for 2022

ID	Dispatch Time	Incident Type	Priority	Units Arrived	Location
5,827,367	2022-04-27 22:15:02	Emergency Transfer	1	2	M6R
7,388,641	2022-01-01 00:00:15	Medical	1	1	M6A
7,388,642	2022-01-01 00:00:33	Motor Vehicle Accident	1	2	M5E

Looking at Table 1, the variable, "ID", is a number that identifies each incident in accordance with a Computer Aided Dispatch (CAD) record (Toronto Paramedic Services 2023). "Dispatch Time" represents the date and time, measured in minutes and seconds, at which paramedics responded to an emergency call. This data further provides information on the type of emergency paramedics responded to with the variable, "Incident Type". "Priority" refers to the urgency of all incoming emergency calls. The priority level is measured using a "Medical Priority Dispatch System (MPDS)" that organizes incoming information from 911 callers into different categories. For instance, in Table 1, the priority level is 1 for all three incidents, meaning that the MPDS assessed the information provided by callers and their situations as extremely urgent. "Units Arrived" is a count of the number of paramedic units that were present at the scene. Lastly, "Location" characterizes the approximate location of each incident and is measured using Forward Sortation Areas (i.e. the first three characters of postal codes).

2.2 Analysis Data

For this analysis, the variables of interest are the different types of incidents that are recorded. The Paramedic Services Incident Data lists five different incident types: (1) medical emergencies, (2) motor vehicle accidents, (3) emergency transfers, (4) fires, and (5) airport standbys. Each type refers to a different circumstance under which individuals may call 911 for EMS.

As the objective is to understand the driving factors of EMS demand, the actual data that is used within this analysis reflects the total EMS demand and the demand for each incident type over the course of six years (2017-2022). All recorded incidents were aggregated together by incident type to see the number of emergency calls for each type. Then, the number of emergency calls for each incident type were summed to produce a total EMS demand count. This process was repeated every year from 2017 to 2022. Table 2 (found below) illustrates

the outcome of this process, and summary statistics for this analysis data can be found in the Appendix (Section A).

Table 2: Organized Paramedic Services Incident Data (2017-2022)

Year	Medical Calls	Vehicle Accident Calls	Emergency Transfer Calls	Fire Calls	Airport Standby Calls	Unclassified Calls	Total Emergency Calls
2017	254454	13242	9282	880	71	681	278610
2018	271935	13011	9192	896	54	663	295751
2019	274495	12790	8675	804	49	536	297349
2020	254209	8395	6594	782	7	613	270600
2021	269296	8317	7134	760	4	630	286141
2022	271755	8507	7077	694	31	626	288690

The column "Unclassified Calls" in Table 2 represents the emergency calls that were not assigned an incident type. It is important to note that throughout the analysis, these records are omitted.

2.3 Map Data

To further understand what drives EMS demand, this analysis uses the Forward Sortation Areas (FSA) provided by the Paramedic Services Incident Data (2017-2022) to map EMS demand across all the locations Toronto Paramedic Services respond to. The map is based on the Paramedic Services Incident Data from 2022. By grouping the data shown in Section 2.2 by FSAs, the types of incidents recorded within each unique FSA and the number of incidents that occurred with each incident type could be found. The "driver" of EMS demand for a given FSA was determined by the incident type that had the most number of calls. This data is shown below in Table 3. The column, "CFSAUID" contains every FSA that Toronto Paramedic Services responded to in 2022.

Table 3: Modified Analysis Data for Mapping

CFSAUID	Incident Type	Emergency Transfers	Medical Emergencies	Vehicle Accidents	Fires	Airport Standbys	EMS Demand Driver
K0K	Emergency Transfer	1	0	0	0	0	Emergency Transfers
K0M	Emergency Transfer,Emergency Transfer	2	0	0	0	0	Emergency Transfers

To map this data, a shapefile with the spatial information for all recorded FSAs is combined with the data shown in Table 3. The shapefile from the 2021 Census is provided by the Open Government Data portal from the Government of Canada (Open Data Canada 2024). Additional information about this dataset, including how it is used can be found in the Appendix (Section A).

3 Results

3.1 EMS Demand from 2017 to 2022

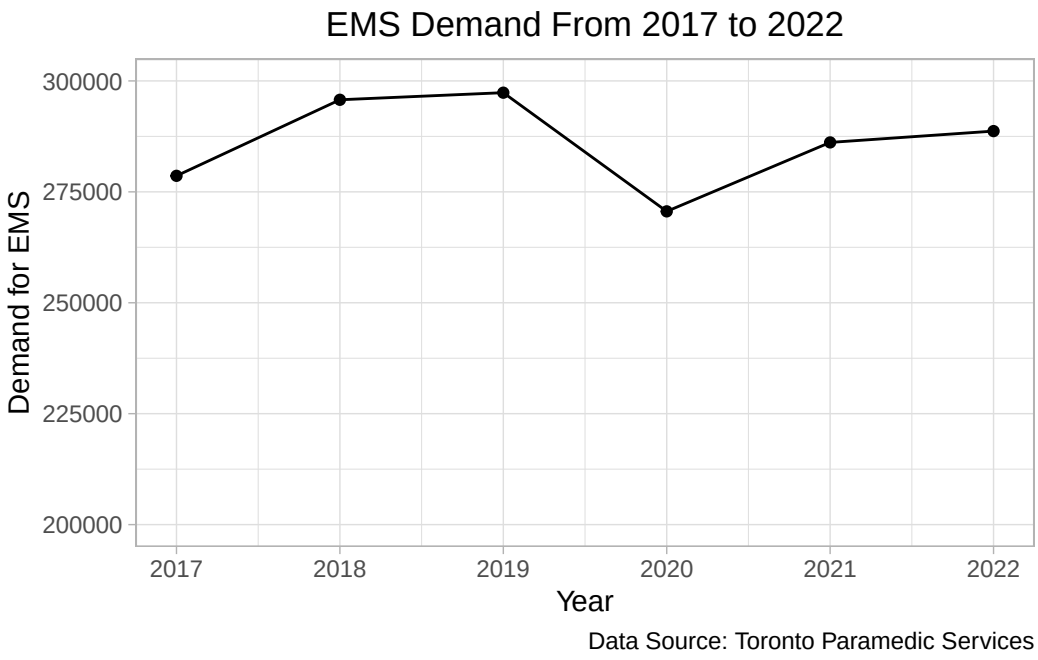

Figure 1: Total EMS Demand for Each Year between 2017 and 2022

Figure 1 displays the total number of emergency calls for each year. The total number of emergency calls appears to increase in 2020 after a notable decrease in 2019. This pattern likely reflects the onset of the covid-19 pandemic. Though the number of emergency calls appears to fluctuate over the years, the change is not drastic, indicating that there has consistently been a heightened demand for EMS.

3.2 EMS Demand from 2017 to 2022 Based on Incident Type

To further unpack what is driving this EMS demand, the number of emergency calls for each incident type are also considered. Figure 2 illustrates the number of emergency calls for each incident type along with the total number of emergency calls. Based on Figure 2, demands for EMS are markedly higher for medical emergencies than any other incident type, suggesting that medical circumstances are key drivers that propel EMS demand.

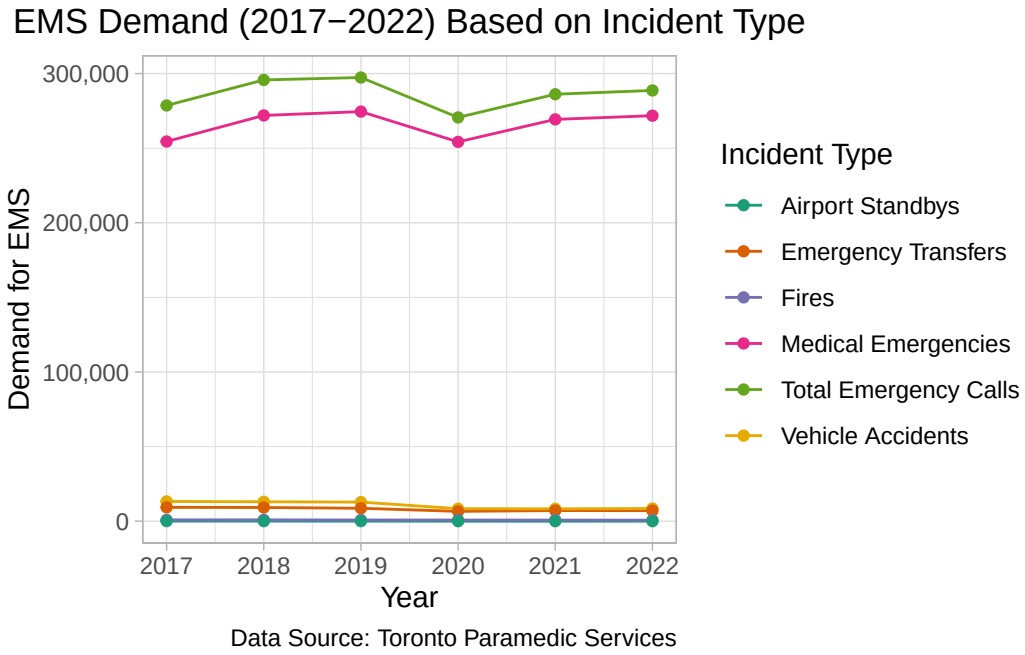

Figure 2: EMS Demand for Each Year between 2017 and 2022

By zooming into the lower portion of Figure 2 with Figure 3 below, a clearer look at the other incident types is provided. With Figure 3, it becomes clear that vehicle accidents and emergency transfers may be other potential drivers of EMS demand, though not as strong as medical emergencies.

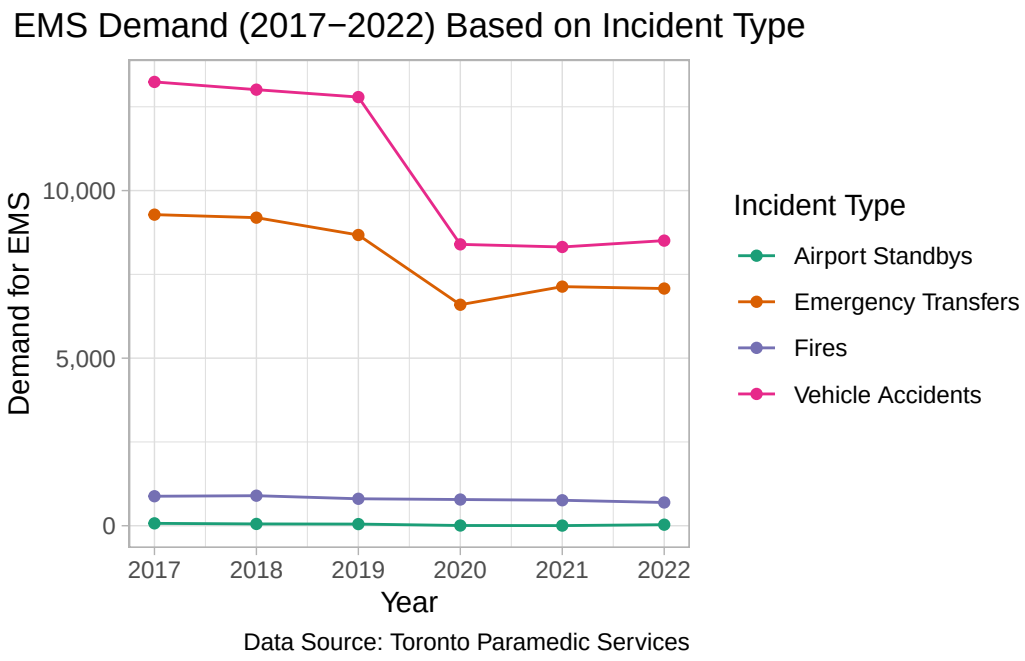

Figure 3: Zooming in on Figure 2

As medical emergencies seem to be prominent drivers of EMS demand, strategies that focus on efficiently managing calls for medical emergencies may help to better navigate EMS demand as a whole. Response times for EMS demand have been greatly impacted by offload delays, staffing/training challenges, and traffic congestion (Draaisma 2024). With medical emergencies, a shortage of doctors has placed pressure on paramedic services as residents rely on and turn to these services more often (Ireland 2024). This in turn, increases in offload delays - the time it takes to offload patients into hospitals. Longer offload delays mean longer response times for other incidents. Putting all of this together, a strategy to better manage EMS demand for medical emergencies may be to focus on promoting primary-care providers (i.e. family doctors) and to allocate resources to provide additional health services (e.g. programs to consult with a health-care professional online from home).

Similarly, as vehicle accidents and emergency transfers can be potential drivers of EMS demand, overall EMS demand may be better managed if paramedic service strategies also target vehicle accident and emergency transfer-related calls. Traffic congestion has been found to increase paramedic response times (Griffin and McGwin 2013), and with the current increase in traffic due to multiple construction projects throughout Toronto, longer paramedic response times and the unavailability of paramedic services can be expected. To efficiently navigate EMS demand for vehicle accidents and emergency transfers, strategies may center around vehicle accident prevention or the allocation of more staff and resources to accident or emergency-prone regions for faster response times.

3.3 Mapping EMS Demand

By examining EMS demand through different incident types, the investigation above finds that medical emergencies are responsible for a significantly large portion of 911 calls. However, this finding is a generalization of all the forward sortation areas that Toronto Paramedic Services responded to over several years. Medical emergencies may not be the main driver of EMS demand for all communities. Thus, the following part of this analysis looks to identify the driver for every unique forward sortation area Toronto Paramedic Services have responded to in 2022. If different forward sortation areas have different drivers of EMS demand, then strategies that are tailored to each community's circumstance may be more effective in managing overall EMS demand.

Figure 4 illustrates the individual drivers of EMS demand for all forward sortation areas. From this illustration, clear differences in what propels EMS demand can be observed. For instance, in the larger forward sortation areas that surround the city of Toronto, incidents that require emergency transfers appear to be factors that raise EMS demand.

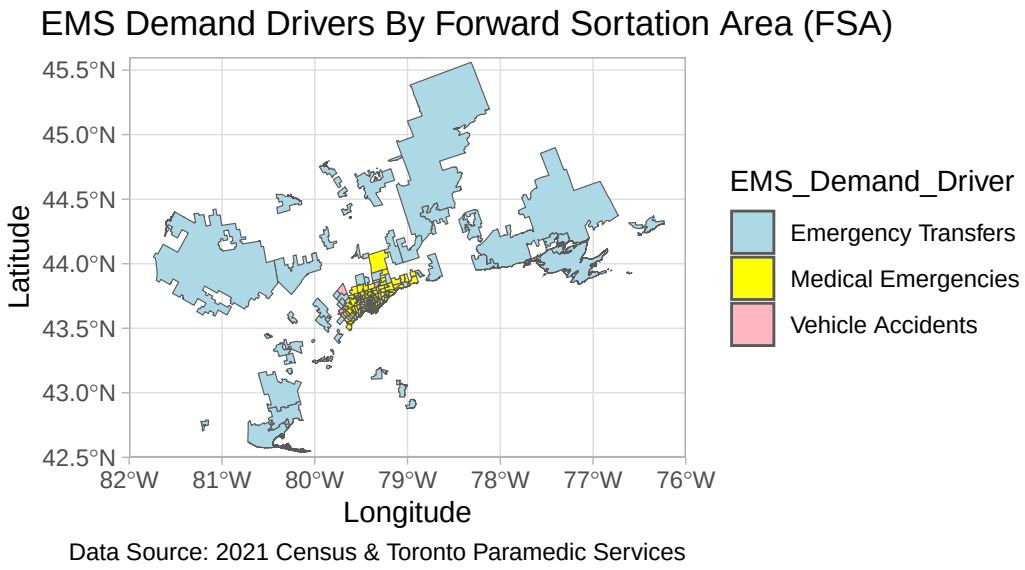

Figure 4: EMS Demand Across Forward Sortation Areas (Based on 2022 Data)

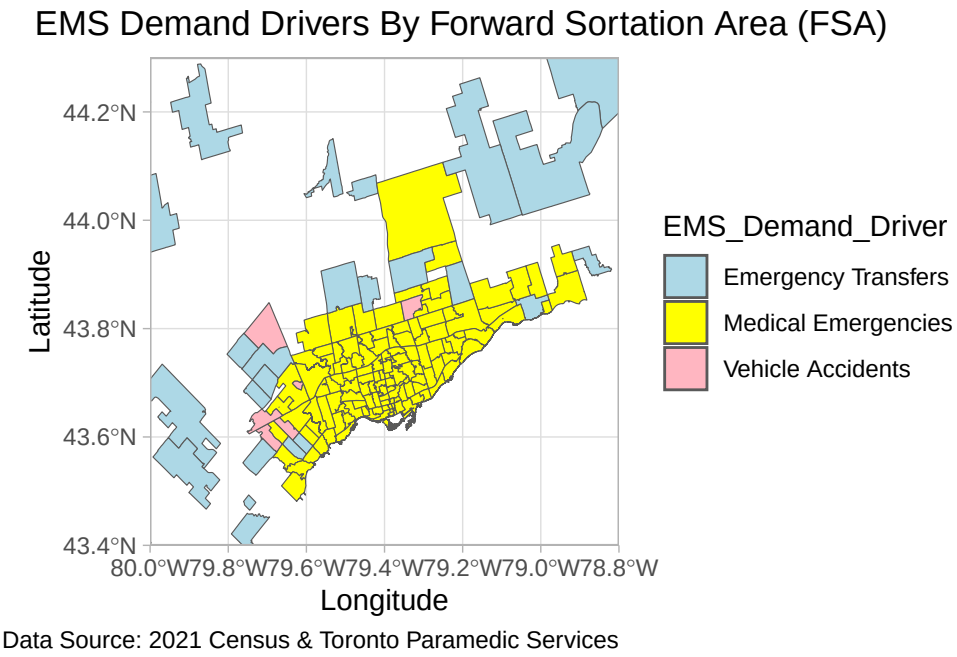

Figure 5: A Closer Look at EMS Demand Across Forward Sortation Areas

By focusing in on the city of Toronto with Figure 5, EMS demand in many communities seems to be significantly driven by medical emergencies, and there are only a few communities whose EMS demand is driven by vehicle accidents or emergency transfers.

These results support the findings from Section 3.2. Medical emergencies, emergency transfers, and vehicle accidents are shown to be relevant drivers of EMS demand. The findings further imply that what drives EMS demand is dependent on the characteristics of a particular region. Socio-economic or demographic factors such as income or population density of a given area can impact the types of incidents that occur, total number of emergency calls that are made and the severity of each incident. Given this, general, blanketing strategies that target the three main drivers of EMS demand may not be effective for all communities. Thus, there is a need to consider the characteristics of different communities to build community-based strategies that effectively address the main drivers of EMS demand.

4 Discussion

4.1 Summary

As high demand for EMS continues to be a challenge, identifying the areas where most of the demand comes from can help to inform effective demand-management strategies. Through an investigation of EMS demand, the present analysis identifies three main drivers of EMS demand (medical emergencies, incidents requiring emergency transfers, and vehicle accidents) and also considers how these drivers might differ across various communities.

To further this research, the relationship between the driver of EMS demand and socio-economic or demographic characteristics for each forward sortation area should be examined. As there are many variables that can impact one's health and ultimately, whether or not they have to seek EMS, understanding how factors like income or population density affect the occurrence of medical emergencies, emergency transfers, and vehicle accidents can allow for the formation of effective community-based strategies. It may also be helpful to consider ambulance station locations in addition to Figure 4 in Section 3.3 to see whether ambulance stations and resources are optimally distributed and if additional resources are needed based on the EMS demand driver for a particular community.

In short, the findings of this analysis offer a deeper understanding about what drives EMS demand, and this understanding can further facilitate the exploration of various strategies that allow paramedic services to effectively operate even under high demand.

4.2 Limitations

Though this analysis carefully examines EMS demand, there are some limitations to consider. It is mentioned in Section 2.2 that the records of incidents without an assigned incident type were omitted from the analysis. This may have limited the overall representation of the number of emergency calls for each incident type. Further, it is important to note that Figure 4 in Section 3.3 only considers data from 2022. So, although Figure 4 demonstrates that differences between communities and their drivers for EMS demand can exist, a better reflection of the actual drivers of EMS demand for each community may be achieved by considering multiple years of incident data (i.e. from 2017 to 2022).

A Appendix

A.1 Analysis Data Summary Statistics

Table 4: Paramedic Services Incident Data Summary Statistics

Medical Emergencies	Vehicle Accidents	Emergency Transfers	Fires	Airport Standbys	Unclassified	Total Calls
Min. :254209	Min. : 8317	Min. :6594	Min. :694.0	Min. : 4.00	Min. :536.0	Min. :270600
1st Qu.:258165	1st Qu.: 8423	1st Qu.:7091	1st Qu.:765.5	1st Qu.:13.00	1st Qu.:616.2	1st Qu.:280493
Median :270526	Median :10648	Median :7904	Median :793.0	Median :40.00	Median :628.0	Median :287416
Mean :266024	Mean :10710	Mean :7992	Mean :802.7	Mean :36.00	Mean :624.8	Mean :286190
3rd Qu.:271890	3rd Qu.:12956	3rd Qu.:9063	3rd Qu.:861.0	3rd Qu.:52.75	3rd Qu.:654.8	3rd Qu.:293986
Max. :274495	Max. :13242	Max. :9282	Max. :896.0	Max. :71.00	Max. :681.0	Max. :297349

Table 4 presents the summary statistics for each recorded incident type for the years 2017 to 2022.

A.2 Map Data

Table 5: Forward Sortation Areas Location Data

CFSAUID	DGUID	PRUID	PRNAME	LANDAREA	Geometry
K0K	2021A0011K0K	35	Ontario	5,464.2	MULTIPOLYGON (((7367258 987...
K0M	2021A0011K0M	35	Ontario	5,512.5	MULTIPOLYGON (((7286128 112...
K7L	2021A0011K7L	35	Ontario	140.8	MULTIPOLYGON (((7442037 104...

The shapefile that is used in this analysis contains the forward sortation area boundaries for every province and territory of Canada. In this file, every forward sortation area is matched with spatial information (i.e. coordinates). Table 5 illustrates this data. "CFSAUID" contains

every FSA in Canada, and "DGUID" refers to the "Dissemination Geography Unique Identifier (DGUID)" - an ID that all geographic areas in Canada have. The variables, "PRUID" and "PRNAME", represent province numbers and names, respectively. "LANDAREA" is the total area in square kilometers of each forward sortation area, and "Geometry" holds the spatial information for every area.

To isolate the forward sortation areas given in the Paramedic Services Incident Data for 2022, ArcGIS Pro software (Esri, 2024) was used to remove any areas that were not recorded. Specifically, the forward sortation areas that were not present within the Paramedic Services Incident Data were deleted from the shapefile's attribute table (i.e. data table) and re-saved as a new shapefile. After making the necessary modifications, the spatial data for forward sortation areas was merged with the data present in Table 3 and mapped to show the "EMS Demand Driver" for every area. The final map is shown in Figure 4 in Section 3.3.

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