Dynamic Deployment Models for High-Performance Emergency Medical Services

M. Bosnyak

While the emergency medical services profession has evolved substantially, the way that paramedic resources respond to these incidents has stayed relatively the same, mostly mirroring deployment models utilized by fire departments. The problem is that fire and paramedic services require two very different types of staffing. Fire departments are mainly tasked with protecting property, and therefore follow a static 24/7 deployment model due to predictable demand (PRPS, 2020a). This is not the case however with paramedic services. While fire departments focus on property, paramedics requires a greater focus on protecting people and health. Over the past decade, there has been a staggering increase in medical calls, which has overwhelmed paramedic services across Canada. During the COVID-19 pandemic, most of the world saw ambulance call volumes and response times increase by up to 50% (Amiry & Maguire, 2021), especially for life-threatening emergencies (Prezant et al, 2020). It proves the importance of keeping staffing and deployment planning current to adequately deal with these surges. With regular instances of little to no ambulances available, even on regular days, there need to be improved methods identified for better resource management. For the purposes of this study, the deployment plans at two of Ontario's largest and busiest paramedic services (referred to as Service A and Service B) were examined, to determine how different deployment models help paramedic services adapt to their call volume and remain prepared for larger-scale emergency responses.

Background of Study

Service A divides operations into four dispatch quadrants, each with 10 to 12 stations. All crews work 12-hour shifts, with shift changes occurring at 07:00 and 19:00. This creates a critical situation at shift changes where there are very limited resources to service emergency calls. Either the outgoing or incoming crews are forced into mandatory overtime, which has greatly contributed to fatigue, decreased morale, liability, and increased operational costs due to increased overtime (Edgerly, 2013). For evening shift changes, additional peak coverage can assist only if they aren't already servicing other calls. Peak coverage is extra staffing that is provided during busier times of the day, in addition to minimum 24/7 staffing. Only 9 out of 47 stations operate without this peak coverage. The remaining stations only have one ambulance each for peak coverage. As an ad hoc solution, services may rely on dispatchers to constantly reposition crews to fill these coverage gaps in real time. From an emergency management perspective, these inefficiencies drastically reduce the service's ability to provide seamless coverage to the service area.

Contrary to Service A, Service B saw an opportunity to implement a brand-new model of dynamic ambulance deployment (Elrod & Fortenberry, 2017) which was found to be more effective in dealing with the exponential growth and call volume variability that Service B was dealing with. Service B operates four districts, each containing a reporting station as its hub. This is where all paramedics report for work and where centralized functions are performed (Region of Peel, 2019). Paramedics pick up their ambulances and get deployed from here to one of several satellite stations within their division, which are smaller spaces for crews to rest in between calls and respond from shorter distances. Their smaller size makes them easier to strategically locate and build in collaboration with other municipal services for economies of scale. Shifts are also 12 hours long, but crews start and end their shifts at multiple staggered times (i.e., 5:30, 6:00, 6:30, etc.). Peak coverage shifts begin every half hour from 9:30 to 13:00, with at least one to two crews starting each half hour during this period.

These increased numbers of staggered shifts conducted by Service B provides dispatchers with more options to avoid unnecessary overtime. The centralized book-on system ensures incoming crews no longer need to wait for ending crews to return to station with their ambulance, as they can take one of many other cleaned and restocked ambulances already at the reporting station. Centralized cleaning and restocking functions are now done in bulk by specialized logistics staff prior to shift changes. Crew scheduling is also made easier with fewer locations to begin shifts. All these benefits help to ensure Service B maintains a seamless emergency response capacity throughout all shift changes and can adapt to any fluctuations in call volume.

Because ambulance demand changes based on many variables, resource management methods need to reflect this extremely variable environment. A permanent and static deployment plan cannot work well for many years without adapting to the changing environment. To maintain proper emergency preparedness, paramedic services need to be prepared for these acute changes in demand. Service A uses the traditional approach of maintaining a static model of deployment and staffing, whereas Service B seems to adapt better to this dynamic environment. This study examines how these two deployment models can help improve adequate emergency planning, resource management, and staffing levels for paramedic services.

Literature Review

Ambulance call volumes across North America have been on the rise over the past decades, due to many socioeconomic, environmental, and medical factors. Agarwal et al. (2019) cite very common indicators both on the micro and macro level. Micro-level indicators include a neighbourhood's income level, rates of poverty and food security, which are likely to lead to neglected chronic illnesses and increased substance abuse. Macro-level indicators include Canada's recent federal immigration policy changes, lack of adequate social services funding, aging populations, and increasing urban sprawl and density (Agarwal et al., 2019). Huang et al. (2001) also cite that location and time factors play a major role in determining call volume. There are strong correlations cited in relation to hour, month, season, and local area. Furthermore, urban areas had higher instances of acute medical calls, whereas suburban and rural areas saw trauma more commonly (Huang et al., 2001). Andrew et al. (2019) further cites rates of mental illness, age-related illnesses, alcohol and drug abuse, and pre-existing chronic health conditions as key indicators highly dependent on location and environment. Another major contributor is the opioid crisis occurring across Canada. Klimas et al. (2014) identify that most overdose deaths occur during daytime hours and in densely populated urban areas.

These factors have mutually contributed to increasing demand for paramedic services, at a rate commonly exceeding population growth (Andrew et al, 2019). Nationwide, we already see these effects through increasing time spent in hospitals waiting to offload patients (CUPE, 2020), increased financial expenditures, and increased repetitive system use by the same patients (Andrew et al, 2019).

The consequence of a healthcare system operating above capacity is inadequate preparedness for major emergencies. According to Ontario's Emergency Management Framework (2021), some of the key principles of emergency preparedness and response are lacking in the healthcare field. These include flexibility, risk-based decisions, and continuous improvement (Emergency Management Ontario, 2021). As paramedic services can be classified as "infrastructure that is vital to human life and safety" (OCIAPS, 2021), proper staffing must be always maintained. Further, the Emergency Management & Civil Protection Act (1990) states explicitly that annual reviews of preparedness strategies are mandatory to stay compliant.

In recent years, there has been a shift in paramedic service delivery models that further integrate into needs-based healthcare (Beck et al, 2012). The focus is not only on response but also on prevention and mitigation of chronic and low-acuity cases. This concept is known as mobile integrated healthcare (MIH) (Beck et al. 2012), which encourages community-based partnerships, continuous evidence-based improvements, increases in paramedic scope of practice, and services matching local community needs. Paramedic services that have already implemented MIH have noted many benefits, such as a 50% reduction in expenditures, transports to hospital, and paramedics' time-on-task (Feng et al, 2021). These benefits have massive potential in increasing system capacity to respond to the most life-threatening calls and emergencies faster.

For response, research has identified a need to focus on more dynamic resource allocation strategies. The traditional strategy focuses on immediate operational response through post assignments, tiered response agreements, and diversion to higher-priority calls. Real-time system status management by dispatchers is identified as the most effective short-term remedy, but only if the system is not already above capacity (Lam et al, 2016). However, there is a large gap identified with long-term strategic planning, which includes policy changes, increasing staffing/hiring, call volume analysis and building new ambulance bases based on urban growth (Lam et al, 2016). These long-term changes are needed to increase system capacity and resiliency.

An ideal dynamic deployment strategy resembles a hub-and-spoke model, which other forms of hospital-based healthcare have found to be much more effective and adaptable to changing environments. Elrod & Fortenberry (2017) recommend that the most effective organizational design involves an "anchor-type hub" that acts as a central core to several other satellite facilities in surrounding communities. Satellite facilities are best for frontline operations, whereas the hub facility provides more specialized services (Elrod & Fortenberry, 2017). Enayati et al (2018) further notes that strategic repositioning or posting of ambulance crews not only prevents unequal workloads, but also reduces travel times, unnecessary fatigue, and burnout. It also ensures that coverage losses due to call surges are made up through spreading out resources appropriately (Enayati et al, 2018).

These many different potential benefits warrant further study to determine feasibility in paramedic services. This study will aim to first examine the level of variability in call volume data for Service A, followed by how system performance compares for both Service A and Service B. To support this dynamic deployment model and concept, we will need to see improved system performance in Service B versus Service A, and high levels of variability across the different call volume demographics. The high variability would support that a dynamic deployment model is required to adapt to the community's unique needs.

Method

This study involved a longitudinal, quantitative analysis of various datasets from both the City of Toronto (2021) and Ontario's Ministry of Health (MOH). The first portion involved reviewing Toronto's ambulance call data from January 1st, 2011, to December 31st, 2020. Data was retrieved from a public archive in compliance with PHIPPA. The following was the sample selection criteria:

- Only calls within Toronto's borders were sampled. The only exceptions to this rule were the 3 busiest peripheral postal codes (L3S, L3T and L4J).
- Only incidents of a 911-call origin were counted.

Starting with the entire 10-year period, major call parameters were analyzed to identify any noticeable trends. All call data was placed into both tables and line graphs, for both visual and exponential regression analyses. A further detailed analysis was conducted for the last 5 years of ambulance call data (2016-2020). The city was geographically divided into five distinct sectors, where call volume data was re-analysed by the same factors using exponential regression analysis, to see if geographic variability exists between them. The purpose of this second detailed analysis is meant to determine and emphasize levels of variability based on the different geographic sectors within the entire service area.

The second portion of the study involved reviewing key performance indicators for both paramedic services, which include annual changes in population and density, average response times, and percentile compliance with performance standards set by each service. These datasets help identify which service is more compliant and efficient in delivery of paramedic services, while operating with different deployment models in similar urban and suburban environments.

Results

Analysis of Call Volume and Priority

CALLS BY PRIORITY										
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DELTA	80,616	84,143	85,843	90,663	93,742	96,707	102,809	109,658	110,932	100,650
CHARLIE	32,295	31,849	30,813	33,578	33,196	35,238	35,187	37,330	38,777	38,867
BRAVO	57,671	58,583	59,223	60,303	63,658	66,941	65,837	70,458	71,170	64,061
ALPHA	37,970	39,319	42,868	43,519	47,576	56,125	58,159	61,682	60,490	52,478
ECHO	4,363	4,450	4,511	4,654	4,658	5,292	6,149	6,222	6,339	6,643
Total Calls	**212,915**	**218,344**	**223,258**	**232,717**	**242,830**	**260,303**	**268,141**	**285,350**	**287,708**	**262,699**
Growth Rate from previous yr		2.55%	2.25%	4.24%	4.35%	7.20%	3.01%	6.42%	0.83%	-8.69%

Table 1: Ambulance Call Volumes by Priority Level, 2011-2020 (Toronto Paramedic Services, 2021)

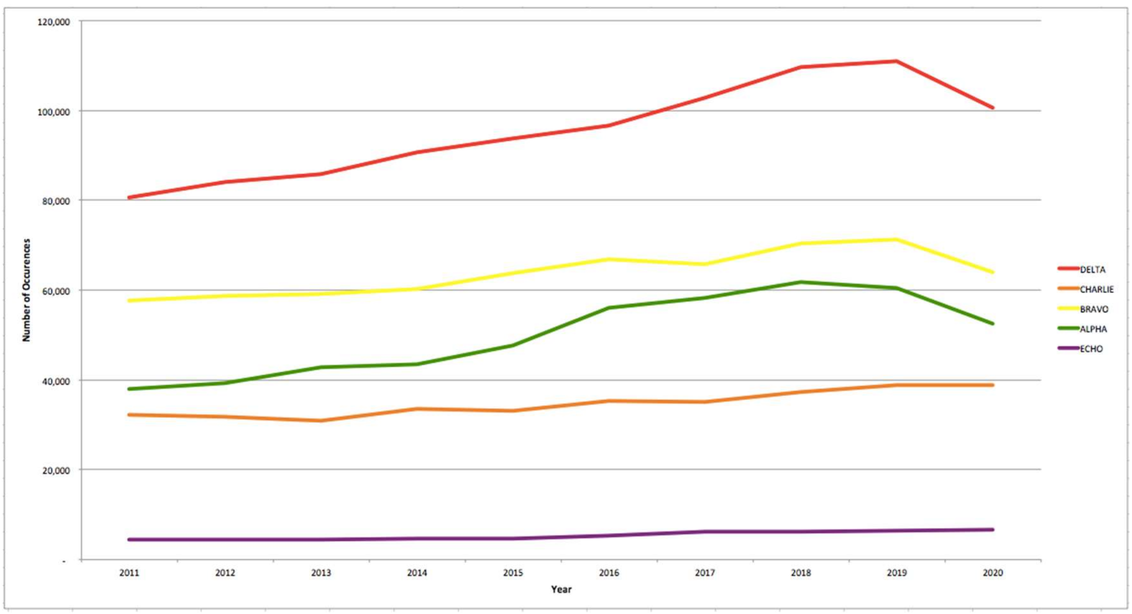

Figure 1: Ambulance Call Volumes by Priority Level, 2011-2020 (Toronto Paramedic Services, 2021)

Service A utilizes the Medical Priority Dispatch System (MPDS), which divides emergency calls into 5 categories. Alphas are the least serious and Echo's are most serious (see Table 3 and Figure 1). These call priorities are defined roughly as the following (Scott et al, 2016):

- Alpha: Basic Life Support, no lights or sirens required
- Bravo: Basic Life Support, lights and siren are optional but not required
- Charlie: Advanced Life Support, lights and siren are optional
- Delta: Advanced Life Support, lights and siren indicated
- Echo: Any closest unit + Advanced Life Support, lights and siren mandatory

From 2012 until 2019, Toronto saw a call volume increase of approx. 3.9% every year. The year 2016 saw the largest spike in call volume, at 7% higher from the year before. In 2020, there was a drop of 8.7% due to the COVID-19 pandemic. Over 10 years, Delta calls were the most common priority, with an average annual increase of 3.9%, and a 27% increase over 10 years. With the life-threatening category of calls increasing the fastest, this shows an urgent requirement to increase staffing annually to best maintain response time compliance.

Analysis of Call Volume by Postal Codes & Geographic Areas

TOP 15 POSTAL CODES YEAR BY YEAR										
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
1	M6K	M6K	M6K	M6K	M6K	M5A	M5A	M5A	M5A	M5A
2	M5A	M5A	M5A	M5A	M5A	M6K	M6K	M6K	M6K	M6K
3	M1E	M4Y	M4Y	M4Y	M1E	M1E	M4Y	M4Y	M5V	M4Y
4	M9V	M1E	M1E	M1E	M4Y	M4Y	M1E	M5V	M4Y	M1K
5	M9W	M9W	M1K	M1K	M1K	M9V	M9V	M1E	M5B	M5V
6	M6M	M9V	M9V	M9V	M2N	M5V	M1K	M5B	M1E	M1E
7	M1K	M1P	M6M	M5R	M9V	M5R	M5V	M1K	M1K	M3N
8	M1P	M2N	M1P	M6M	M5B	M9W	M9W	M9V	M9W	M9V
9	M4Y	M1K	M2N	M4C	M5R	M1K	M5R	M9W	M5R	M5R
10	M3N	M6M	M1L	M6H	M6M	M2N	M6H	M6H	M6H	M5B
11	M2N	M5R	M4C	M5B	M5V	M6H	M5B	M5R	M9V	M2N
12	M4C	M4C	M9W	M1L	M6H	M3N	M2N	M3N	M1L	M1L
13	M5R	M6H	M6H	M1P	M4C	M5B	M6M	M2N	M3N	M4C
14	M1L	M3N	M5B	M2N	M1P	M6M	M3N	M6M	M2N	M1B
15	M1J	M1L	M5R	M9W	M9W	M4C	M1L	M1L	M6M	M6M

Table 2: Top 15 Postal Codes Year-by-Year (2011-2020) (Toronto Paramedic Services, 2021) Over 10 years, only 3 postal codes remained within the top 15. Otherwise, the busiest 15 postal codes fluctuated greatly annually by up to 5 ranks. Neighborhoods that are increasing by approximately 3% every year and would benefit the most from increased surveillance and staffing include Downtown, Parkdale, Liberty Village, The Annex, Willowdale, Rexdale, Thistletown, Amesbury, Weston, West Hill, and The Danforth. This confirms that call location variability is extremely high, likely due to constant urban expansion and growth (see Table 4).

Figure 2 (see below) provides a visual representation of the data found in Table 4. The postal codes that are coloured have appeared in the top 15 rankings the greatest number of years. Yellow signifies less than half of the years studied, orange signifies between 50-75%, red signifies 75-100%, and dark red signifies that they were in the highest rankings for the entire decade examined.

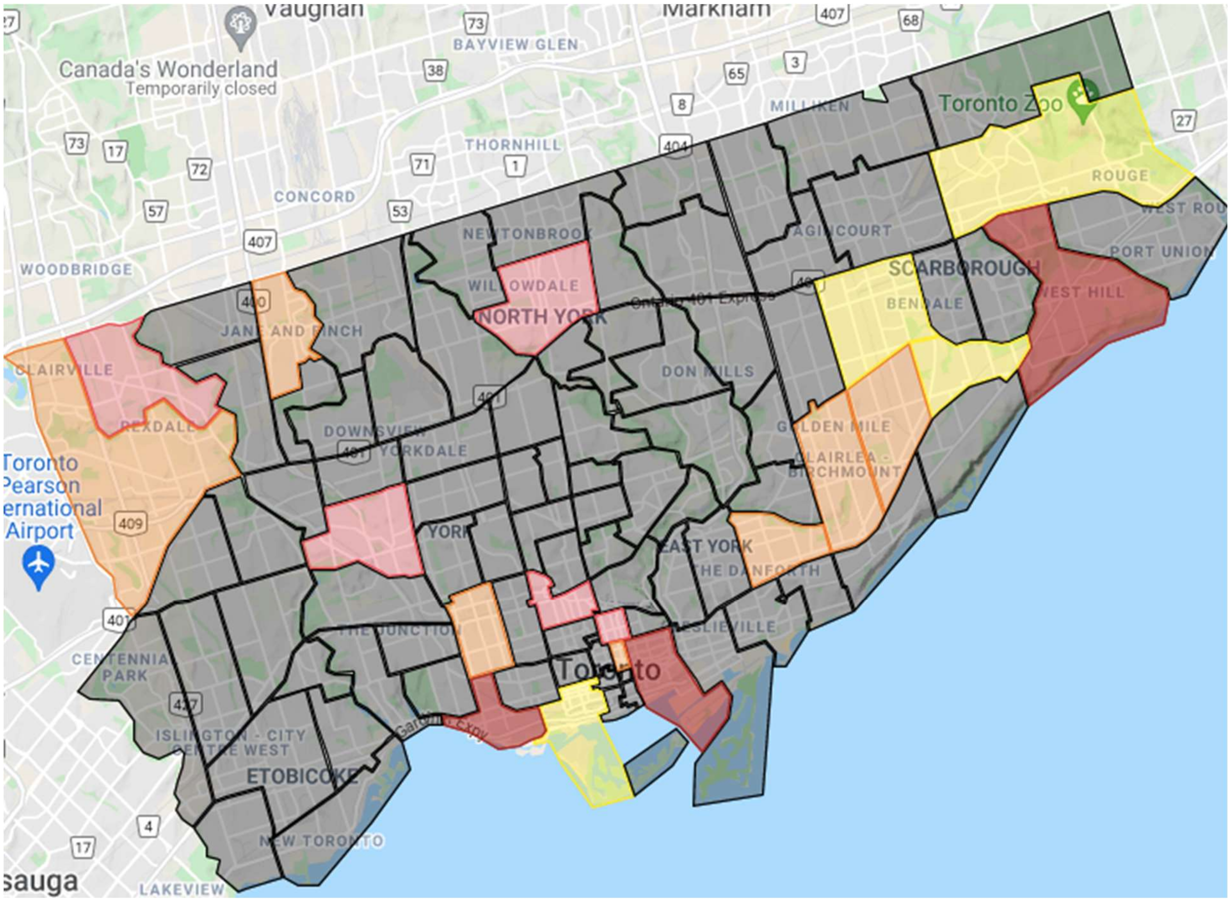

Figure 2: Map of the Busiest Postal Codes in City of Toronto (Toronto Paramedic Services, 2021)

Analysis of Call Volume by Hour, Day & Month

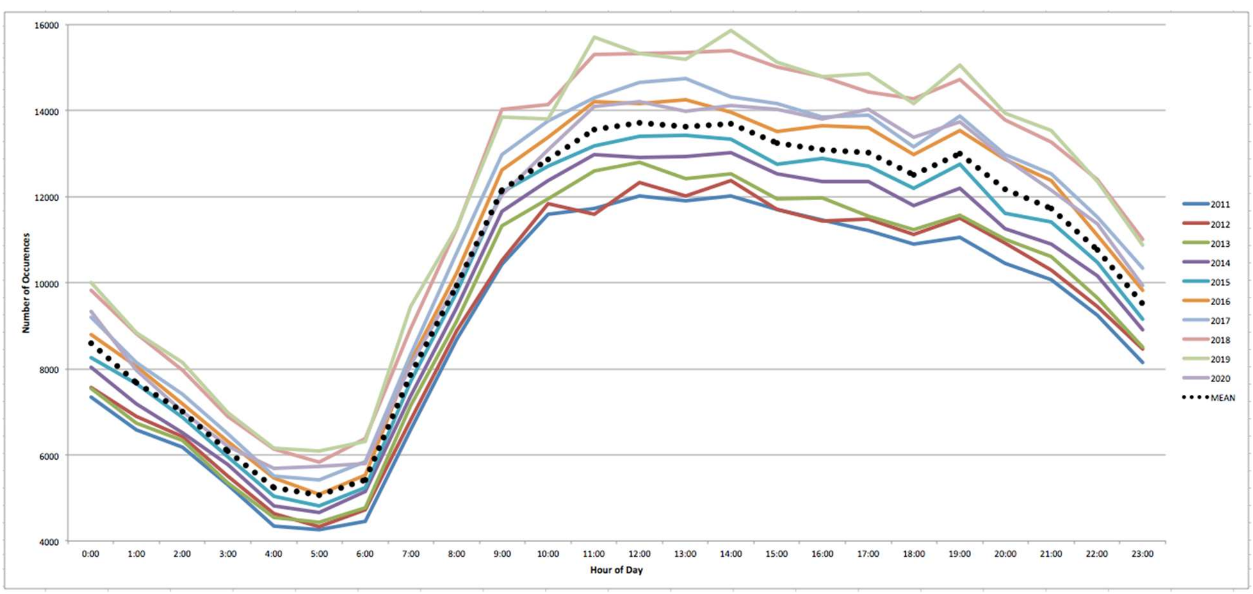

Figure 3: Ambulance Call Volume by Hour of Day (2011-2020) (Toronto Paramedic Services, 2021)

Over 10 years, strong correlations and variability were observed based on time of day. The busiest hours citywide are between 09:00 and 22:00, while the least busy are 04:00 to 06:00. There's a consistent decline in calls from 20:00 to 05:00, and then a rapid increase from 06:00 onward. A shift change at 06:00 has great potential in reducing mandatory overtime and warrants further research to see if it's more appropriate.

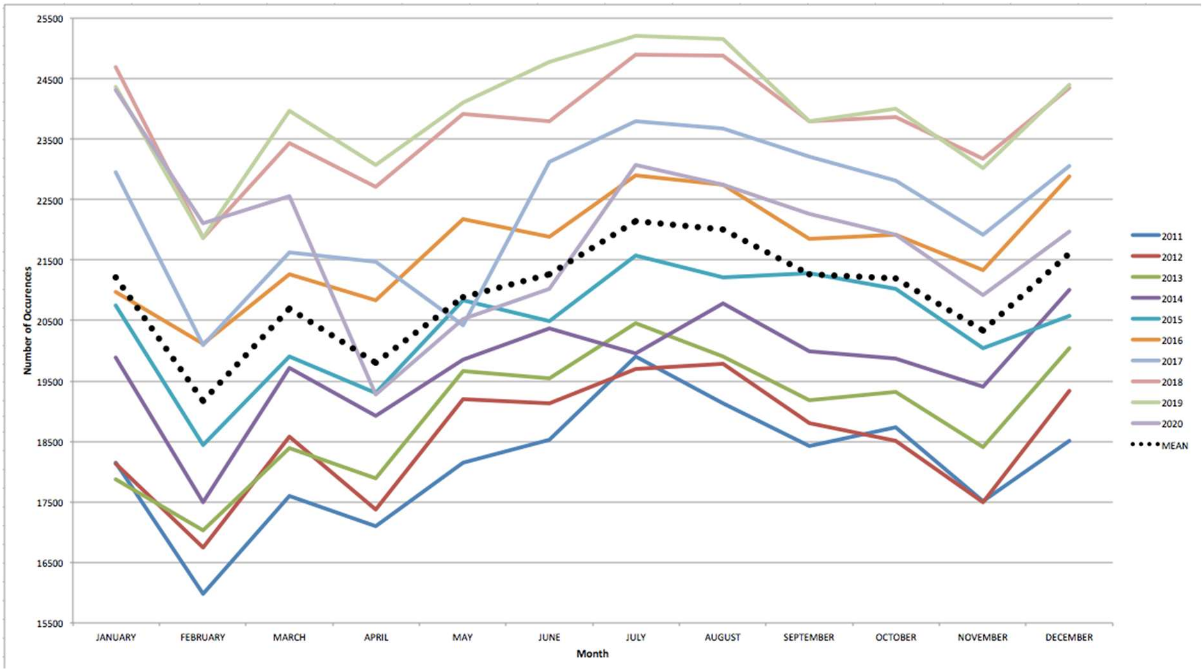

Figure 4: Ambulance Call Volume by Month (2011-2020) (Toronto Paramedic Services, 2021)

Consistent seasonal demand peaks are noted during summer months (May to September), winter holidays (December to January), and March Break. These monthly fluctuations can best be dealt with using part-time paramedic staffing and voluntary overtime.

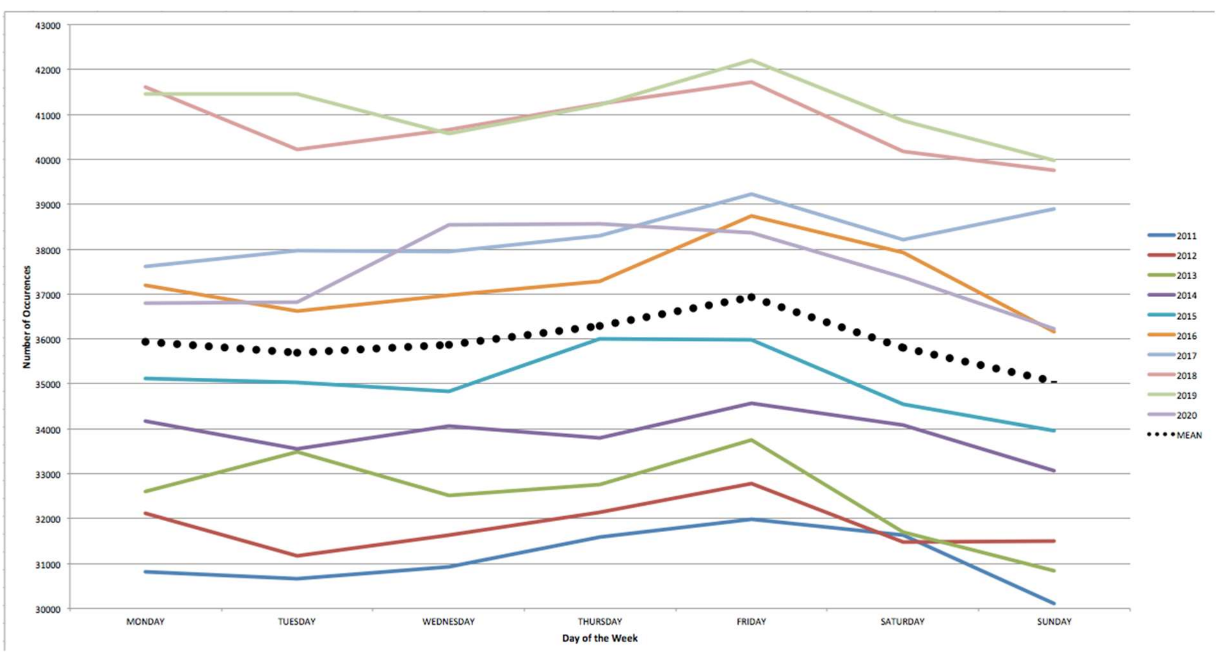

Figure 5: Ambulance Call Volume by Day of Week (2011-2020) (Toronto Paramedic Services, 2021)

Days of the week also showed very high variability. Fridays tended to be busier than other weekdays, whereas weekends showed slight reductions likely due to commuters. Weekend demand can be explained by the city's nightlife, whereas Sundays are traditionally a day of rest and hence the lowest call volume.

Detailed 5-Year Analysis by Sectors

POSTAL CODES Divided by Sector									
NORTHWEST		NORTHEAST		SOUTHWEST		SOUTHEAST		Downtown Core	
M2N	M6A	M1B	M2K	M5V	M8Z	M1J	M4L	M4T	M6G
M2P	M6B	M1C	M2L	M6C	M9A	M1K	M4M	M4V	M6J
M2R	M6C	M1E	M2M	M6E	M9B	M1L	M4S	M4W	M7A
M3H	M6L	M1G	M2N	M6G	M9C	M1M	M4T	M4X	
M3J	M6M	M1H	M2P	M6H		M1N	M4W	M4Y	
M3K	M9A	M1J	M2R	M6J		M1R	M4X	M5A	
M3L	M9B	M1K	M3A	M6K		M3A	M5A	M5B	
M3M	M9C	M1P	M3B	M6M		M3C	M5V	M5C	
M3N	M9L	M1R	M3C	M6N		M4A		M5E	
M4N	M9M	M1S	M4G	M6P		M4B		M5G	
M4P	M9N	M1T	M4N	M6R		M4C		M5H	
M4R	M9P	M1V	M4P	M6S		M4E		M5J	
M4V	M9R	M1W	M4R	M8V		M4G		M5P	
M5M	M9V	M1X	M4S	M8W		M4H		M5R	
M5N	M9W	M2H		M8X		M4J		M5S	
M5P		M2J		M8Y		M4K		M5T	

Table 4: Postal Codes Divided by Sector

5-Year Sector Analysis by Call Volume and Priority

CALL VOLUME & GROWTH BY SECTORS					
	2016	**2017**	**2018**	**2019**	**2020**
Downtown Core	51291	53468	57740	58343	50028
		4.07%	***7.40%***	***1.03%***	***-16.62%***
NE	73589	75852	80332	79123	75013
		2.98%	***5.58%***	***-1.53%***	***-5.48%***
NW	79017	80872	85461	85198	79949
		2.29%	***5.37%***	***-0.31%***	***-6.57%***
SE	68759	70317	75330	77227	73015
		2.22%	***6.65%***	***2.46%***	***-5.77%***
SW	61524	62872	66883	66727	61286
		2.14%	***6.00%***	***-0.23%***	***-8.88%***

Table 5: Call Volume & Growth Rates, Sorted by Sector

Over the past 5 years, northwest Toronto has consistently been the busiest, which may be explained by the prevalence of poverty and inequity in some of these areas. Northeast was second busiest and is also geographically the largest. Downtown has been the least busy in comparison but is also geographically the smallest. All sectors presented an average growth rate around 3% over 5 years, with the Downtown Core and Southeast growing the fastest. This growth rate variability means that paramedic staffing in each sector should be increasing by different percentages every year.

It is important to note that call volumes dropped dramatically citywide during 2020 due to the COVID-19 pandemic. Downtown saw the largest drop due to less commuters and increased remote work.

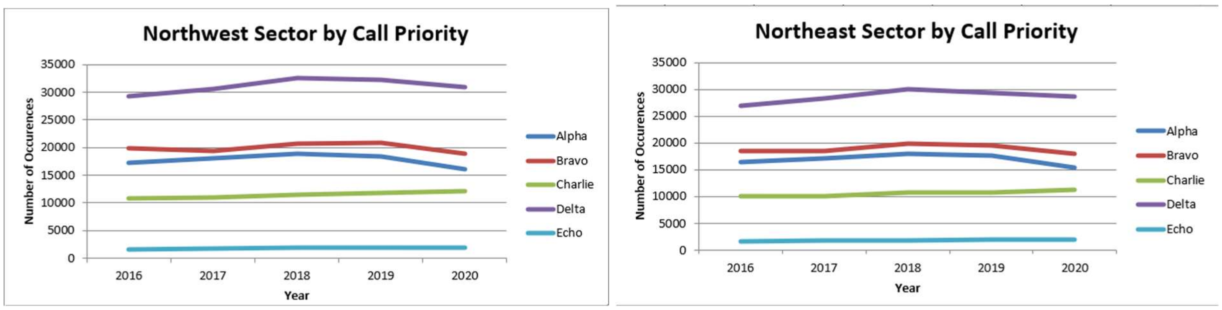

Figure 6: Northwest and Northeast Sector Analysis by Call Priority (Toronto Paramedic Services, 2021)

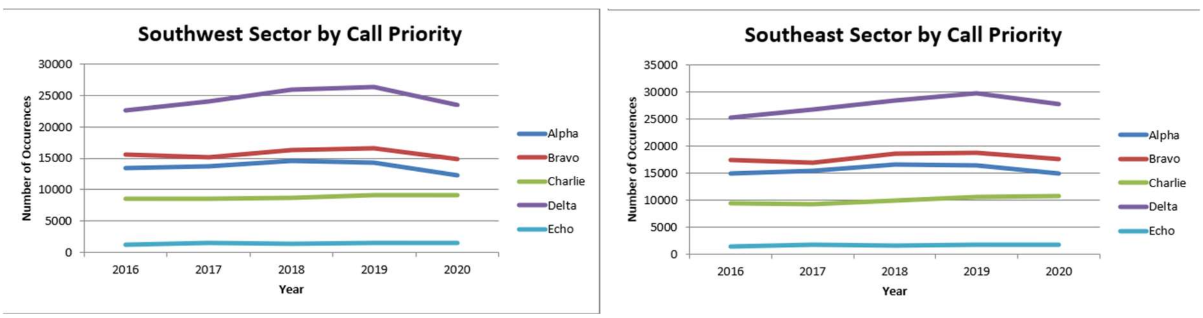

Figure 7**:** Southwest and Southeast Sector Analysis by Call Priority (Toronto Paramedic Services, 2021)

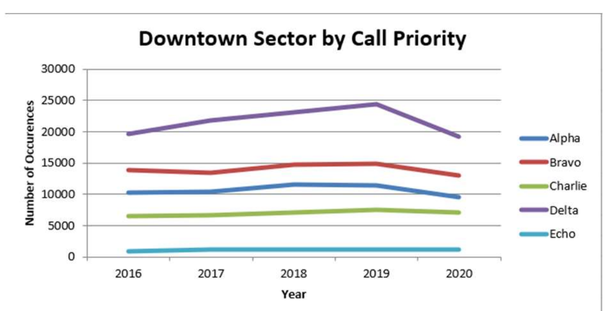

Figure 8**:** Downtown Sector Analysis by Call Priority (Toronto Paramedic Services, 2021)

There were no statistically significant differences between sectors based on call priority. One finding of note is that Downtown is responsible for a very large amount of the city's most life-threatening calls, which could be explained by increased homelessness, drug use, and mental health issues in these areas (Klimas et al, 2014). However, in all sectors, Delta remains the most common priority.

5-Year Sector Analysis by Hour of the Day

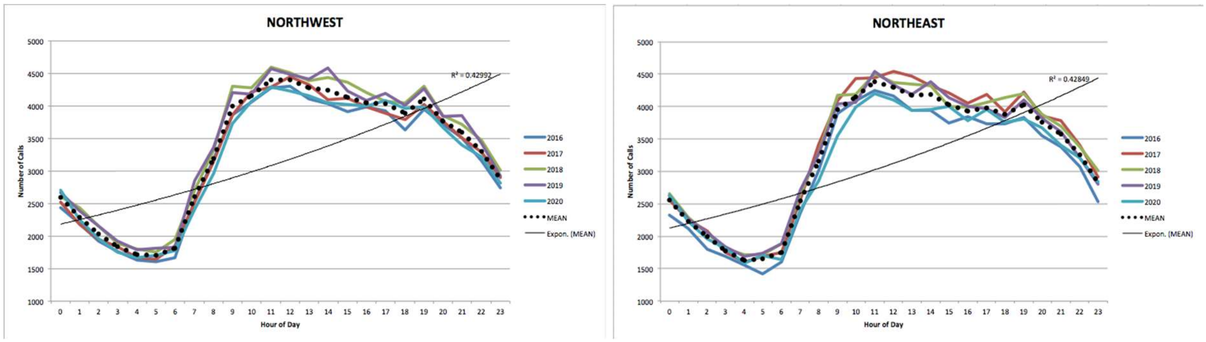

Figure 9: Northwest and Northeast Sector Analysis by Hour of the Day (Toronto Paramedic Services, 2021)

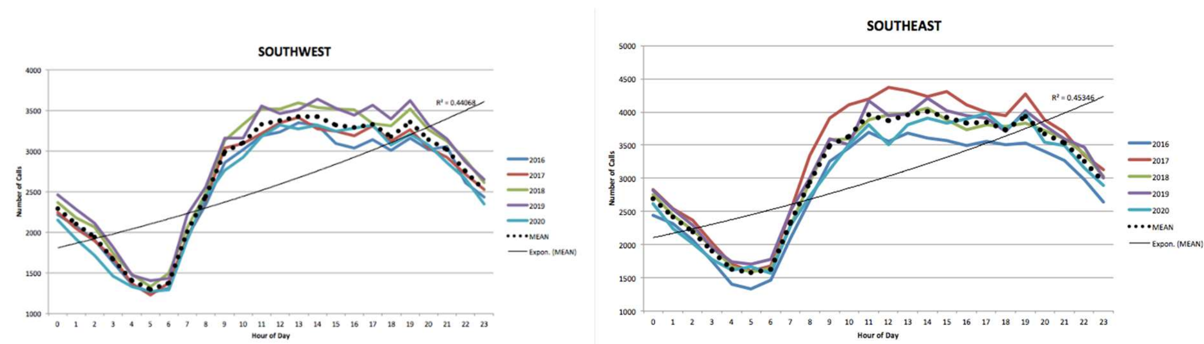

Figure 10: Southwest and Southeast Sector Analysis by Hour of the Day (Toronto Paramedic Services, 2021)

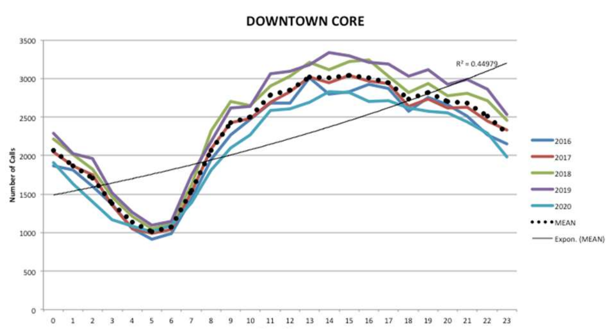

Figure 11: Downtown Core Sector Analysis by Hour of the Day (Toronto Paramedic Services, 2021)

Based on hour of the day, all sectors showed sharp increases from 06:00 onward. The suburban sectors (Northwest and Northeast) observed peak call volumes around 11:00, whereas urban sectors (Southwest, Southeast, Downtown) observed peaks later in the afternoon around 14:00. The evening decline in the suburbs tends to begin around 20:00 whereas in the urban sectors' decline doesn't begin until between 21:00 and midnight. When regression analysis was calculated, R^2 values were on average 0.44, meaning a correlation exists but with large amounts of variance.

5-Year Sector Analysis by Day of the Week

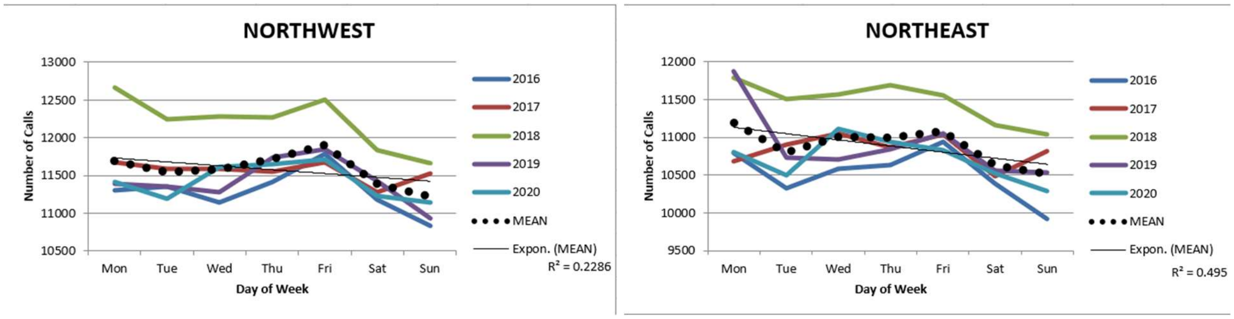

Figure 11: Northwest and Northeast Sector Analysis by Day of the Week (Toronto Paramedic Services, 2021)

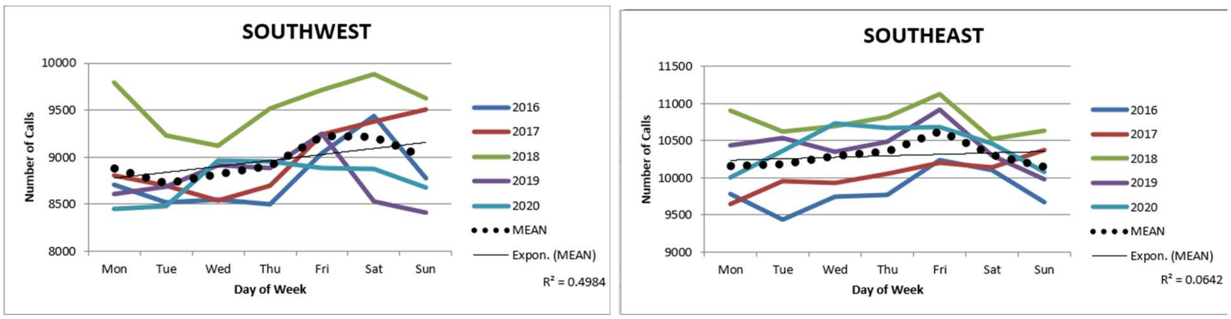

Figure 12: Southwest and Southeast Sector Analysis by Day of the Week (Toronto Paramedic Services, 2021)

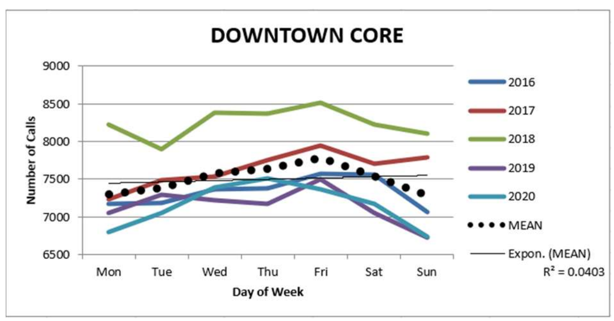

Figure 13: Downtown Sector Analysis by Day of the Week (Toronto Paramedic Services, 2021)

Suburbs observed higher call volumes during weekdays, while urban areas saw higher call volumes on Fridays and weekends instead. During regression analysis, the Northwest and Downtown sectors had R^2 values below 0.25, meaning there is a very minimal correlation. Other sectors had R^2 values of 0.5 on average, suggesting a stronger correlation. Either way, there is certainly some consideration required for day of the week when scheduling paramedic crews.

5-Year Sector Analysis by Month of the Year

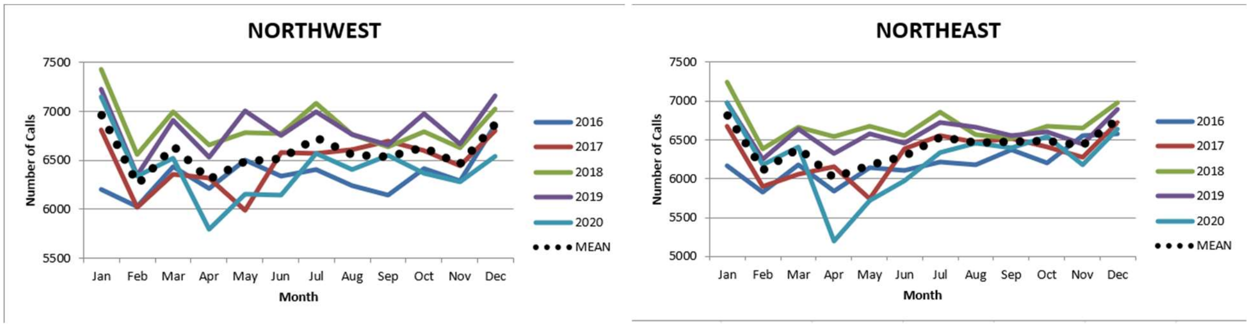

Figure 14: Northwest and Northeast Sector Analysis by Month of the Year (Toronto Paramedic Services, 2021)

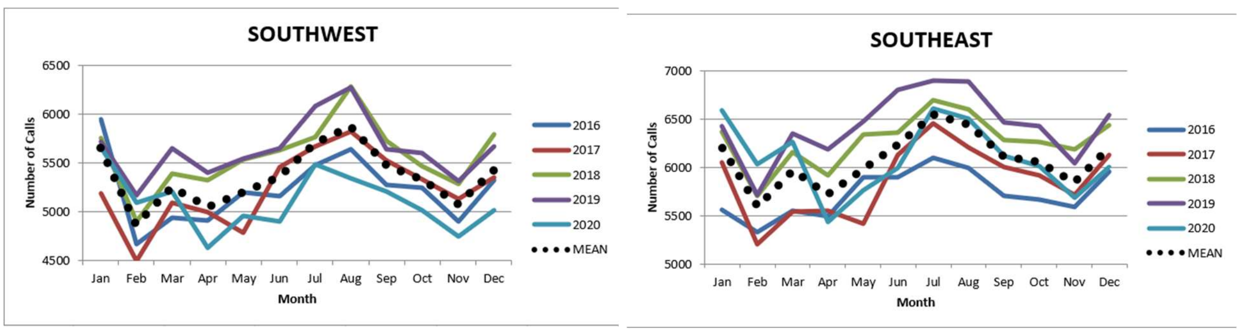

Figure 15: Southwest and Southeast Sector Analysis by Month of the Year (Toronto Paramedic Services, 2021)

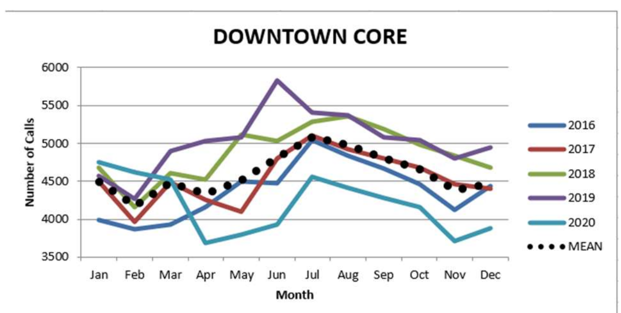

Figure 16: Downtown Sector Analysis by Month of the Year (Toronto Paramedic Services, 2021)

Sector analysis by months yielded very weak results, with all sectors displaying the same macro trends noted earlier. Difference to note include that Downtown showed a smaller peak in December, with many commuters taking vacation during this time. Suburban sectors had their busiest months in the winter (December & January), whereas urban sectors had their busiest months in the summer (July & August). These trends can help with scheduling during these known peaks in demand based on area of the city.

Land Ambulance Key Performance Indicators

Key performance indicators were analysed over 6 years (2015-2020 inclusive): population, population density, average response time, and percentile compliance based on patient condition.

	SCA (6 mins 60%)	CTAS 1 (8 mins 75%)	CTAS 2 (10 mins 75%)	CTAS 3 (15 mins 75%)	CTAS 4 (20 mins 75%)	CTAS 5 (25 mins 75%)	Population Estimate	Pop.Density (ppl/sq km)	Average Response Time
2015	88.5%	79.8%	90.7%	86.7%	93.9%	98.0%	2,827,234	4,487.7	7:20
2016	87.5%	78.9%	92.7%	87.1%	94.2%	98.1%	2,876,095	4,565.2	7:11
2017	85.5%	81.4%	88.2%	87.5%	94.0%	97.6%	2,929,886	4,649.0	7:02
2018	86.0%	82.3%	88.4%	88.3%	94.4%	98.1%	2,956,024	4,690.5	7:35
2019	85.1%	81.6%	75.7%	84.6%	92.7%	97.9%	2,956,024	4,690.5	8:01
2020	83.5%	88.3%	85.8%	87.7%	95.4%	98.5%	2,965,713	4,705.9	7:42
MEAN	**86.0%**	**82.1%**	**86.9%**	**87.0%**	**94.1%**	**98.0%**			**7:28**

Table 7: Service A – Key Performance Indicators (Ministry of Health, 2022)

	SCA (6 mins 70%)	CTAS 1 (8 mins 75%)	CTAS 2 (10 mins 90%)	CTAS 3 (13 mins 90%)	CTAS 4 (14 mins 90%)	CTAS 5 (14 mins 90%)	Population Estimate	Pop.Density (ppl/sq km)	Average Response Time
2015	77.0%	74.0%	89.0%	97.0%	97.0%	97.0%	1,438,165	1,153.3	6:53
2016	71.0%	76.0%	89.0%	97.0%	97.0%	97.0%	1,471,613	1,180.1	6:58
2017	66.0%	68.0%	84.0%	94.0%	95.0%	95.0%	1,500,633	1,203.5	7:03
2018	87.0%	70.1%	83.5%	93.7%	94.7%	93.6%	1,477,196	1,184.7	7:05
2019	72.0%	76.8%	86.6%	94.6%	95.3%	93.9%	1,477,196	1,184.7	6:42
2020	70.0%	69.2%	87.0%	95.1%	95.7%	95.8%	1,541,994	1,236.7	6:45
MEAN	**73.8%**	**72.4%**	**86.5%**	**95.2%**	**95.8%**	**95.4%**			**6:54**

Table 8: Service B – Key Performance Indicators (Ministry of Health, 2022)

Service A's area saw an increase in both population and population density of 4.6% over the period assessed, whereas Service B's area saw an increase of 6.7% at the same time. Average response time during these 6 years was 7 minutes 28 seconds for Service A and 6 minutes 54 seconds for Service B. Therefore, the service with a dynamic deployment model observed a higher population growth rate, but still maintained shorter response times on average.

Response time standards were broken down into 6 separate categories based on the Canadian Triage Acuity Scale (CTAS). For these 6 categories, each municipality sets its own standard based on a benchmark (Ambulance Act, 1990). For example, Service A aims to respond to all sudden cardiac arrest (SCA) calls within 6 minutes 60% of the time, and measures its compliance based on this benchmark. Given that both services set their own benchmarks for response time compliance, this resulted in a minimal level of bias in comparing results. For example, Service A has higher compliance for their SCA response times, but their benchmark is also set lower (see Tables 1 and 2).

On average, Service B sets their benchmarks slightly higher than Service A, however Service B shows higher overall response time compliance in almost all categories even with stricter benchmarks. The evidence is that the service with the dynamic deployment model operates more efficiently, matches their call demands better, and therefore executes more appropriate resource management practices to be more prepared for surges and other mass casualty emergency situations.

Discussion

To review, key performance indicators identified quickly that the service with the dynamic deployment model saw higher rates of population growth but still maintained shorter response times and showed higher overall compliance on average even with stricter benchmarks. We can conclude with a high degree of confidence that like the needs-based healthcare system studied by Beck et al (2012), a dynamic deployment model is better at mitigation, and matched changing demand patterns and call volumes better than the traditional model utilized by Service A.

When analyzing Toronto's call statistics to detect these same trends and variability, correlations were identified in almost all categories. Call priority data has identified a need for both more advanced life support resources and a general increase in staffing. Certain neighborhoods of concern were identified based on chronically high demand and high variance, like what was observed by Huang et al (2001).

Variability on call location is statistically high and requires frequent analyses to determine appropriate staffing increases. There is a need identified for increased peak period staffing, to meet the increased demand during daytime hours as well as staggered shift change times to match hourly changes (Lam et al, 2016). Increased staffing is also required for seasonal peaks in the summer and winter months.

When statistics were broken down by sectors, urban sectors are growing at a faster rate than suburban sectors. Percentages remain highly unpredictable, as seen in the sharp drop in demand during the COVID-19 pandemic. Suburban sectors tend to be busiest on Mondays, and from mid-morning until late evening. Meanwhile, urban sectors are busiest between Friday and Sunday, and from early afternoon until the early morning hours. Seasonal variations display highest demand during winter months in the suburbs, while summer months are busiest in the urban areas. Neighbourhoods with higher poverty rates and inequity were also identified as busiest year-round (Agarwal et al, 2019).

Regarding biases identified, the COVID-19 pandemic did skew some parameters in 2020. Secondly, Toronto's data does not publish the nature/problem of the call, and therefore left a gap in analysis where we could not determine what specific types of calls are most common based on local areas. Finally, response time statistics were difficult to compare accurately as both services set their benchmarks differently. Even with these biases identified, we can still defend the original hypothesis with a high degree of confidence that a dynamic deployment strategy, such as a hub-and-spoke model (Elrod & Fortenberry, 2017) utilized by Service B, is a more appropriate method of resource allocation for paramedic services.

Recommendations

Some key recommendations this research aims to suggest include:

- Annual paramedic staffing increases matching local call volume growth rates
- Implementation of a more dynamic deployment model, such as a hub-and-spoke model
- Mobile health integration implementation based on local demand
- Amending shift change times which may include shift changes both at 6:00 and 7:00 (hybrid model), to reduce mandatory overtime for paramedics
- Increased staffing for peak hours based on local call volume statistics
- Seasonal increases in paramedic staffing for seasonal spikes in demand
- More frequent analysis of call volume statistics to detect trends earlier and adapt appropriately.

Conclusion

The key takeaway remains that due to the highly dynamic nature of medical call volume, a well-performing paramedic service cannot sustain operations on a static deployment model. Not only does staffing need to increase on a regular basis to match the rising call volumes to maintain emergency response capacity, but furthermore certain specific areas of the city require additional staffing and resource allocation at different times based on local demand. This research intends to provide an initial framework in which paramedic services can begin to modify their deployment plans, whether it involves remaining with the traditional model like Service A, switching to a dynamic model such as Service B's hub-and-spoke, or taking aspects from each and developing a hybrid model between the two. By adapting staffing and deployment to better match demand for emergency calls, it is in the hopes that paramedic services will continue to build on their resilience and emergency preparedness capabilities for their service areas.

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