Analysis Report for Peel Regional Paramedic Services

Long Term Facilities Capital Planning

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Executive Summary

The purpose of this report is to present the analyses performed to estimate future demand for paramedic services, which inform the development of the 10-Year Capital Facility Plan (2021-2030) for Peel Regional Paramedics Services (PRPS).

Two key drivers of system demand, population growth and population age, are studied to show how and where the population is expected to grow over time. Historical and future trends demonstrate that the Region has grown by 19.2 per cent from 2006 to 2016 and is expected to continue to grow by 35.5 per cent by 2036. Growth in population is uneven across the municipalities within Peel; Caledon is anticipated to double in total population and employment, but Mississauga and Brampton still have higher overall totals. Population and employment are further studied by space, with Brampton and Mississauga downtown cores and the north east and west corners of Brampton anticipated to experience the highest growth. When examining the population by age and sex, the senior population (those aged 65 and over) is anticipated to grow by seven per cent by 2036. With a growing and aging population, it is expected that future call demand will increase.

Demand, as measured by call volume, is examined to illustrate past trends, confirm key drivers, and determine the impacts on service delivery. On average, call volumes have increased by 5.2 per cent per year over the last 15 years. Areas in Peel with the highest growth in call volumes are found in the downtown cores of Mississauga and Brampton. User characteristics, specifically age and sex, were examined to identify the age groups that tend to use PRPS more frequently; those aged 50 and over were the heaviest users (57.8 per cent of users in 2019). With growing call volume and changing client demographic over the last 15 years, total service delivery time almost doubled during this period, demonstrating increasing pressure on paramedic services.

Future demand and estimates of paramedic resources needed over time are also predicted. These predictions are based on prior call volume trends and consider the two main drivers of call volume, population growth and aging. The predictive analyses show that call volumes are expected to almost double by 2036 and call volume density is expected to further intensify in the downtown city cores of Mississauga, Brampton and Caledon (i.e., Bolton) by 2036. Apart from the downtown city cores, the areas with the highest anticipated growth in call volume density by 2036 are found in the north west corners of Brampton and Mississauga. It is predicted that PRPS will require 111 more ambulances by 2036 to meet future call demand (increase of 82.8 per cent). Given the predicted number of ambulances needed, three new reporting stations and five new satellite stations will be required and strategically situated around the areas expected to experience the highest growth in demand by 2036.

Given the predicted increase in demand and service pressures, process improvements and system efficiencies should continue to be considered and implemented to mitigate the burden on paramedic services.

Introduction

This Report is intended to illustrate the findings of several descriptive and predictive analyses conducted to support the development of the next 10-Year Capital Facility Plan (2021-2030) for PRPS.

The First Chapter focuses on the key drivers of paramedic service call volumes. Paramedic service demands and system pressures are examined further in Chapter 2 to describe changing user demographics over time and visualize how and where demand has changed in the Region of Peel. Historical demand trends and analyses of user characteristics confirms the key drivers selected to study Paramedic Service demand and sets the stage to develop future predictions.

Prediction models are described in detail in Chapter 3 to demonstrate the expected trends in call volume demand up to 2041. Based on these predictions, the number of resources needed, in the form of ambulances, reporting and satellite stations, are quantified over the next 15 years.

Chapter 4 discusses past and current process improvement programs and initiatives that have either been implemented by PRPS or the health system to enhance paramedic service delivery. Potential initiatives are recommended to continue enhancing processes, while managing the anticipated future demand.

Finally, Chapter 5 summarizes the main findings, and offers caveats and other important information for appropriately interpreting the demand and resource projections.

Chapter 1: Drivers of paramedic service call volume

When planning and considering capital needs for PRPS, it is essential to have an understanding of what drives paramedic service call volumes; key drivers include population growth and population age.[1] The following will summarize these drivers in the context of the Region of Peel, as well as describe other drivers.

1.1. Population growth
- **1.1.1. Forecasted trends in population, residential and commercial units, and employment**
- **1.1.2. Forecasted trends in population and employment by geographic area**

1.2. Population age
1.3. Other

1.1. Population growth

Population growth is a key driver of paramedic service call volume. The Region of Peel's population has grown by 19.2 per cent between 2006 to 2016 and is expected to continue to grow in the future. Each of the three municipalities that make up Peel experienced population growth at varied levels. Brampton experienced the most growth in overall population, an increase of 36.8 per cent, followed by Caledon at 16.6 per cent and Mississauga at 7.9 per cent. See Table 1 for an overview of the total and per cent change in population for Peel's municipalities between 2006 and 2016. The table also includes land area and population density for each municipality.

Table 1. Total and per cent change of population, land area, and population density per Municipality and Region, 2006 and 2016[2]

Land Feature	Caledon			Brampton			Mississauga			Peel		
	2006	2016	%Δ	2006	2016	%Δ	2006	2016	%Δ	2006	2016	%Δ
Population	57,050	66,502	16.6%	433,806	593,638	36.8%	668,549	721,599	7.9%	1,159,405	1,381,739	19.2%
Land area (km²)	687.2	688.2	0.1%	266.7	266.4	- 0.1%	288.5	292.4	1.3%	1,242.4	1,247.0	0.4%
Population density per km²	83.0	96.6	16.4%	1,626.5	2,228.7	37.0%	2,317.1	2,467.6	6.5%	933.2	1,108.1	18.7%

Note: Numbers rounded to the nearest tenth. Population totals represent the unadjusted totals archived for census years 2006 and 2016; totals are not adjusted to include the census undercounts (number of residents not recorded in the census) for both years (4.9 per cent and 3.3 per cent in 2006 and 2016, respectively). Land area changes between 2006 and 2016 are a result of restructuring processes for municipal boundary realignment (e.g., Ninth Line Lands transferred from Halton to Peel in 2010).

With the increasing growth in population across Peel, further analyses were conducted to develop a deeper understanding of the population's characteristics.

1.1.1. Forecasted trends in population, residential and commercial units, and employment

Calls for paramedic services are made by people, whether from their residence or from their place of employment, as such, both residential and employment populations were studied. Furthermore, another measure was created by combining the number of commercial units (derived from the number of commercial permits) with the number of residential unit forecasts to capture total potential locations from which calls may originate. This combined measure is important as there are several areas within Peel that are primarily residential or commercial, or a mixture of both, see Map 1 for general land use within Peel. Knowledge of how and where these populations, and respective residential and commercial units, are expected to change over time will support the identification of areas of future demand for paramedic services.

Population, residential and commercial unit, and employment forecasts[3] from 2016 to 2036 were analyzed at the regional and municipal levels to determine respective areas of change. The analysis demonstrates that the Region is projected to experience over 30 per cent growth in all three domains over the next 20 years. At the municipal-level, Caledon is projected to experience the greatest growth rate by 2036 with a population increase of 71,538 people or 107.6 per cent. By comparison, the population increases in Brampton and Mississauga are much greater (260,522 and 158,841, respectively) over the same time period but at lower percentage increases of 43.9 per cent for Brampton and 22.0 per cent for Mississauga. This general trend is also apparent for both residential and commercial units and total employment, where Caledon can expect the highest per cent change followed by Brampton and Mississauga, while still having the lowest number of residential and commercial units and total employment.

Overall, Mississauga has greater population, residential and commercial unit, and employment totals in comparison to Brampton and Caledon, while Caledon is anticipated to experience the highest per cent growth in all three domains. The differences in totals and growth per sector may lead to differing paramedic service usage or demand patterns across the three municipalities.

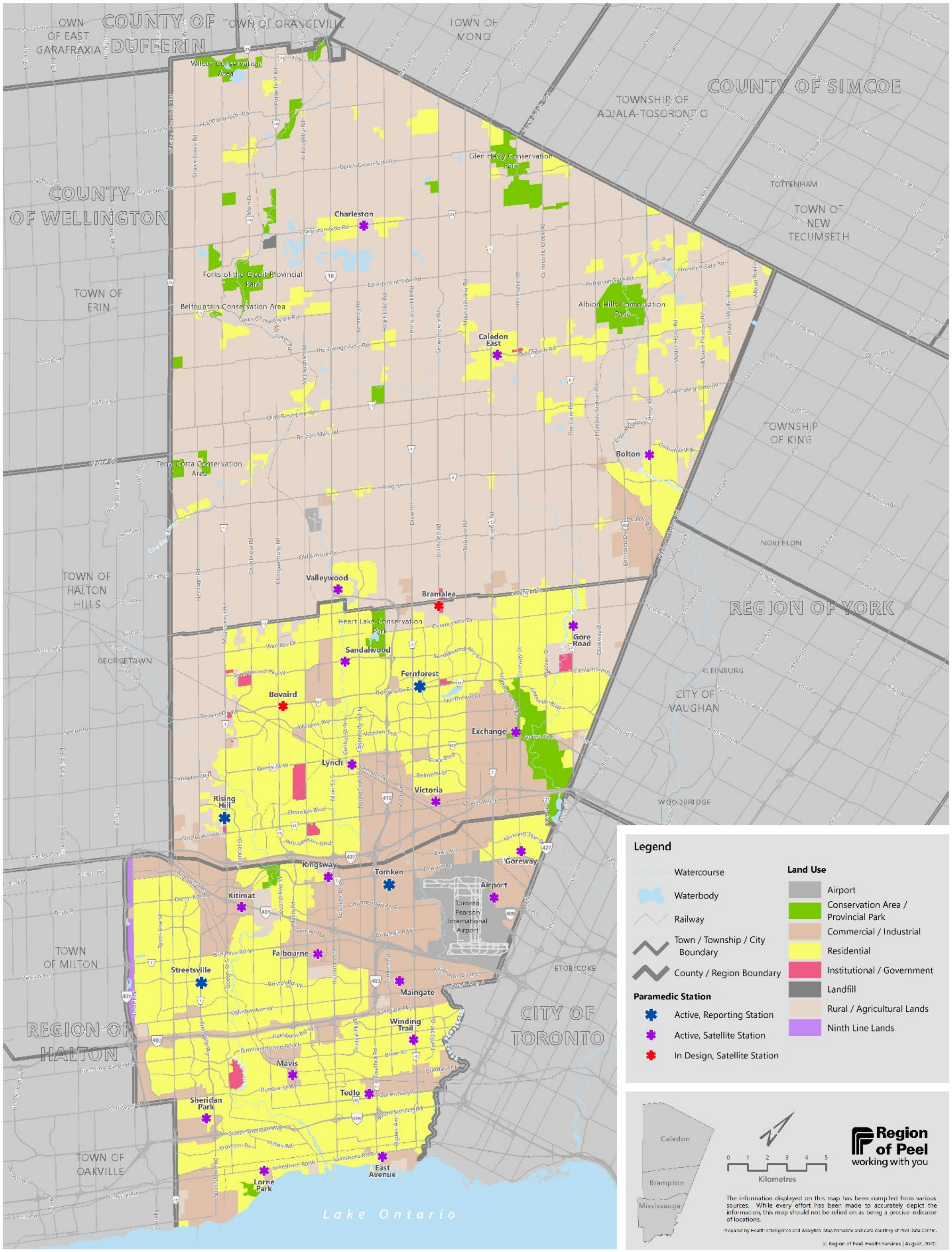
Table 2. Future growth in population, residential and commercial units, and employment per Municipality and Region, 2016 and 2036

Municipality/ Region	Total Population			Total Residential[4] and Commercial[5] Units			Total Employment[6]		
	2016[7]	2036[8]	Δ (%)	2016	2036	Δ (%)	2016	2036	Δ (%)
Brampton	593,638	854,160	260,522 (43.9%)	174,964	246,604	71,640 (40.9%)	191,330	303,880	112,550 (58.8%)
Caledon	66,502	138,040	71,538 (107.6%)	22,096	44,726	22,630 (102.4%)	26,820	62,980	36,160 (134.8%)
Mississauga	721,599	880,440	158,841 (22.0%)	242,733	298,463	55,730 (23.0%)	476,790	547,560	70,770 (14.8%)
Peel	**1,381,739**	**1,872,640**	**490,901 (35.5%)**	**439,828**	**589,828**	**150,000 (34.1%)**	**694,940**	**914,420**	**219,480 (31.6%)**

*Note: Forecasts of total residential population by census year to the 2036 planning horizon, calculated with the census undercount included (2016 undercount rate = 3.3 per cent). Residential units represent all types of housing, such as single-detached, semi-detached, row houses, and apartments. Number of commercial units is a measure of the total number of building permits for commercial purposes, provided by Peel Data Centre. Total employment is the number of people who work in Peel but may or may not live in Peel. It is the total employment with “place of work status” in Peel, which is defined by the 2016 census as including home-based employment or worked at a specific address (usual place of work) in Peel.

Appendix I

Paramedic Services Long Term Facilities Capital Plan, Key Supporting Analyses



Map 1. General land use within Peel, 2019

1.1.2. Forecasted trends in population and employment by geographic area

Population and employment forecasts[9] were also examined spatially by Secondary Plan (SP) areas within Peel. SP areas are administrative boundaries used in Official Plans by each municipality, corresponding to specific areas such as new communities, employment areas, older neighbourhoods, downtown/core areas, rural settlements and rural service centres.

As shown in Table 2, the population of Peel is expected to grow 35.5 per cent by 2036. Mapping the absolute change in total population and employment between 2016 and 2036 at the SP level reveals areas with the most growth during this period. Consequently, we may expect that SP areas with higher total population and employment may have a higher demand for paramedic services.

Map 2 shows the absolute population change between 2016 and 2036 at the SP level within Peel. Most of the population growth is projected to occur along the outskirts of the major city centres of Brampton and Mississauga, with pockets of moderate to high growth around Palgrave Estates, Caledon East and Bolton in Caledon. The downtown city cores of Mississauga (area around Square One, Hurontario Street and Rathburn Road) and Brampton (Queen and Main Street corridor) are forecasted to grow in population. According to current Caledon SP plans, population growth is designated in undeveloped greenfield areas located around the smaller rural settlements, specifically Mayfield West, Caledon East and Bolton; the anticipated growth around these smaller rural settlements and towns in Caledon amounts to over 10,000 residents by 2036. Conversely, Brampton and Mississauga have intensification targets for the redevelopment of existing lands with medium and higher-density land uses (e.g., apartments) within central urban areas.[10]

Map 3 shows the absolute change in the employment between 2016 and 2036 at the SP level within Peel. The areas with high growth in employment include Brampton downtown core (Queen and Main Street corridor) and Mississauga downtown core (Square One area), Tullamore, Huttonville North, Coleraine (north east corner of Brampton), Meadowvale and areas south of Toronto Pearson International Airport and along Hurontario Street between Kingsway and Falbourne satellite stations. Some other areas of more moderate growth include Bolton, Mayfield West, Mount Pleasant, Castlemore, Ebenezer and Churchville.

When comparing Maps 2 and 3, there are certain areas with expected growth in both total population and employment or growth in only one domain between 2016 and 2036. Brampton and Mississauga downtown city cores and the north east and west corners in Brampton (Huttonville, Mount Pleasant and Coleraine) are anticipated to experience increases in total population and employment. By contrast, the areas with growth only in employment include Tullamore, areas around Toronto Pearson International Airport, Meadowvale and south west corner of Mississauga (Southdown area). These trends reflect the mixed landscape of Peel, where Caledon is a highly rural area with dispersed populations in hamlets/towns and a condensed population in the city of Bolton, while Brampton and Mississauga contain certain areas that are primarily residential or commercial/industrial, or a mixture of both.

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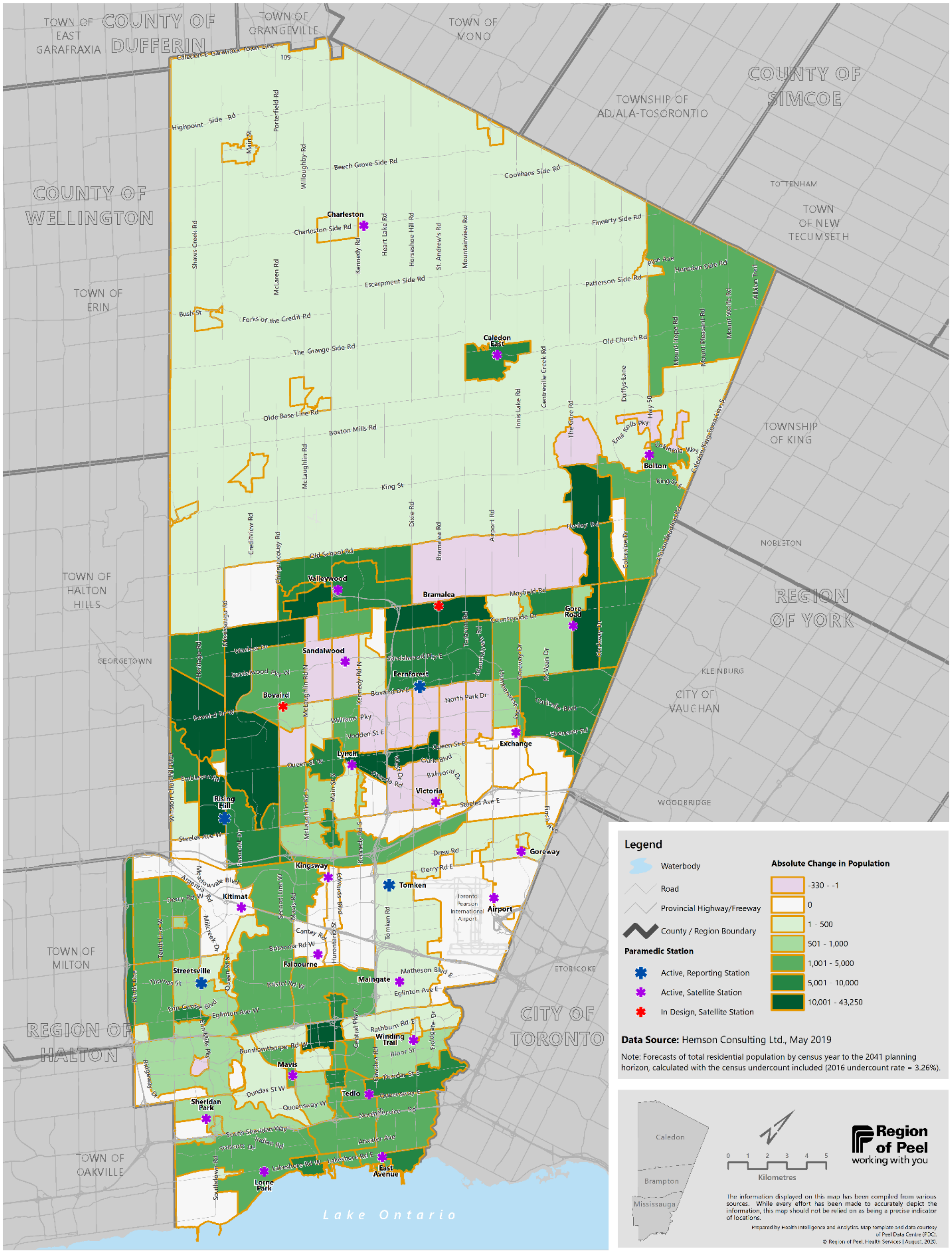

Map 2. Total forecasted population change by SP areas, 2016 and 2036

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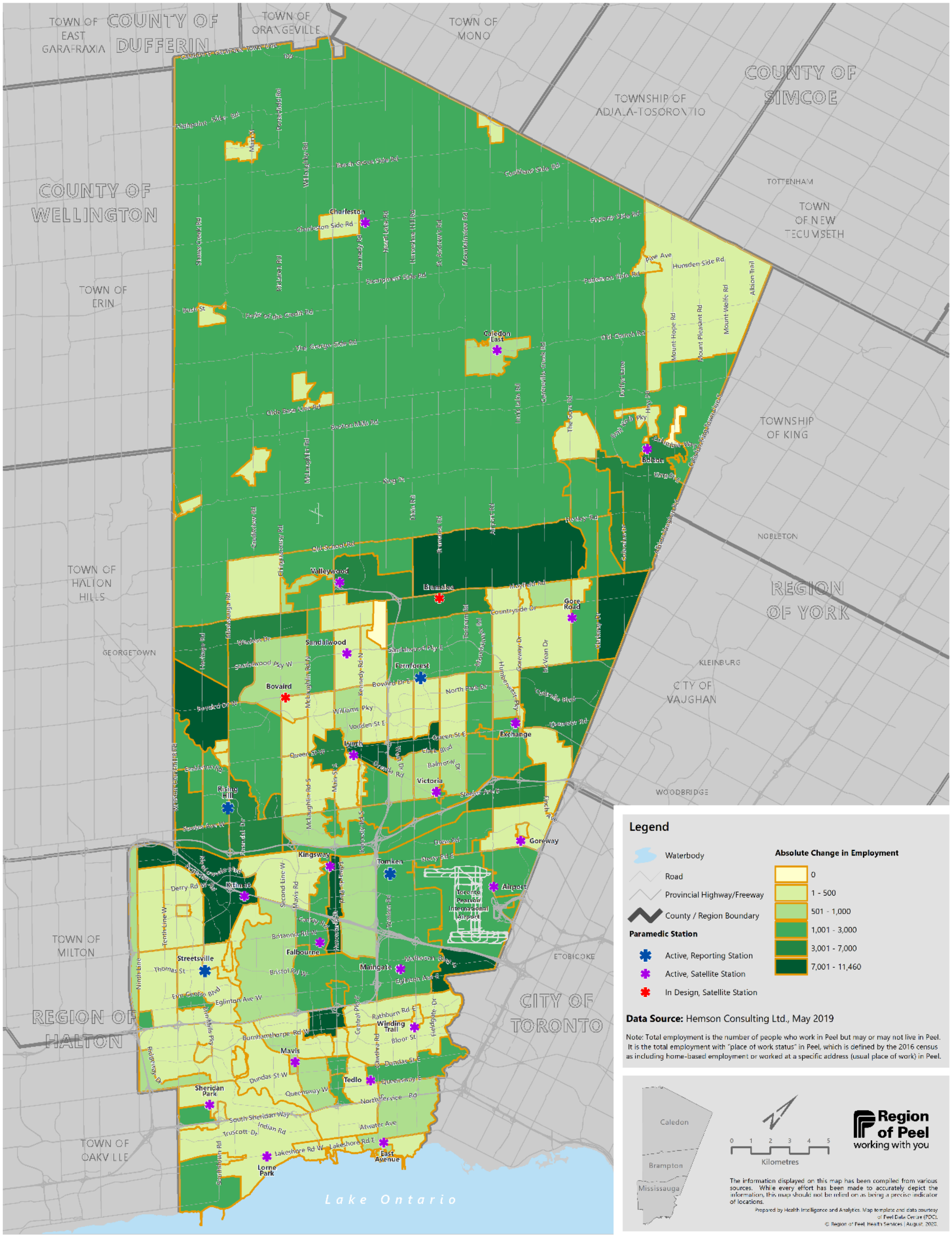

Map 3. Total forecasted employment change by SP areas, 2016 and 2036

1.2. Population age

The population forecasts[11] were further subdivided by age and sex, comparing 2016 and 2036, see Figure 1. This information is important as certain population subgroups have different health care needs and access resources differently. Knowledge of which population subgroups are anticipated to experience the greatest change over time will inform future health care planning and care provision needs.

The comparative analyses of the population by age and sex distribution in 2016 and 2036 indicate that the population of seniors (aged 65 years and over), both males and females, is projected to increase by seven per cent by 2036. Conversely, the proportion of the population under 64 years of age, both males and females, is anticipated to decrease by seven per cent, with an average decline of 0.5 per cent by age group and sex. The forecasted shifts in the population will have impacts on the way health care resources are accessed and used, including paramedic services.[12,13] The anticipated growth in the senior population may potentially increase the complexity of calls and affect how pre-hospital care is administered by paramedics.

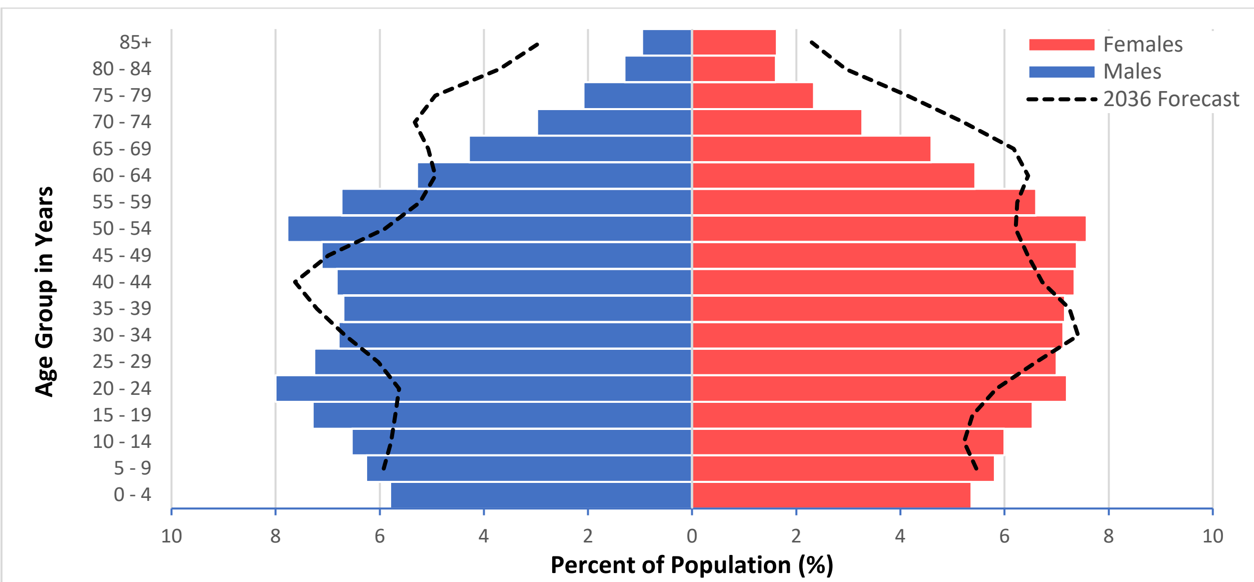

Figure 1. Population distribution by age group and sex, Peel, 2016 and 2036

1.3. Other drivers

Other drivers of paramedic service use include client health status, availability of social supports, costs associated with ambulance transport, reduced access to primary care supports, and knowledge and use of health services and conditions.[14] These potential drivers were excluded from the predictive analyses as they are difficult to measure and quantify or there are data limitations and/or lack of data availability.

Chapter 2: Demand Trends and Service Pressures

In this study, *demand* for paramedic services is measured by call volume. As the call volume has increased over time, there is added demand on the existing system and a resulting pressure on paramedic resources available to meet those demands. These demands and the pressures will be further studied to understand their effects on the service over time.

- **2.1 Call volume trends:**
  - **2.1.1 Overall**
  - **2.1.2 Geographic area**
    - **2.1.2.1 Current spatial distribution of calls**
    - **2.1.2.2 Spatial distribution of calls over time**
    - **2.1.2.3 Areas with the highest growth**
- **2.2 PRPS clients**
  - **2.2.1 Age and sex distribution over time**
  - **2.2.2 Call volume trends by age**
- **2.3 Service delivery trends**

2.1. Call volume trends

2.1.1. Overall

Over the last 15 years, paramedic service call volume has grown from 67,956 calls in 2005 to 137,741 calls in 2019, an increase of 69,785 calls or 102.7 per cent. See Figure 2 for annual call volumes from 2005 to 2019. A closer examination of call volume over this period shows that the year-over-year growth in calls has fluctuated, being on average 5.2 per cent. Figure 3 shows the annual per cent change during the same period. This preliminary analysis of call volumes shows that the number of calls has been steadily increasing over time and is expected to climb as the population continues to grow and age.

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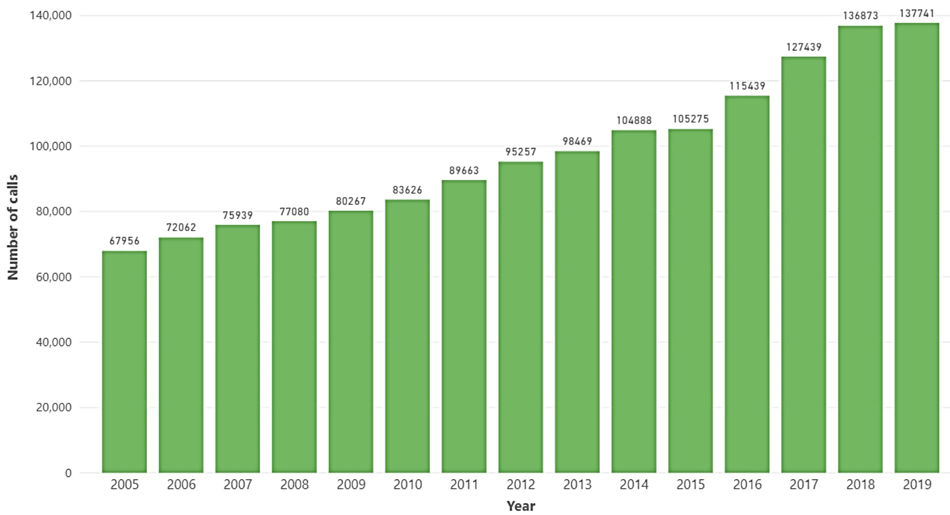

Figure 2. Call volume over time, 2005 to 2019

While call volume growth rates have increased each year (as seen in Figure 3), the smallest increase was seen in 2015 (0.4 per cent increase from previous year). The period between 2016 and 2018 has seen the highest increase, with an average annual increase of 9.1 per cent. However, this increase slowed down in 2019 with only a 0.6 per cent increase from 2018, which is slightly higher than the years with the lowest rate of growth.

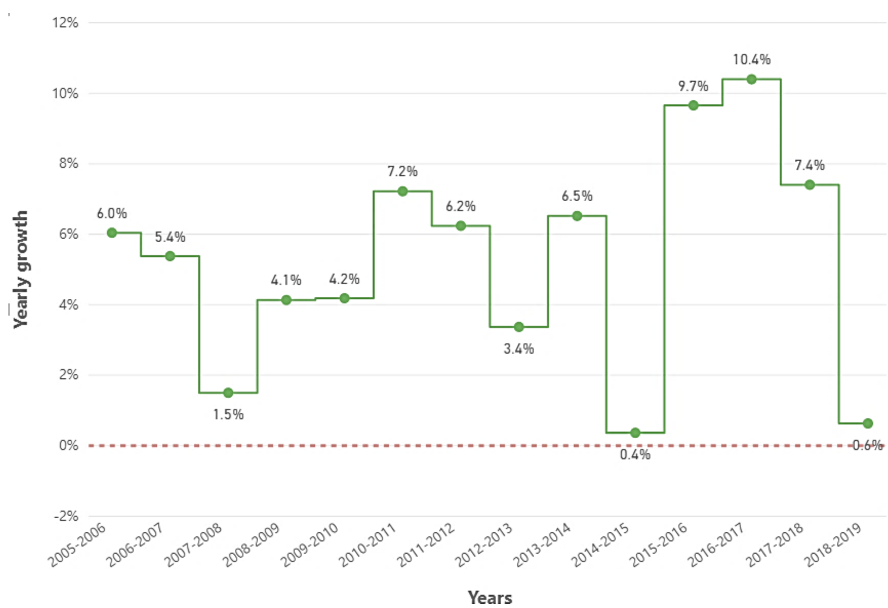

Figure 3. Annual call volume growth, 2005 to 2019

2.1.2. Geographic area

2.1.2.1. Current spatial distribution of calls

Call volumes in 2019 were investigated by their spatial distribution (see Map 4); this type of analysis allows the identification of areas (UTM grid cells) with the highest call volumes, representing higher demand for paramedic services. Areas are colour coded, with darker tones representing higher call volume areas.

Map 4 shows that higher call volumes are found in the main and smaller city centers of Brampton and Mississauga. Brampton and Mississauga city center cores (Main Street and Queen Street corridor in Brampton and Square One area extending south to Queensway in Mississauga) have the highest call volumes. Areas with moderate call volumes in Brampton are found near Churchville, Mount Pleasant, Snelgrove, Avondale, and Bramalea. Mississauga has areas with moderate to high call volumes in Milton, Meadowvale, Erin Mills, Port Credit, Toronto Pearson International Airport, and areas north of Clarkson and Dixie. By contrast, Caledon has lower call volumes, with Bolton being the only area with moderate call volume.

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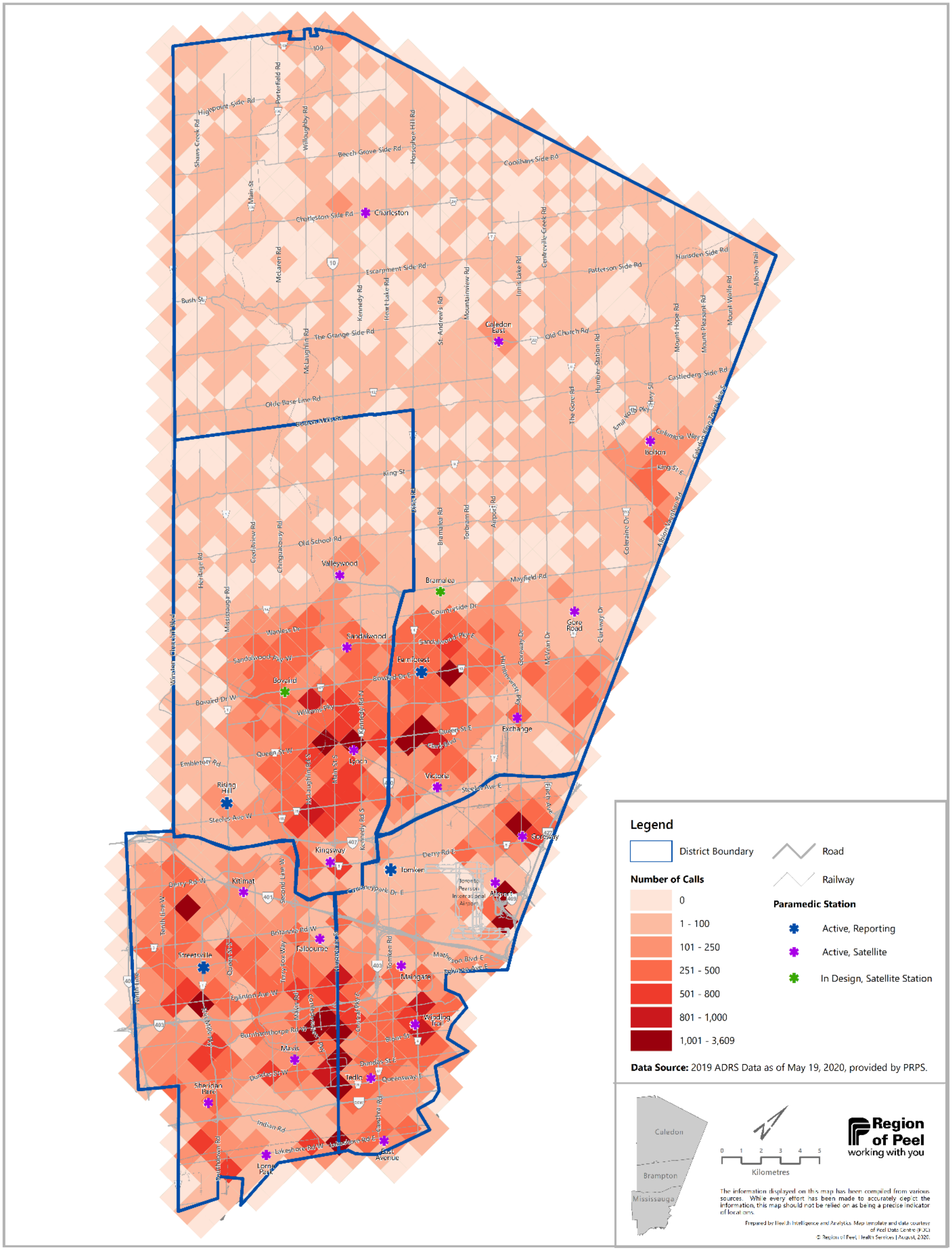

Map 4. Spatial distribution of calls by UTM grid cells in 2019

Note: Only calls with valid coordinates were included (representing 99.9 per cent of total calls for 2019)

2.1.2.2. Spatial distribution of calls over time

Changes in call volumes by geographic area were also studied by calculating the difference in call volumes between the years 2005 and 2019. With this analysis, geographic areas with changing call volumes can be detected. As call volumes are being used as an indicator of service demand, those areas with the greatest difference in volumes demonstrate areas where service demand has changed over time. Such changes may be attributed to increases in population.

An analysis of the spatial distribution of call volumes in 2005 versus 2019 (see Map 5) demonstrates that certain areas within the Region have experienced higher rates of change. Green hues indicate the areas that had increased call volumes and purple indicates areas that had seen a decrease in call volume between the two time periods. In each case, the hue darkens as the change is more pronounced. Most of the areas with moderate to high growth are found in the major city centre cores of Brampton (Queen and Main Street corridor) and Mississauga (Square One area extending down south to Queensway). Areas with more moderate growth in call volumes in Brampton include those around Peel Memorial Hospital, Brampton Civic Hospital, Springbrook, Mount Pleasant, Alloa, Mayfield West, Churchville, Castlemore and Ebenezer. Areas in Mississauga with an increase in call volume since 2005 include the Square One area (Cooksville), Credit Valley Hospital (Meadowvale and Erindale), Toronto Pearson International Airport, Malton, Dixie, Port Credit, Clarkson and Gateway. Meanwhile, Bolton is the only area with moderate growth in Caledon, with more modest growth in Caledon East, Palgrave and area surrounding Orangeville.

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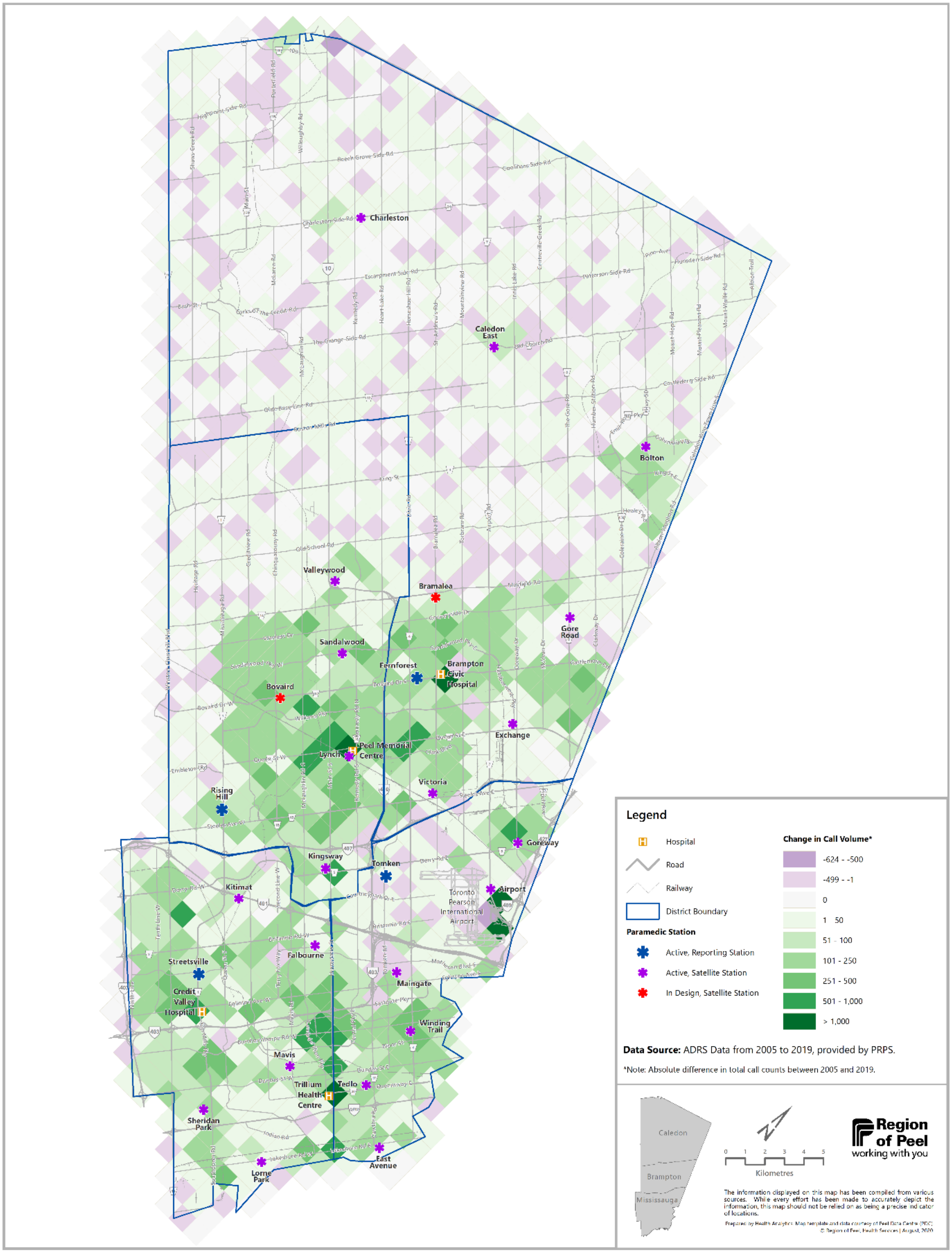
Paramedic Services Long Term Facilities Capital Plan, Key Supporting Analyses



Map 5. Absolute change in call volume per UTM grid cell between 2005 and 2019

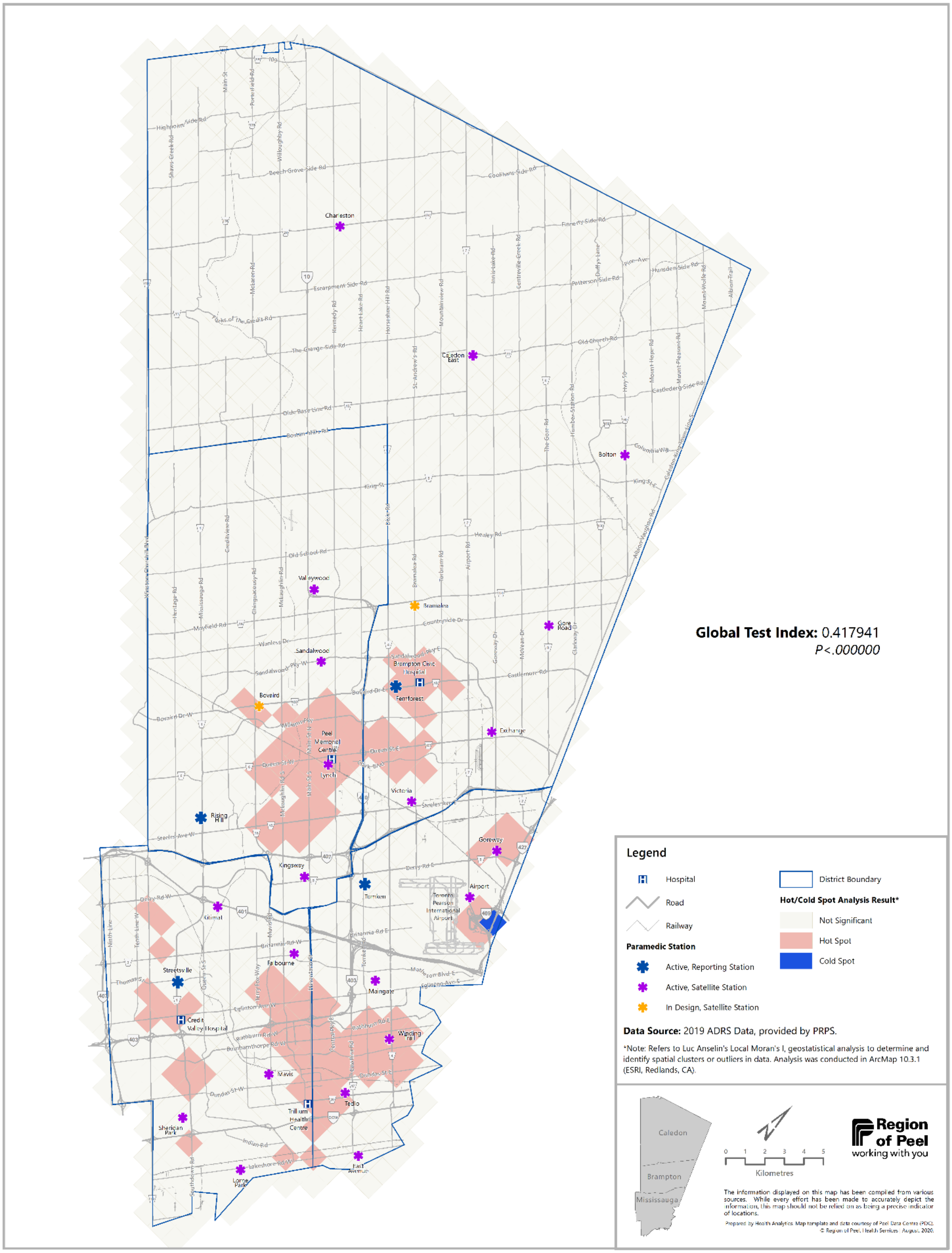
Note: Only calls with valid coordinates were included from both years (representing 97.7 per cent and 99.9 per cent of total calls for 2005 and 2019, respectively)

2.1.2.3. Areas with the highest growth

Analyses were also conducted to determine which areas in the Region had significantly higher or lower than expected number of calls; as a relative measure, the number of calls per area are compared and used for this detection. This type of analysis enables the identification of areas that have a statistically significant higher or lower demand for paramedic services.

To determine whether there are areas (UTM grid cells) with higher or lower than expected (i.e., greater or lower than the mean) call volumes in 2019, two different *hot spot* analyses were conducted. An overall (global) test assesses the overall spatial correlation of call volumes by measuring how similar the values are with each other. The results from the test (0.417941 index, P <.001) indicate that call volumes in 2019 are highly correlated with each other. A local hot spot test allows the identification of areas (UTM grid cells) with higher than expected call volumes (i.e., hot spots), and areas with lower than expected call volumes (i.e., cold spots); the results of this test are presented in Map 6 with areas shown in red (hot spots) and blue (cold spots).

There were no hot spots or cold spots within Caledon. Both Mississauga and Brampton each have large hot spots around and extending from their downtown cores. Other smaller hot spots were found around Pearson Airport, Meadowvale, areas southwest of Streetsville, northwest of Erindale, north of Clarkson, and Malton in Mississauga. Peel hospitals are surrounded by hot spots, which can be attributed to the transfers from hospital to other facilities. The only cold spot was found next to the hot spot at Toronto Pearson International Airport.



Map 6. Call volume hot spot analysis, UTM grid cells 2019

Note: Only calls with valid coordinates were included (representing 99.9 per cent of total calls for 2019)

2.2. PRPS clients

2.2.1. Age and sex distribution over time

For a better understanding of the clients using paramedic services over time, age and sex profile of the user population in 2005 (illustrated by the blue and red bars) was compared to 2019 user population (represented by the black bar outlines) in Figure 4. Knowledge of the age and sex of clients is relevant as health conditions and health behaviours, including the way health care services and resources are accessed, can be related to age and sex profiles of the population. This information enhances the knowledge of ambulatory care use patterns.

The age and sex profiles reveal shifts in the demographics of the clients accessing paramedic services in 2005 compared to 2019. Figure 4 illustrates the proportion of clients by five-year age groups and sex in 2005 and 2019. Overall, there is an uneven distribution in the proportion of females using paramedic services compared to males; females aged 85 and over tend to call more than their male counterparts, 15.0 per cent compared to 9.9 per cent. Most notably, the greatest growth in clients between 2005 and 2019 was among the oldest age group (aged 85 years and above) for males, an increase of 3.5 per cent, and the 80 to 84 age group for females, an increase of 2.5 per cent. The analysis by age groups indicates that paramedic services continues to be more heavily used by those aged 50 years or above, representing 52.8 per cent and 57.8 per cent of users in 2005 and 2019, respectively.

The differences between the age and sex structures over the period can point to changing paramedic services usage patterns. As these cohorts continue to age in place over the next 15 years, it will be crucial to ensure that PRPS has the appropriate resources to ensure timely service delivery.

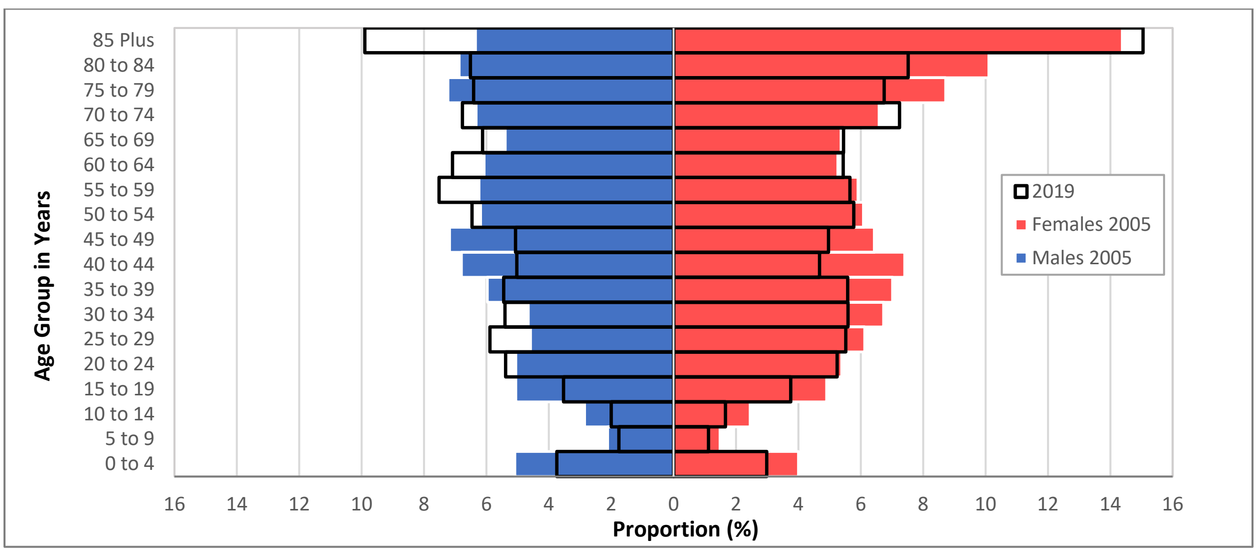


Figure 4. Client distribution by age group and sex, 2005 and 2019

Note: Data were derived from Ambulance Call Reports (ACR) also known as Patient Care Reports or Interdev's iMedic database; Data reported exclude records without age and/or sex specified, which represent 1.4 per cent and 11.4 per cent of total records in 2005 and 2019, respectively.

2.2.2. Call volume trends by age

To better understand the effect of age on call volumes, a trend analysis of calls by age group over time was conducted. The results of this analysis are shown in Figure 5. The oldest age group, comprised of callers aged 80 years and above, is seen to consistently have the highest number of calls over time compared to all the other age groups. However, the highest increase in calls by an age group over time was seen in those aged 60 to 69 years old (8.3 per cent average annual increase). The second highest increase was seen in those aged 20 to 29 (8.1 per cent average annual increase). The smallest increase in calls is seen in those aged 40 to 49 (5.1 per cent average annual increase), along with the two youngest age groups (5.8 per cent and 5.1 per cent average annual increase for those between the ages of 0 to 9 years and 10 to 19 years, respectively). The age trend analysis demonstrates that, while generally the number of calls over time increases across all age groups, the magnitude of the increase differs across different age groups. Thus, age is a contributor to call volumes, and it is factored as an important variable in the prediction analysis.

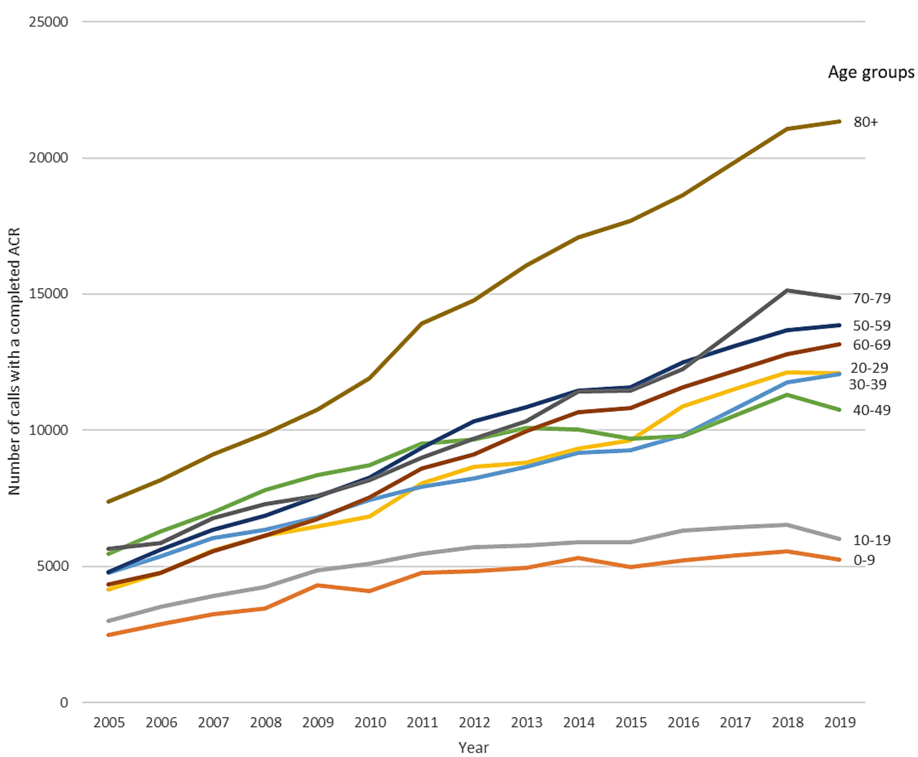


Figure 5. Call volume trends by age, 2005 to 2019

Note: Data were derived from Ambulance Call Reports (ACR) also known as Patient Care Reports or Interdev's iMedic database; Data reported exclude records without age specified, which represent less than two per cent every year. The calls reported include only those with an ACR completed, which represent on average 81 per cent of all calls.

2.3. Service delivery trends

With growing call volume and changing client demographic over the last 15 years, total service delivery time has also increased during the same time period. Total service delivery time is defined as the time paramedics spend on duty (also known as time on task), and includes the following call response time components:

1. *On route to call*: time paramedics spend to arrive on scene after being notified of an emergency call.
2. *At scene on call*: time paramedics spend to provide pre-hospital care on scene and/or prepare patient for transport to hospital (if right not waived).
3. *On route to hospital*: time paramedics spend traveling to hospital after leaving the scene of the emergency call.
4. *Hospital offload time*: time paramedics spend in hospital with patient to transfer care.

A close examination of the different call response time components can help identify where there is added pressure on paramedics to provide timely pre-hospital care, while also quantifying resource use. Greater service delivery hours translates into more time and resources (medical supplies, equipment, fuel and ambulance prep) being spent on responding to emergency calls.

There were 165,927 more service delivery hours in 2019 compared to 2005, which is almost double the total service delivery hours in 2005 or the equivalent of 13,827 12-hour shifts. See Figure 6 for the total service delivery time in hours (green dotted line) along with the hours per each response time component from 2005 to 2019. The total service delivery time has grown on average by 11,852 more hours (approximately 990 12-hour shifts) or an increase of 4.4 per cent annually since 2005. The largest increase in service delivery hours was in 2007, with a increase of 47,258 hours (equivalent to 3,938 12-hour shifts) or 21.1 per cent; meanwhile, 2015 had the largest reduction, with 23,229 less service hours (equivalent to 1,936 12-hour shifts) or 8.3 per cent reduction. When comparing the most recent years, 2019 saw a slight reduction in total service delivery hours, amounting to 7,339 fewer hours (equivalent to 612 12-hour shifts) or decrease of 2.2 per cent compared to the previous year.

The response time components show different patterns over time. *Hospital offload time* consistently leads with the greatest magnitude of and increase in service hours since 2005; *hospital offload time* increased by 76,056 hours (equivalent of 6,338 12-hour shifts) between 2005 and 2019. On average paramedics spend 52.2 per cent of their time waiting in hospital to transfer care, followed by *on scene at call* (26.7 per cent), *on route to call* (11.3 per cent) and *on route to hospital* (9.9 per cent). The response time with the lowest increase in number of service delivery hours between 2005 to 2019 was *on route to call* with 13,613 more hours (equivalent of 1,134 12-hour shifts).

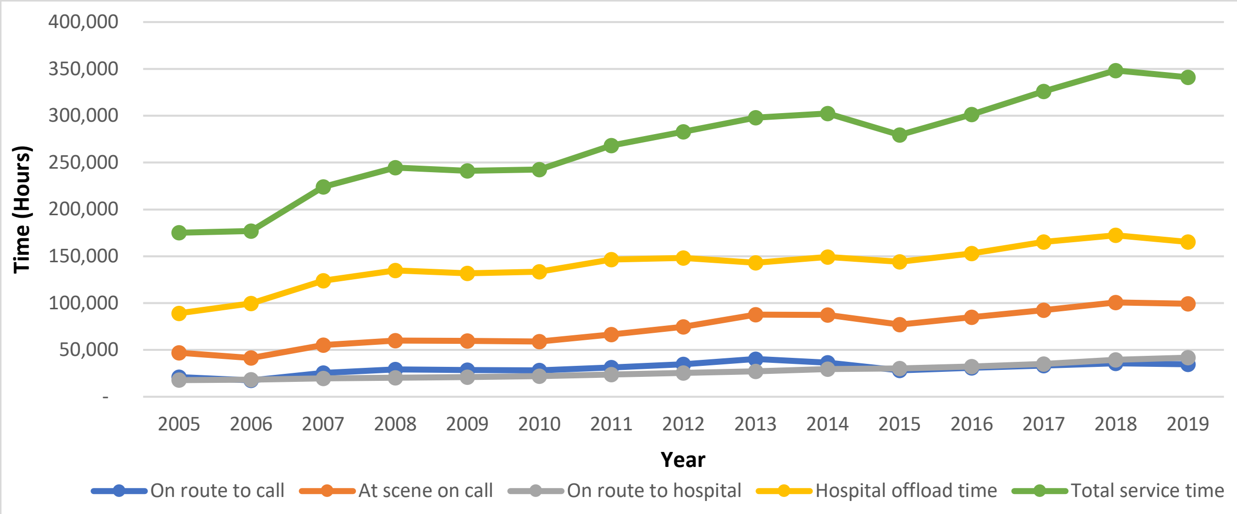


Figure 6. Total service hours per call response component, 2005 to 2019

As call volumes have been increasing over time, total service delivery time was further drilled down to determine whether there are patterns in the amount of time spent per call. Average time spent per call was computed by dividing the yearly total service delivery time by the total call volume for the corresponding year. This measure is useful for predicting future resource need (e.g., ambulances) as it is a data driven estimate of time that paramedics typically spend providing pre-hospital care. Figure 7 illustrates the average time spent per call from 2005 to 2019.

The average time spent per call has declined by approximately six minutes, or 4.2 per cent, from 2005 to 2019. The peak average time spent per call occurred in 2008 (over 3 hours), with the following years declining on average by approximately four minutes. This decline may be attributed to the implementation of the offload delay nurse program which was initiated in 2008 and fully implemented in all three Peel hospitals by 2015. 2006 had the lowest average time spent per call at two and a half hours, which is only slightly lower than 2019, having a difference of one minute and twenty seconds.

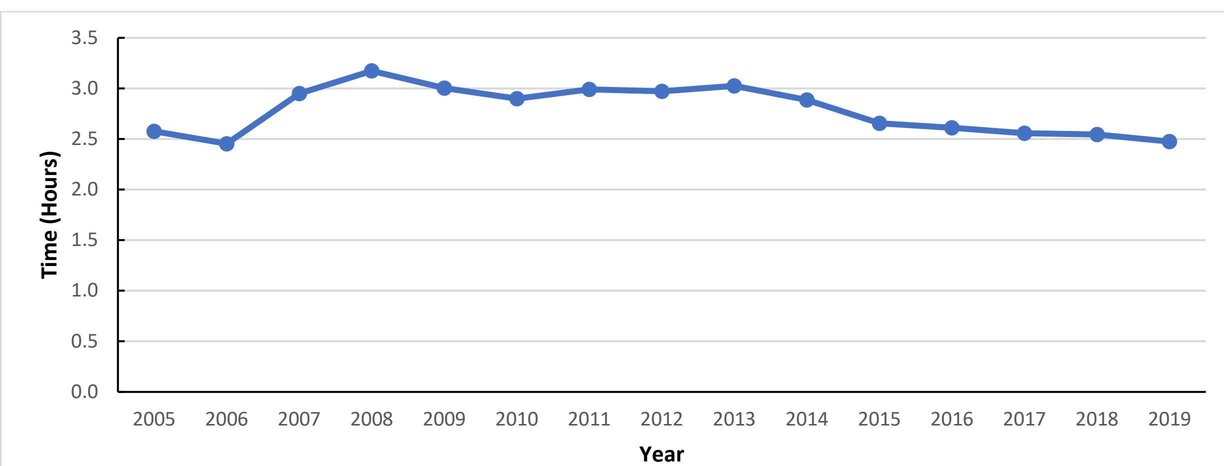


Figure 7. Average time spent per call, 2005 to 2019

Chapter 3: Predictions

Chapters 1 and 2 provided an overview of the drivers of paramedic services and the trends in service demand over time. This Chapter focuses on the prediction of future demand, and the prediction of paramedic resources needed to meet the demand over time. These predictions are underpinned by the trends discussed in the previous chapters.

3.1. Forecasting future call volumes

The previous sections have illustrated several drivers of call volume, including population growth and client age. As such, it is important to consider these drivers when predicting future call volumes.

Several prediction models were tested using daily, monthly and yearly call volume data. The types of models tested included:

1. **Time series analysis**

   Many different types of time series models based on daily and monthly call volume data were tested. These models were chosen because of the nature of the data (i.e., calls over time). These types of models account for trend, seasonality and relationships between data points that occur close to each other. In all time series models, the historical trend in the data is crucial and, in most cases, the only predictor of future values. The resulting predictions tend to be highly influenced by more recent trends. Different models use different parameters to estimate future values, and the further in time the models try to predict the more unstable the estimates become. Most of these did not show a high degree of accuracy. For those reasons the time series models were not chosen.

2. **Regression analysis**

   Various types of regression models, including linear regression, multiple regression, and generalized linear regression were also tested on yearly data. While some of these models were able to incorporate other variables of interest, such as age and population, they led to highly unstable and inaccurate estimates that were neither close to nor matched the observed data. The latter results were mainly due to trend in call volumes not being incorporated. For those reasons these models were not chosen.

3. **Age-period-cohort analysis**

   Various type of age-period-cohort (APC) models were tested using a variety of different parameters. These models were chosen because they incorporate trend, age and population, the most critical factors that drive call volumes. Such models have been used successfully for other long-term projections, predominantly for predicting long-term trends in cancer incidence.[15] The models also account for trends by age group. One of these models, the *Age-Period negative binomial log regression model with age-specific trends* (referred to as an AP model) resulted in the best fit and yielded estimates that were more reliable compared to all the APC models tested. For this reason, the AP model was chosen for long term predictions of PRPS calls.

In all models tested, 15 years (2005 to 2019) of historical call volume data were used. Using a robust set of historical data allows for more reliable predictions with improved accuracy (i.e., lower error). Although these analyses are intended to support the development of a 10-Year Capital Facility Plan, the following projections go beyond this timeframe in order to provide a more thorough long-term picture of the future call demand.

Predictions from the AP model show a continued growth in calls in the future; Figure 8 illustrates the actual number of calls (blue line) and predicted number of calls (orange line) from 2005 to 2041. Also noted is the 95 per cent prediction interval (light orange shaded area), which represents the range of values within which the future calls are expected to fall with 95 per cent probability. It is predicted that there will be 272,661 calls in 2036, with a 95 per cent prediction interval between 208,633 and 356,603 calls, refer to Table 3 for actual and predicted number of calls by five-year increments starting from 2019. The predictions show that the number of calls is expected to almost double between 2019 and 2036 or increase by 97.9 per cent in this period. The resource predictions outlined later in this report are based on the predicted number of calls (orange line).

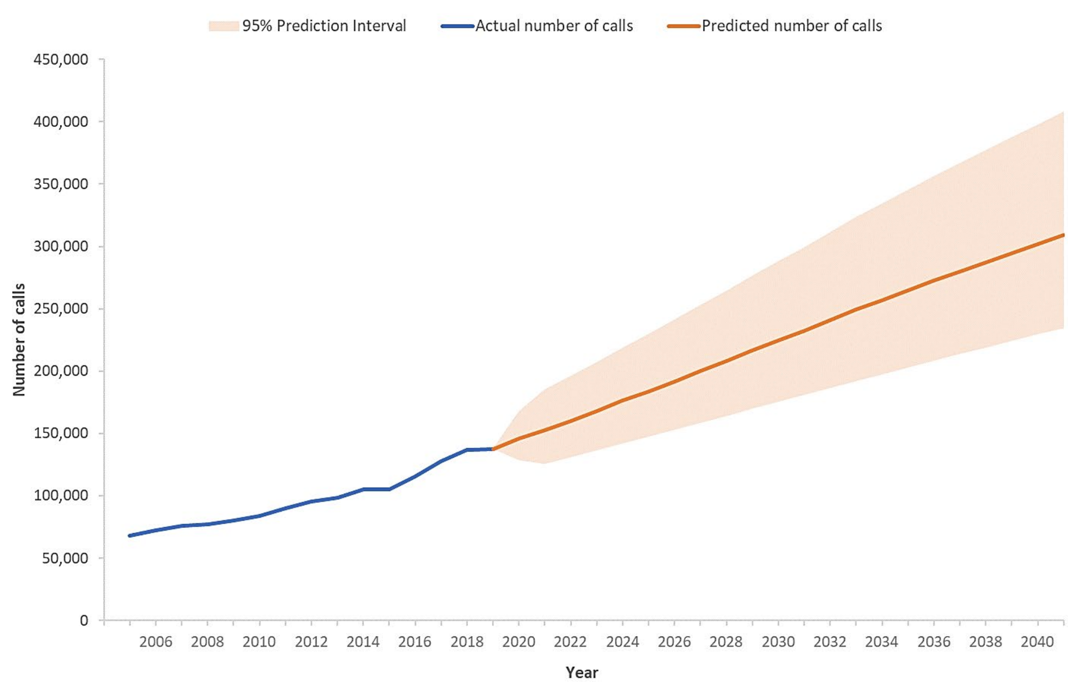


Figure 8. Actual and predicted number of calls over time, 2005 to 2041

Table 3. Actual and predicted number of calls by five-year increments, 2021 to 2041

Year	Predicted number of calls	95% Prediction Interval	% Change from 2019
2019 (actual)	137,742		
2021	152,480	(125,477 -185,426)	10.7%
2026	191,815	(152,744 – 241,071)	39.3%
2031	232,492	(180,720 – 299,324)	68.8%
2036	272,661	(208,633 – 356,603)	97.9%
2041	309,294	(234,665 – 407,948)	124.5%

The model allows a further drill-down to assess the change in calls that can be attributed to population growth and aging, as seen in Table 4. Population aging accounts for 31.8 per cent of the change in calls from 2019 to 2036, while population growth accounts for 26.6 per cent. The remaining 39.5 per cent is attributed to other unknown drivers.

Table 4. Per cent change in call volume due to population growth, population aging and other factors, 2005 to 2041

Cause of change	Magnitude of Change			
	2005-2019 (observed)	**2019-2031 (predicted)**	**2019-2036 (predicted)**	**2019-2041 (predicted)**
Population growth	31.2%	19.8%	26.6%	33.4%
Population aging	29.1%	19.5%	31.8%	44.4%
Other factors	42.4%	29.4%	39.5%	46.8%
Overall change in call volume during specified periods	**102.7%**	**68.8%**	**97.9%**	**124.5%**

3.2. Forecasting areas of high demand

In the previous section, future call volume predictions were reviewed and illustrated. In the following section, call volumes are mapped within Peel Region to highlight areas expected to experience high demand for paramedic services.

Geographically weighted regression was used to quantify call volume growth by SP area within Peel over time. As with the previous analyses, the population was considered as a driver of call volume. However, in these analyses, the total workforce population, including those living in Peel or outside of Peel, as well as the number of residential and commercial units per SP area[16] were factors used to estimate future call volumes. These populations were favoured over the total population because there are several areas in Peel that are commercially driven with little to no population residing within those areas, but still contributing to demand for paramedic services.

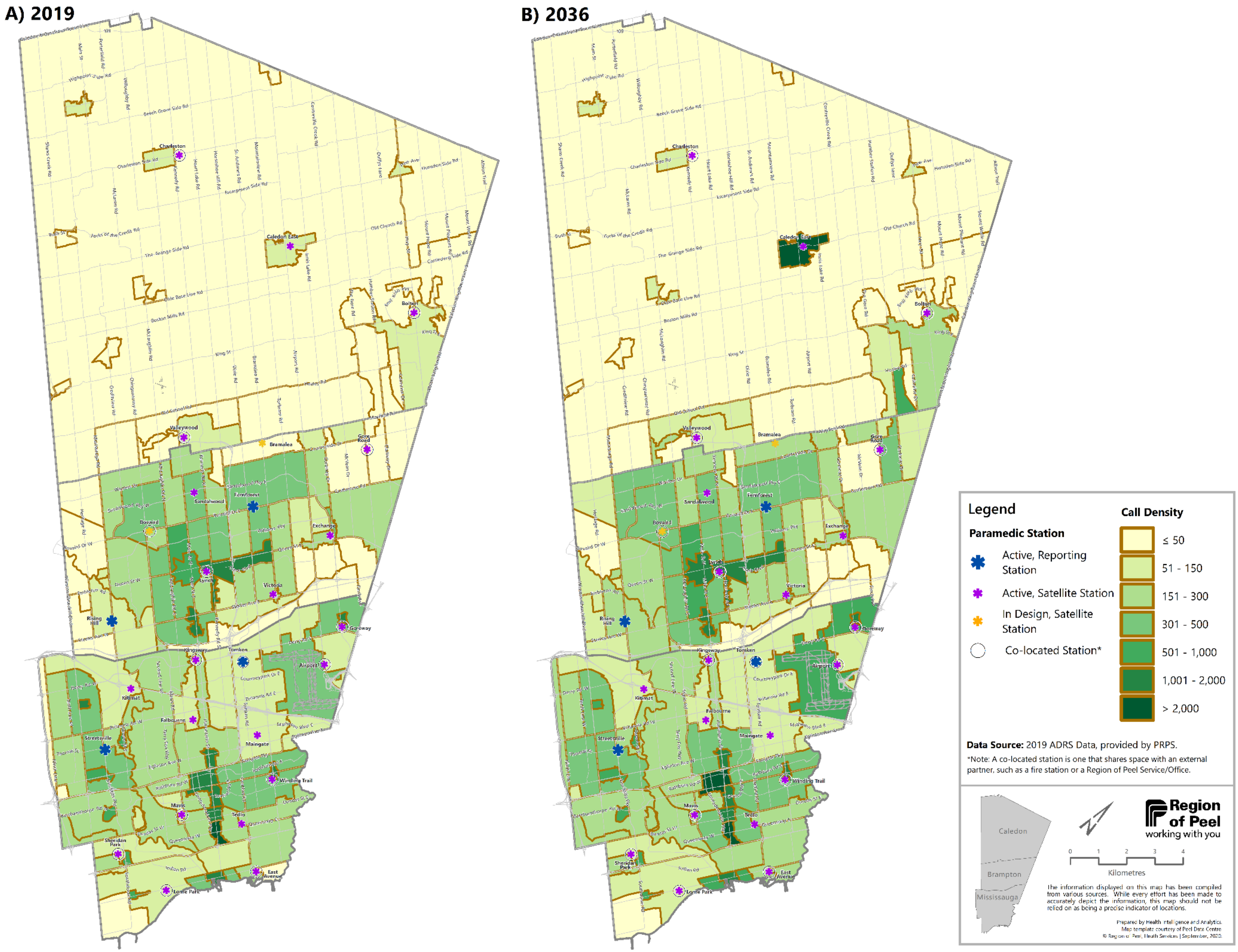
The main strength of this method comes from its ability to consider both where people live and/or work and make emergency calls when estimating call volume densities. In some cases, adjustments were made to call volume densities for certain SP areas, such as the Airport and surrounding areas. Such SP areas represent outliers or occurrences where there are few to no residents or employed individuals but high call volumes adjacent to SP areas with more residents or employed individuals but low call volumes. Adjusting the estimated call volume densities for these SP areas ensured that the unique and varying demographic patterns remained in the models, which would otherwise be eliminated through aggregation.

The results of the spatial analyses show that call volume density is expected to further intensify in the downtown city cores of each municipality by 2036; estimated increases of 1,925 calls per square kilometre are anticipated in Mississauga's downtown core (area around Square One Mall and Hurontario Street corridor), 1,279 calls per square kilometre in Brampton's downtown core (Main Street and Queen Street corridor), and 775 calls per square kilometre in Caledon's major town (Bolton). See the following Map 7 for 2019 and 2036 call volume densities across Peel.

Within each municipality it is predicted that call volume density will increase in certain areas by 2036. For Brampton, the north east corner, which captures the Vales of Humber, Gore Rural Estates and Highway 427 industrial SP areas, is expected to increase the call volume density by 882 calls per square kilometre. More moderate increases are expected in the south west corner, including the southern part of Huttonville (473 more calls per square kilometre) and Mount Pleasant area in the north west corner (251 more calls per square kilometre).

Apart from Bolton, the SP areas with anticipated higher call volume densities in Caledon include Caledon East (2,150 more calls per square kilometre) and Mayfield West (286 more calls per square kilometre).

There are several areas in Mississauga with higher growth in call volumes densities for 2036. Calls per square kilometre are estimated to increase as follows: 484 for Port Credit, 338 for Toronto Pearson International Airport, 279 for Lakeview waterfront, 191 for Streetsville and Cooksville, 177 for Clarkson and Lorne Park area, and 166 for Malton.



Map 7. Actual and predicted call volume densities by secondary plan areas, Peel, 2019 and 2036

3.3. Forecasting future service resource needs

The previous sections reviewed call volume projections and illustrated where geographically those calls are expected to originate in future. In the following section, the future resource needs will be measured to meet the growing demand. *Resources* are defined as ambulances, reporting stations and satellite stations.

3.3.1. Number of ambulances needed

Currently, Peel paramedic services has a total of 134 ambulances. Of these ambulances, 97 are scheduled for deployment throughout the day, whether on a 12 hour day or night shift, while eight (or 11.0 per cent of fleet) act as backfills to ensure deployment levels and 29 (or 19.0 per cent of fleet) are set aside to ensure additional deployment levels, address vehicle breakdown, deep cleaning needs, and regular vehicle maintenance. In order to appropriately estimate the number of ambulances needed over time, all three components of the fleet are considered in the resulting projections.

Given the composition of the ambulance fleet, the following formula was created to generate ambulance predictions over time.

$$\text{Total ambulances needed} = \frac{\begin{pmatrix}\text{Predicted call}\\ \text{volume}\end{pmatrix} \times \begin{pmatrix}\text{Time spent per call}\\ \text{in a given year}\end{pmatrix}}{\begin{pmatrix}\text{Total adjusted service time a 12}\\ \text{hour shift ambulance provides}\end{pmatrix}} + 11\% + 19\%$$

Where:

- Predicted call volume refers to any given year in the overall call volume forecasts described in Section 3.1.
- Time spent per call in a given year represents the average time Peel paramedics spent per emergency call (in minutes) described in Chapter 2, Section 2.4.
    - Peel paramedics spent on average 148 minutes per call in 2019 (341,030 service hours [20,461,800 minutes] divided by 137,741 calls).
- Total adjusted service time a 12-hour shift ambulance provides represents the total time paramedics are on duty (responding to calls), accounting for meal breaks, long offload delays and other service interruptions (e.g., deep cleaning needed, vehicle readying and other breaks).
    - Total service time 12-hour shift ambulance provides in a year is 262,800 minutes (365 days a year multiplied by 12 hours per day and multiplied by 60 minutes).
    - Total time paramedics are allotted for meal breaks in a year is 21,900 minutes (365 days a year multiplied by 1 hour per day and multiplied by 60 minutes).

   - Total other non-service-related time in a year is 24,090 minutes (10 per cent of the total service time after considering meal breaks: (262,800 minus 21,900) multiplied by 0.10)
   - Total adjusted service time a 12-hour shift ambulance provides is 216,810 minutes (262,800 minus 21,900 and 24,090).
- 11.0 per cent represents the number of ambulances set aside as backfills.
- 19.0 per cent represents the number of ambulances set aside to ensure additional deployment levels, address vehicle breakdown, deep cleaning needs, and regular vehicle maintenance.

The formula was applied to each forecasted year to quantify the number of ambulances needed over time. Figure 9 illustrates the number of current (orange dotted line) and predicted (blue dotted line) ambulances from 2017 to 2036. A total of 245 ambulances will be needed by 2036, which is an increase of 111 ambulances or 82.8 per cent in fleet size compared to 2020.

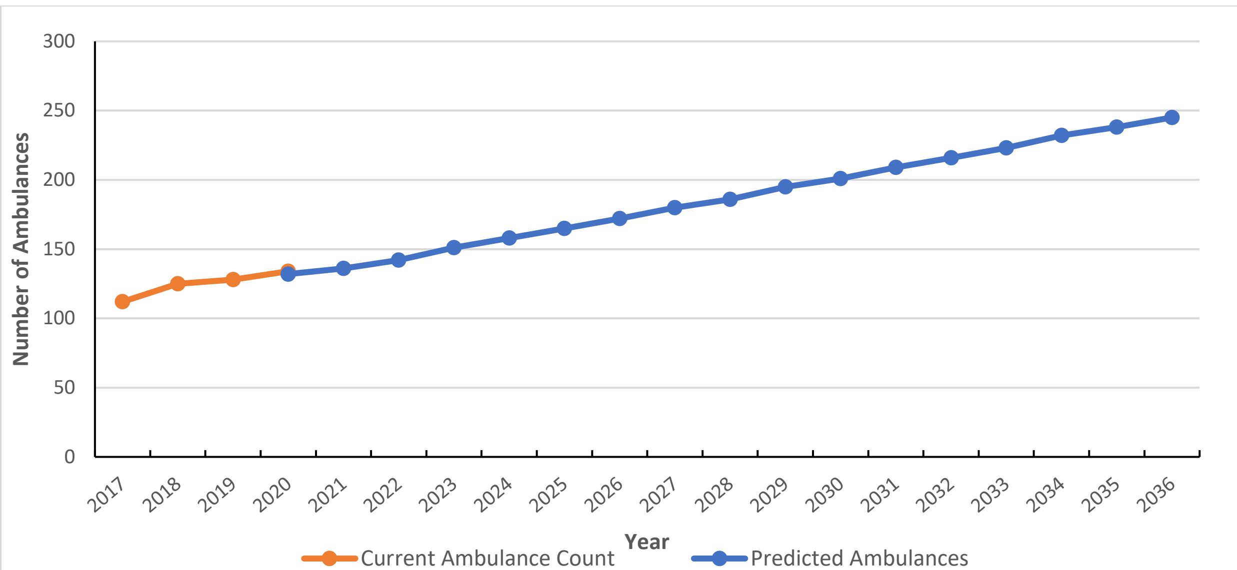


Figure 9. Number of current and predicted ambulances over time, 2017 to 2036

It is important to note that the number of ambulances required over time assumes that the demand patterns from 2005 to 2019 in the prediction models extend into the future. As the ambulance needs appear to continue to grow in the foreseeable future, an evaluation of the effectiveness of fleet size and type should be considered by PRPS.

3.3.2. Number of reporting stations needed

The previous Section illustrated that there is an increasing need for more ambulances to meet the future demands. Consequently, more reporting stations will be needed to house the growing ambulance fleet. Since reporting stations have limited spaces to hold ambulances, PRPS will reach *capacity* when those spaces are no longer available. As of January 2020, PRPS reached maximum capacity; there are no free spaces remaining in the four current reporting stations to house additional ambulances.

Given that the ambulance predictions grow in tandem with anticipated call volume, reporting station predictions were generated for the next 10 years. It is recommended that call volume and ambulance predictions be re-visited annually to confirm forecasted trends and resource needs in the future. Ambulance predictions from the previous Section and default number of parking spaces in new Reporting Station designs (30 spaces) are used to predict when a new reporting station is needed over the next 10 years. Figure 10 illustrates the current (orange dotted line) and predicted (blue dotted line) number of ambulances needed over time with years indicating when a new reporting station will be needed (yellow bars).

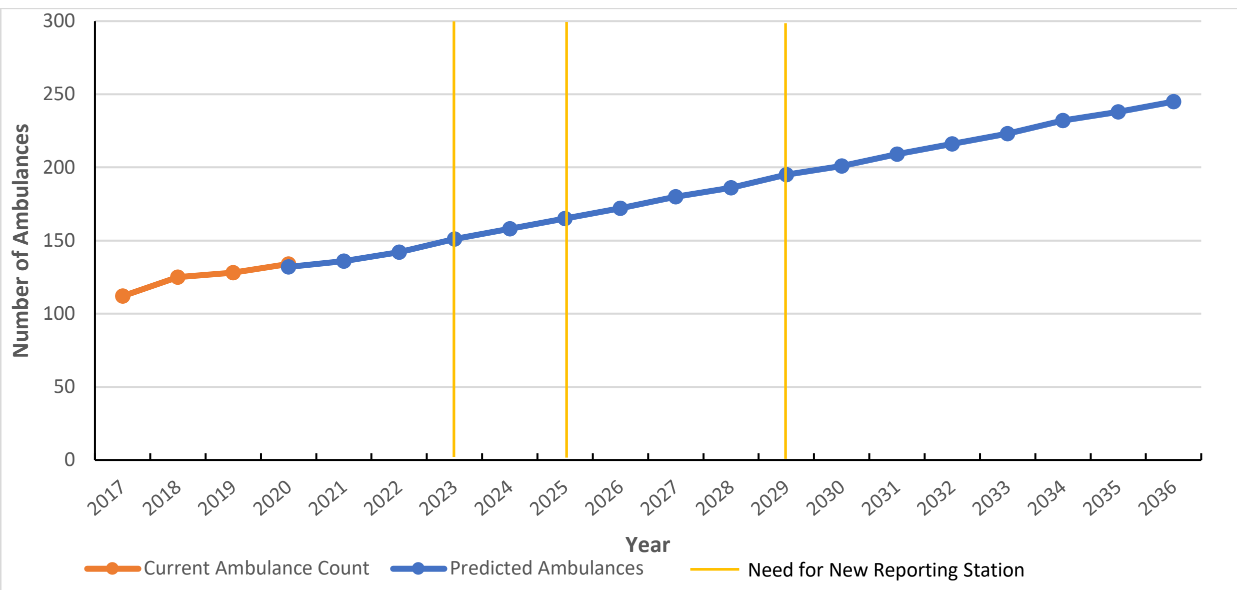


Figure 10. Number of current and predicted ambulances, and reporting stations needed over time, 2017 to 2036

3.3.3. Number of satellite stations needed

As the demand for paramedic services increases across Peel, so does the need for satellite stations. Currently, PRPS has 21 separate satellite stations, as well as three satellite stations each with an attached reporting station and two satellite stations in the design phase (net of 26 stations). Satellite stations have a dual purpose, they provide space for paramedics to take breaks (e.g., meal, mental health, washroom, etc.) while traveling from post to post, and they are potential starting points from which paramedics can quickly respond to emergency calls. These stations are strategically placed in areas with higher call volumes to reduce response times, and thus provide timelier pre-hospital care.

Many of the existing satellite stations are in areas with high call volumes; however, there are still some areas without stations that are predicted to experience a growth in call volume. A total of five new satellite stations can be strategically placed to provide timelier pre-hospital care in areas anticipated to grow in call volume by 2036. Satellite stations are assigned to one of the four existing reporting stations based on proximity (travel time) and a roughly equal distribution of satellite stations per reporting station. With the build of new reporting and satellite stations, PRPS has an opportunity to consider reassignment of satellite stations to each reporting station. See Table 5 for details on the proposed number of satellite stations between 2023 and 2036.

Table 5. Proposed year and number of satellite stations, 2023 to 2036

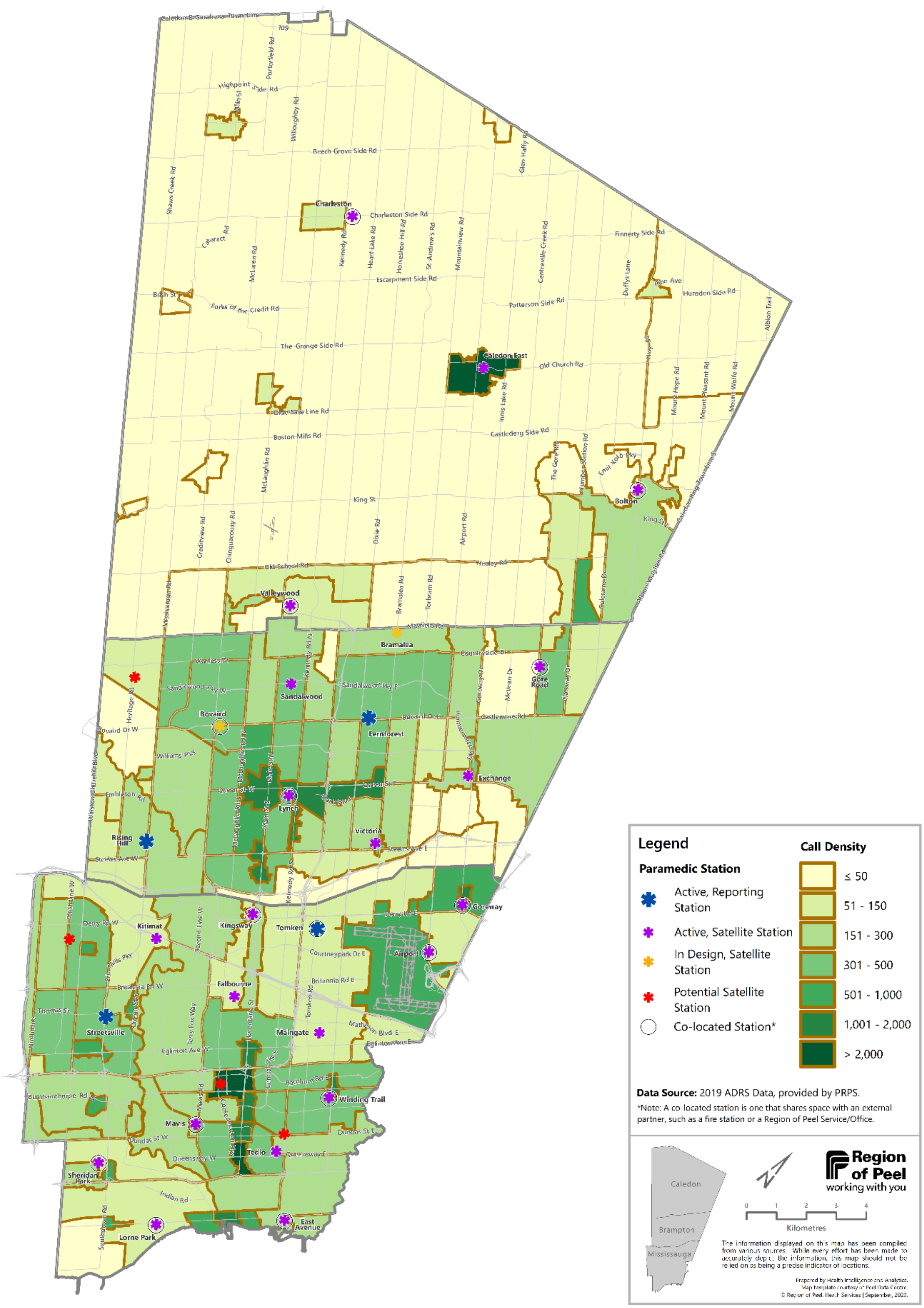
Proposed Year	Number of New Satellite Station(s)
2023	3
2025	1
2029	1
Total number between 2023 - 2036	**5**

The Real Property and Facility Acquisitions team has identified potential sites for new stations, see Table 6 for an overview of acquired and potential locations for new satellite stations. Given the locations of these potential sites, three (Living Arts Drive and Prince of Wales, Sandalwood Parkway and Heritage Road, and 6627 Tenth Line West) are strong candidates for new satellite stations as they are situated in areas that are anticipated to grow in call volume by 2036. Map 8 shows the anticipated call volume densities per SP area by 2036 with current reporting stations (blue asterisks), active satellite stations (purple asterisks), satellite stations in design (yellow asterisks), and potential satellite station locations (red asterisks).

Table 6. Overview of acquired and potential satellite station site locations

Acquired Satellite Station Locations		Potential Satellite Station Locations	
1	11797 Bramalea Road	1	Sandalwood Parkway and Heritage Road
2	917 and 927 Bovaird Street West	2	Dundas Street and Cawthra Road
		3	Living Arts Drive and Prince of Wales
		4	6627 Tenth Line West (may be updated)

Data Source: Addresses provided by Real Property and Facility Acquisitions, Region of Peel

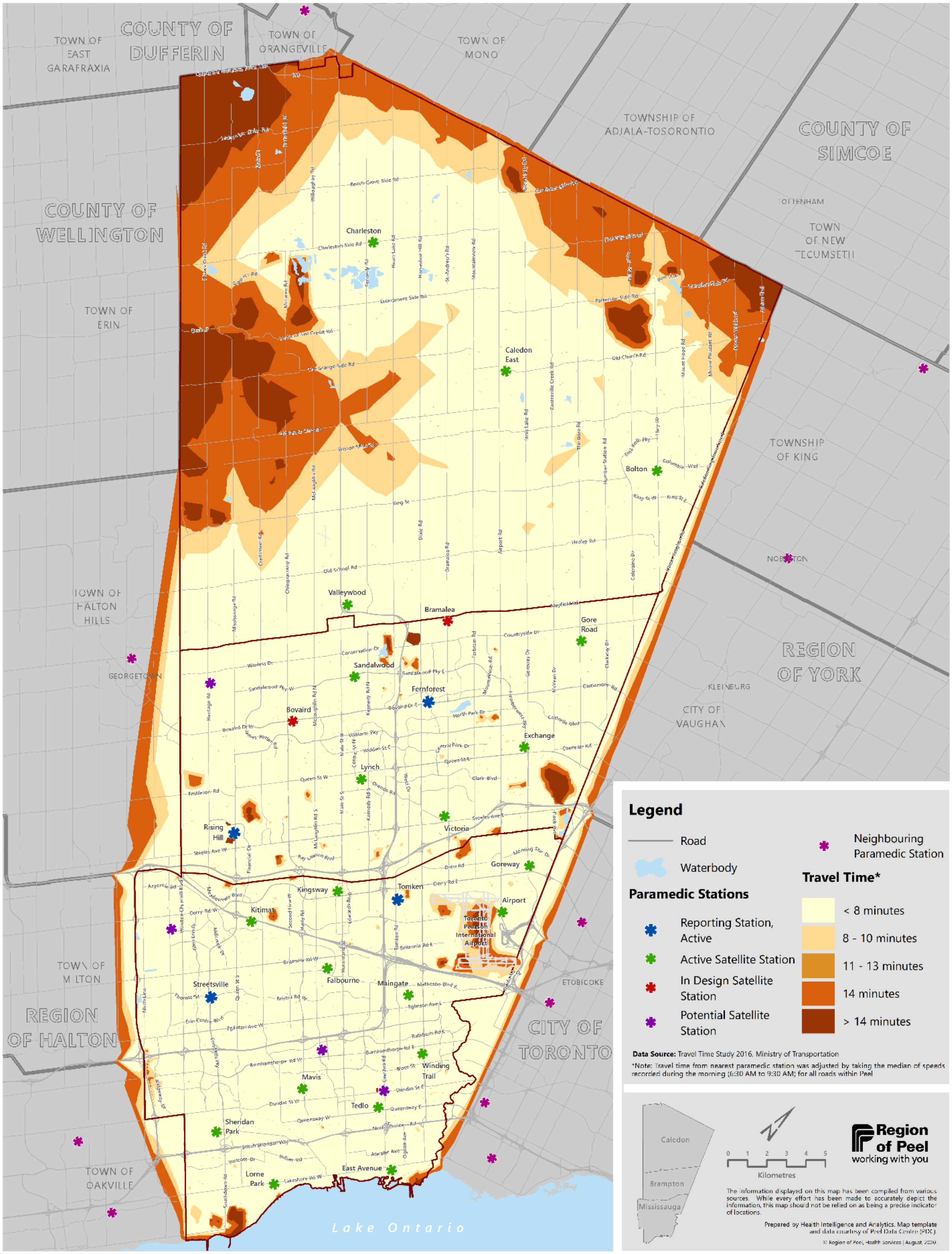


Map 8. Predicted call volume density by SP area with active, in design and potential satellite stations, 2036

To further demonstrate impact of the three potential sites considered to be strong candidates for placement of new satellite stations, *geographic coverage* or extent of spatial reach of the paramedic stations was mapped. *Geographic coverage* captures the estimated amount of travel time that it will take for an ambulance to reach locations within specified areas. Traffic data from the *2016 Travel Time Study* (TTS) conducted by the Ministry of Transportation were used in travel time calculations to better represent the road traffic conditions for ambulances when deployed from the nearest paramedic stations at certain times during the day. Several maps were generated per season and time of day; however, the same general patterns can be discerned from each season and time of day combination. Map 9 shows the travel time (in minutes) from the nearest reporting station (blue asterisk), active satellite station (green), satellite stations in design (red) and potential satellite station (purple) during the morning rush hour period (6:30am to 9:30am) in the Fall season.

The results show that the placement of the new satellite stations at these sites further extends the overall geographic reach of all stations, indicating that more of the Region can be reached within eight minutes from the nearest paramedic station. In particular, a potential station situated south of Heritage Road and Wanless Drive reduces the travel time from between nine to 14 minutes in the north west corner of Brampton and south west corner in Caledon to within eight minutes, while the north west corner of Mississauga experiences a similar travel time of within eight minutes from a potential satellite station situated south of Tenth Line and Derry Road West.

It is important to note that ambulances can be deployed from any location, not just from a station. In this respect, the geographic reach from the paramedic stations indicates most of the Region is well-served, demonstrating a high level of station-level coverage, except along the borders of Caledon which is sparsely populated. Considering the fluid deployment model used by the Region and other neighbouring municipalities, such areas in Caledon would be serviced by Peel paramedics as well as by paramedics from other municipalities (neighbouring paramedic stations denoted by the pink asterisks). Though seasonal and temporal traffic patterns were considered in the geographic coverage maps, the model cannot account for the fluid deployment plan and other impediments to travel time, such as road closures and construction detours.



Map 9. Travel time from nearest paramedic station as of January 2020

Chapter 4: Potential System Efficiencies

PRPS has implemented and continues to think of programs and initiatives that enhance service delivery and create process efficiencies. Considering that demand for PRPS has increased over time and is expected to grow considerably over the next 15 years, it will be even more critical to strive for continuous quality and process improvement.

PRPS implemented the Rapid Response Unit (RRU) program and "Make Ready" process to reduce response times and increase paramedics time in the field. Through coordinated efforts between PRPS and Peel hospitals, the offload delay nurse program and other process improvement initiatives[i] were developed and implemented to enhance and expedite the transfer of care, enabling paramedics to respond to more emergency calls. Figure 11 depicts key interventions implemented and resources added by PRPS and the health care system (provincial government, hospitals) over time to show their impacts on response times from 2005 to 2020.

Several other process and service delivery improvement initiatives and programs, including those recently implemented and those under consideration by PRPS and the Province, are noted below. Initiatives are categorized and presented by two main aims:

- *Aim 1: Strategies for managing growing demand and improving service delivery*
    - Community Paramedicine aims to reduce avoidable emergency calls and hospital visits by having paramedics conduct clinics and in-home visits
    - Patient care standard changes, which would allow paramedics to transport patients to other healthcare service providers, or treat and refer patients safely without having to transport to a hospital (known as "Treat, Refer and Release")
    - Fit to Sit program would change the way care for low acuity patients (CTAS 4 and 5) is transferred at hospitals by allowing patients to wait for care on their own
- *Aim 2: Strategies to improve logistic processes*[ii]
    - Digitalize documentation using mobile computers (e.g., tough-books)
    - Migrate to a new inventory and asset management system with RFID/barcode scanning technology
    - Modularize inventory, pre-stock modules and re-deploy vehicles earlier
    - Increase fleet management capacity by increasing resource support and leveraging technology

[i] Initiatives include strengthened partnerships between paramedics and hospitals, accepting ECG results conducted by paramedics, creating a shared space where ACRs can be accessed by ED personal, and creating simultaneous triage and registration processes.
[ii] Recommendations from the PRPS Logistics Program Review conducted by Optimus Consulting.

As sustainability may become a challenge with the growing resource needs, it is recommended that PRPS consider these process improvement initiatives and programs to mitigate future system pressures.

Appendix I
Paramedic Services Long Term Facilities Capital Plan, Key Supporting Analyses

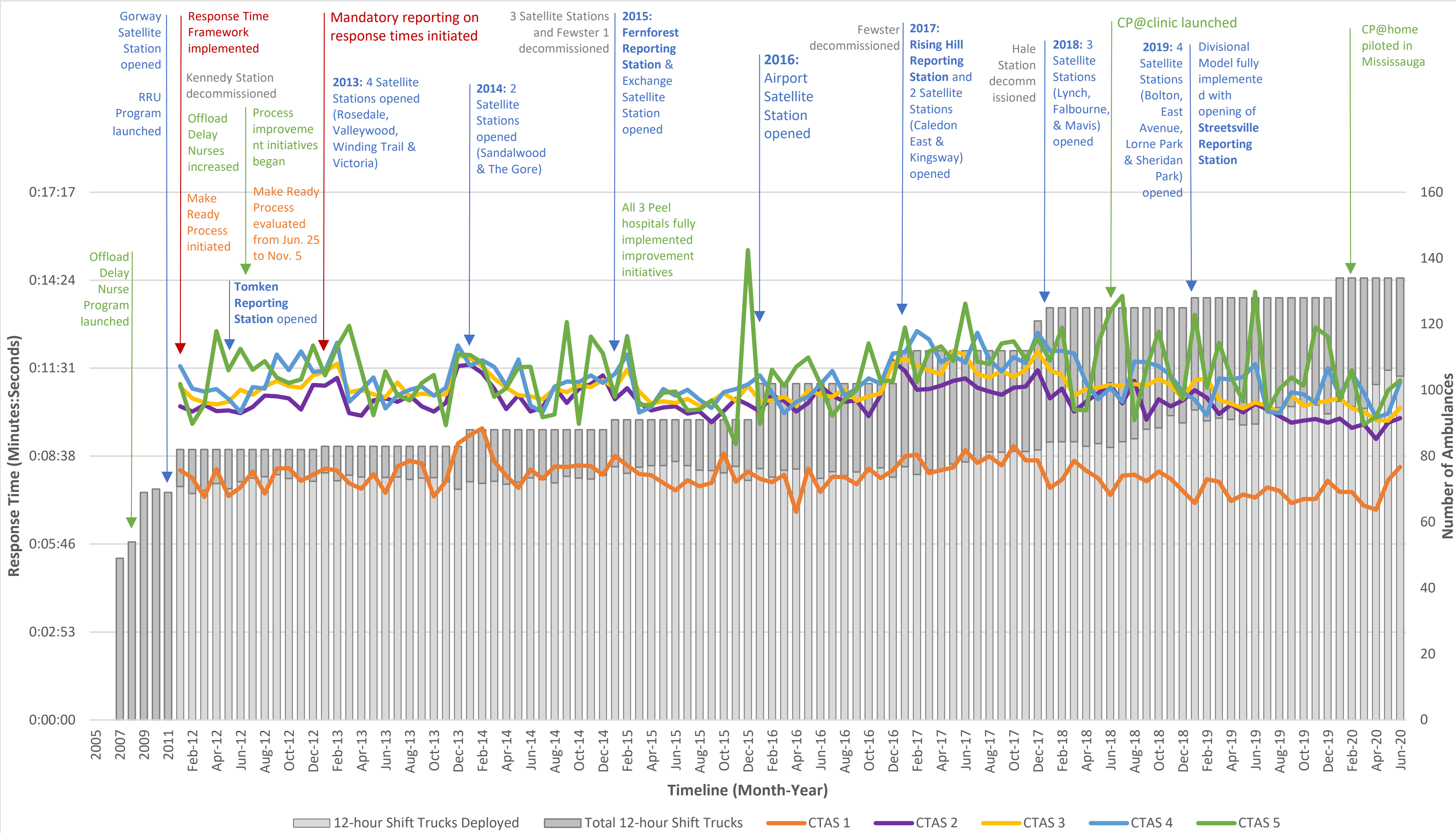


Figure 11. Effect of program interventions and fleet size (deployed and total) on response times, 2005-2020

Chapter 5: Discussion

This report describes the analyses and models used to predict future demand for Peel paramedic services and the resources that will be required to meet those demands. The information and data contained within this report are intended to support the development of the Region of Peel's next 10-Year Capital Facility Plan. The key findings and results include:

- *Chapter 1: Drivers of paramedic service call volume*
  - Population growth and population age are key drivers of paramedic service demand.
  - Peel is anticipated to grow over 30 per cent in total population, residential and commercial units, and employment by 2036.
  - The proportion of seniors (aged 65 years and above) is expected to grow by seven per cent by 2036.

- *Chapter 2: Demand trends and service pressures*
  - Over the last 15 years, call volumes have increased by 102.7 per cent with an average yearly increase of 5.2 per cent.
  - Higher call volumes are seen in main city and other smaller city centers within Brampton and Mississauga.
  - The proportion of females aged 85 and over tend to call more than their male counterparts, 15.0 per cent compared to 9.9 per cent.
  - Clients aged 80 years and above consistently have the highest number of calls over time. High increases in calls are also seen in those aged 60 to 69 years old and those aged 20 to 29 years old.
  - Total service delivery time almost doubled over the last 15 years, while the average amount of time spent per call declined by approximately six minutes.

- *Chapter 3: Predictions*
  - Call volume is expected to almost double from 2019 to 2036, increasing demand for Peel paramedic services.
  - The areas anticipated to experience the highest growth in call volume density are found in the north west corners of Mississauga and Brampton.
  - A total of 245 ambulances will be needed by 2036, which is an increase of 111 ambulances or 82.8 per cent in fleet size compared to 2020.
  - With the anticipated growth in call volume and the corresponding growth in ambulance fleet size, three more reporting stations will be needed to house the growing fleet. Five new satellite stations would also need to be strategically placed in areas with higher expected call volumes by 2036.

- *Chapter 4: Potential system efficiencies*
  - PRPS should continue to implement process and service delivery improvement initiatives and programs to manage the growing demand.

While a rigorous and comprehensive study has been presented, it should be reiterated that the predictions rely on past trends, 2005 to 2019, and do not factor any future changes to the health care system, improvements in processes that may affect demand and service delivery, or changes to population health. For example, the effects of the current COVID-19 pandemic are not considered in the call volume analyses or on PRPS service implications because the long-term impacts are unknown and not expected to be substantial.

As decisions are made regarding acquisition of additional resources (e.g., ambulances, reporting stations and satellite stations), it is recommended that all call volume projections are re-examined annually to ensure the projected trends still hold into the future. Moreover, to manage growing demand and resource needs, PRPS should continue to implement process and service delivery improvement initiatives to ensure system sustainability, mitigate system pressures and enhance service delivery.

Acknowledgments

This Report was led by staff within the Strategic Policy and Performance Division in Health Services. The names and credentials of this core project team members are provided in Appendix 1. It is important to also acknowledge the expertise and insight provided by key members of PRPS management, as well as subject matter experts, including:

- Peter Dundas, Chief and Director, Paramedic Services
- Daniella Samulewski, Manager, Long Term Care
- Claudia Mititelu, Supervisor, Performance & Quality Management, Paramedic Services
- Michelle Chen, Analyst, System Performance, Paramedic Services
- Daniel Maia, Manager, Logistics, Paramedic Services
- Trevor Smith, Supervisor, Fleet, Equipment and Supplies, Paramedic Services
- Cameron Bloomfield, Specialist, Fleet, Paramedic Services

References

1. Lowthian et al. (2011). Increasing Utilisation of Emergency Ambulances. Australian Health Review. 35, pp. 63-69.

2. Census 2006, 2016, Statistics Canada.

3. Hemson Consulting Ltd., Region of Peel Population, Employment and Dwelling Forecasts by Small Geographic Units and Secondary Plan Areas, May 2019.

4. Hemson Consulting Ltd., May 2019.

5. Peel Data Centre, Peel Building Permit Data, October 2019.

6. Hemson Consulting Ltd., May 2019.

7. Census 2016, Statistics Canada.

8. Hemson Consulting Ltd., May 2019.

9. Hemson Consulting Ltd., May 2019.

10. N. Barry Lyon Consultants Ltd., Intensification Incentives in Peel Region, Phase One: Issues and Opportunities, March 2010. Retrieved from: <https://www.peelregion.ca/planning/officialplan/pdfs/i4i-phase1.pdf>

11. Hemson Consulting Ltd., Region of Peel Ward and Census Tract Population Age Structure Forecast, Jan. 31, 2018.

12. Institute of Medicine (US) Committee on the Future Health Care Workforce for Older Americans. Retooling for an Aging America: Building the Health Care Workforce. Washington (DC): National Academies Press (US); 2008. 2, Health Status and Health Care Service Utilization. Available from: https://www.ncbi.nlm.nih.gov/books/NBK215400/

13. Vegda, K., Nie, J.X., Wang, L. et al. Trends in health services utilization, medication use, and health conditions among older adults: a 2-year retrospective chart review in a primary care practice. BMC Health Serv Res 9, 217 (2009). https://doi.org/10.1186/1472-6963-9-217

14. Lowthian et al., 2011

15. Canproj — The R package of cancer projection methods based on generalized linear models for age, period, and/or cohort. Alberta Health Services: 2011-12-16

16. Hemson Consulting Ltd., May 2019.

Appendix 1: Project Team Profiles

Brian Laundry, Director, Strategic Policy and Performance, has over 30 years experience in research, business and policy analysis, strategic planning, and has held senior management positions in the areas of occupational health, primary care, public health, and home and community care, working at the local, provincial and health system (LHIN) level. He has an Honours BSc in Human Kinetics from the University of Guelph and a MSc in Community Health and Epidemiology from Queen's University.

Soma Mondal, Manager, Health Intelligence and Analytics, has over 15 years of experience in the health and health care research sectors, with expertise in policy development, program implementation, and analytics. She has an Honours BSc, a MSc in molecular biology, and a PhD in developmental neurobiology from the University of Toronto.

Patrycja Kolpak, Health Data Analyst, Health Intelligence and Analytics, has over 7 years of experience conducting specialized analyses in the Public Health, Epidemiology and Health Care sector. She has a BA from the University of Toronto and a Master's degree in Spatial Analysis from Ryerson University.

Roxana McCall, Specialist, Health Intelligence and Analytics, has over 11 years of experience in the development, analysis, and interpretation of statistical output and data in health-related fields, in both pharmaceutical and government sector. She has a BSc in Statistics and an MSc in Biostatistics from the University of Western Ontario.

Faraz Zaidi, Advisor, Health Intelligence and Analytics, has over 15 years of experience working with data and analytics. He has a B.S. in Computer Science from the University of Karachi, a Master's degree in Algorithms and Complexity from the University of Montpellier, a Master's degree in Software Engineering from MAJU University, and a PhD in Data Mining and Visual Analytics from the University of Bordeaux.

David Kelly, Health Data Analyst, Health Intelligence and Analytics, has over 20 years of experience compiling and analyzing data. He has a BA from Brock University and a Research Analyst Graduate Diploma from Georgian College.

Hongcheng Zeng, Specialist, Health Intelligence and Analytics, has over 15 years of experience in geospatial analysis, data modeling, and optimization. He has worked in diversified disciplines in universities, research institutes, banks and governments. He has a BSc in geography from Chongqing Normal University, a MSc in cartography from Chinese Academy of Sciences, and a PhD in geographical information systems from the University of Eastern Finland.

Appendix 2: Data Notes

Definition of PRPS calls

- PRPS calls in the context of this analysis are defined as ambulance dispatches.
- It is important to note that if one person calls 911 requesting an ambulance and 3 ambulances are dispatched for that particular call, with the first one arriving on scene providing the care and the other two returning to base, this would be counted as 3 calls.

Data constraints added by Health Intelligence and Analytics on ADRS data:

- Has an appropriate date and time recorded for when ambulance was notified
- Call must have originated within Peel
- Excludes calls where a RRU was also deployed
- Must have an appropriate Priority Code, which indicates the level of severity for a call

Appendix 3: Technical Specifications of Forecasting Methods

Age-Period negative binomial log regression model with age-specific trends (AP model) for estimating future calls	
Description	A modified Age-Period-Cohort model (APC model) was used to produce long term forecasts of call volume. An APC model is a regression model which uses three main factors and their interactions with each other in the calculation of future estimates of the outcome of interest (in our case, calls). The three factors are: • Age - the most important factor which affects risk for calling an ambulance as certain age groups have a greater propensity to access paramedic services (e.g., seniors). • Period effects - correspond to events that change risk regardless of the age group and are usually due to a changing environment (e.g., the introduction of a certain program may affect the call volumes by decreasing them, or the COVID-19 pandemic will slow down the increase of call volumes throughout all age groups). • Cohort effects - represent risk factors that are shared by a specific cohort as they age together and can be considered as “that which is due to early nurture” (e.g., baby boomers or millennials are likely to have different behaviours than older generations and may be more likely to call for an ambulance due to the fact that they are more used to getting their needs met as quickly as possible).
Data and Sources	Calls Data • Yearly ADRS calls, 2005-2019 • Yearly iMedic calls by five-year age groups, 2005-2019 • Yearly calls by five year age groups were estimated by calculating the yearly age distribution of iMedic calls and applying it to the yearly ADRS calls. Population Data • Yearly Peel population estimates by five-year age groups from Statistics Canada, 2005-2019 (intercensal populations were estimated through linear interpolation) • Yearly Peel population forecasts by five-year age groups from Hemson Consulting 2020-2041 (intercensal populations were estimated through linear interpolation)
Method Details	Various types of APC models were tested. Statistical tests for goodness of fit were used to assess the validity of the models. A negative binomial APC model with drift was a good fit. However, the model had issues that were brought on by: • Overfitting: too many model terms for the number of observations which can lead to unreliable estimates. • Evidence of a linear dependency of cohort and period Various methods were tried to fix the issues in the final model • Aggregating data

	• Changing the cohort calculations • Changing the p-value used for statistical tests When removing the cohort, the model is improved. This could be a result of the fact that cohort effects are already included in the population estimates. Some methods work better for data with higher counts, such as what we have for PRPS calls. One such method is: a Hybrid method. For our data, this is: a negative binomial Generalized Linear Model (GLM) with the following predictors: • Age Group as a factor • Age Group (factor) * Period (continuous) • Offset of population size The AP model uses three-year aggregated data to avoid overfitting of the model which can lead to unstable estimates.
Measures of Model Fit and Model Accuracy	Goodness of fit test shows a p-value of 0.0017, suggesting a very good fit.
Assumptions	A zero per cent attenuation of trend for the first five years of projections and a five per cent attenuation of trend after that. These represent the default settings. Other trend attenuation statistics were tested and no significant changes in projections were noted.
Findings and Interpretations	Many different models were tested however this was the only model to account for historical trend as well as the key call volume drivers of population growth and aging without overfitting and producing more reliable predictions.
Method Strengths and Limitations	It uses the effects of the historical trend, population growth and aging in its calculation of the future call volume and the model fits the data very well. The projections will change as more data becomes available.
Relevant Citations	Canproj — The R package of cancer projection methods based on generalized linear models for age, period, and/or cohort. Alberta Health Services: 2011-12-16 Cancer Projections Network (C-Projections). Long-Term Projection Methods: Comparison of Age-Period-Cohort Model-Based Approaches. Alberta Health Services: 2010-12-xx

Geographically Weighted Regression	
Description	Geographically weighted regression was used to determine where call volume is expected to grow spatially by SP area across the Region of Peel. This method fits a regression equation to every SP area that is weighted by the values in the surrounding SP areas (Fotheringham et al., 1998). The weight captures the varying geographic relationships and patterns related to population (e.g., employment and residence) by considering that neighbouring SP areas (those that share borders) are more similar than those further away.
Data and Sources	1. Total 2018 employment and residential unit counts at the SP area level, Small Geographic Unit Forecasts, Hemson Consulting Ltd., May 2019. 2. Count of total non-residential building permits at the SP area level, Region of Peel, Peel Data Centre, October 2019. 3. Count of total calls at the SP area level, ADRS, 2019.
Method Details	The regression model equation fitted to each SP area: $y_i = \beta_0 + \beta_1 x_1 i + \beta_2 x_2 i + \ldots + \beta_n x_n i + \mathcal{E} i$ With the estimator: β’(i) = (XTW(i) X)-1XTW(i)Y In the equation, regression coefficients (β) were determined for the total count of residential and commercial units (β_1) and the total workforce population (β_2) in order to predict call volume (y_i) while accounting for error (Ɛi) at each SP area. The estimator represents the matrix of weights (W(i)), which is specific to each SP area (i) and applied to the regression coefficients (β). Consequently, the observations (SP areas) nearest to i are weighted more than observations further away. The main parameter used to create and apply the matrix of weights to each SP area is the shape and extent of the ‘bandwidth.’ Bandwidth is a number that defines how each SP area is related to one another (also known as neigbours); it can be a distance-based or absolute count measure. Given that the SP areas are irregular in shape and size, especially in Caledon, the average number of neighbours were specified as the bandwidth; the average number of neighbours is six. Neighbours represent SP areas with shared boundaries. In this case, the average count of neighbours ensures that call volume predictions for each SP area should be weighted against independent values in at least six surrounding SP areas.
Measures of Model Fit and Model Accuracy	The model produces various measures to determine the overall fit/accuracy; these include: R^2, Adjusted R^2, Akaike Information Criterion (AIC), and Residual Squares. For each SP area, coefficients, residuals, and standard errors are computed.

Assumptions	Assumes that the dependent (call volume) and independent variables (total residential and commercial units, and workforce population) exhibit spatial patterns and are spatially related.
Findings and Interpretations	The Model produces a table with predictions for each SP area, along with the Local R, residuals, standard errors, and standardized residuals. Such measures determine which areas are over- or under-fitted. The SP areas surrounding and representing Toronto Pearson Airport area and two SP areas in Caledon (Caledon Rural Area and Tullamore) were found to be outliers, and so, required adjustment to ensure predictions are not conflated.
Method Strengths and Limitations	Results subject to the Modifiable Area Unit Problem (MAUP), wherein the results are influenced by the spatial unit chosen and the bandwidth parameter; any change in the spatial unit or bandwidth will produce different results. Model does not account for outliers well. The SP areas at and surrounding Toronto Pearson Airport needed to be adjusted given the large spike in calls at the Airport itself, with little to no calls in some of the neighbouring SP areas.
Relevant Citations	Brunsdon, C., Fotheringham, S. and Charlton, M. (1998). Geographically Weighted Regression-Modelling Spatial Non-Stationarity. *Journal of the Royal Statistical Society. Series D (The Statistician)*, 47:3, 431-443. ESRI. (2018). Geographically Weighted Regression (GWR). Retrieved from: http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-statistics-toolbox/geographically-weighted-regression.htm