Analyzing citizens' needs during an extreme heat event, based on 311 service requests: A case study of the 2021 heatwave in Vancouver, British Columbia

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ABSTRACT

Heat waves are becoming more common and intense with global climate change, which requires deploying resilience strategies of governments to prepare for long-term trends of higher temperatures and carefully plan emergency responses for such extreme heat events. The British Columbia province of Canada is one of the regions severely affected by extreme climatic events in 2021, which resulted in several deaths and put hundreds of thousands of people scrambling for relief. This study examines the public reactions to one of these extreme climatic events, the 2021 Pacific Northwest heatwave, in a non-emergency service request platform to uncover the types of municipal service needs during severe climatic disasters. City of Vancouver 311 system data is used to identify the impact of the heatwave on the frequency and types of service needs and examine the significance of the relationship between climatic conditions and the non-emergency service volumes.

Keywords

Extreme heat, 311 calls, weather-related variables, time-series analysis, hazard preparedness.

INTRODUCTION

Extreme heat exposure as a result of the interactions between heat waves and urban heat islands can affect citizens' lives and well beings in various ways. Such effects range from thermal discomfort in urban areas to heat-related health issues and even fatalities (Curriero et al., 2002; Yang et al., 2019). The extent of such circumstances has put heat-related hazards among one of the most life-threatening natural disasters (Luber & McGeehin, 2008). With global climate change and growing urban populations, the risk of heat exposure fatality is expected to become even more severe (Basu & Samet, 2002). Along with health-related issues, during an extreme heat event, multiple breakdowns might take place, which can interrupt citizens' normal life. One of the renowned examples of such a situation is the Chicago heat wave in 1995, in which, due to intensive heat exposure, 739 people lost their lives, thousands of cars broke down, several roads were blocked, and many citizens experienced extremely unfavorable thermal conditions both in indoor and outdoor environments (Klinenberg, 2003).

To cope with the adverse impacts of extreme heat risk and increase the resiliency level, several actions before, during, and after the disaster should take place. Reducing vulnerability through different measures, accurate forecasting systems, effective risk communications and warning systems, emergency services, and rescue operations are some of the well-known needed actions for the mitigation, preparedness, and response to extreme climatic events (Godschalk, 2003; Cutter et al., 2008; Menoni et al., 2012). However, the uncertainty associated with natural disasters necessitates higher levels of intricacy in identifying the required actions to increase resiliency in the face of fatal natural disasters such as extreme heat. Although well-established actions for mitigation, adaptation, and response to extreme heat exist in theory and practice, the ongoing heat-related damages and fatalities in recent years require some critical shifts in prevailing approaches. To proceed with such a shift

and fulfill the intricacy needed for identifying required actions to increase extreme climatic events resiliency, in this study, we propose some types of bottom-up approaches using the public service requests made by citizens. To this purpose, non-emergency 311 service calls made by citizens can be a great platform for scrutinizing which types of requests are more demanding during severe climatic situations such as extreme heat events.

Recently, researchers have been paying careful attention to 311 systems and their potential value in supporting the disaster management efforts of local governments. The availability of detailed historical and timely data on non-emergency service inquiries enables identifying critical shifts in information and service needs before, during, and after crises, allowing practitioners and researchers to uncover required actions to increase communities' resiliency to such extreme events (Baghersad et al., 2020; Pamukcu et al., 2021; Pamukcu & Zobel, 2021; Wu, 2021). Schellong and Langenberg (2007) highlight the benefits of 311 systems in providing continuous and up-to-date information and services during disasters. Moreover, O'Brien (2016) points out the information reporting feature of this system, where citizens can effectively participate in disaster management by identifying and reporting disaster consequences via the 311 system to speed up the damage and needs assessment activities for improved resource utilization and efficient disaster response. Zobel et al. (2018) note that 311 data help characterize the multidimensional community resilience by examining the changes in non-emergency request behavior of people. Pamukcu et al. (2021) analyze Orange County (Florida) 311 service requests during the COVID-19 pandemic and highlight the system's potential to provide relevant information to the community and uncover specifics of how the community reacts and responds to the evolving disaster situation.

British Columbia province in Canada in 2021 has been struck by multiple climatic shocks, including wildfire, heatwave, and flooding. Those disasters, unfortunately, resulted in many casualties and property damages. Hit by multiple and consecutive shocks in a short period of time indeed affected the resiliency level of the area in the face of consequent disasters. This unique, though adverse, situation makes the study of this area both interesting and important. So, here in this study, by mainly focusing on the most recent heatwave that struck British Columbia province (especially Vancouver) in Summer 2021 and doing a time-series analysis on 311 service calls, we are going to analyze which types of requests arose more in the time span of the recent extreme heat crisis in this area. Moreover, by comparing the number of calls for specific categories of requests during the heatwave period in 2021 with previous years and identifying the abnormal trends, we are going to explore whether there is any statistically significant relationship between the weather-related parameters (e.g., temperature, precipitation, wind speed, etc.) and specific service requests or not. Doing such analysis, besides the promising insights that could provide for extreme heat resiliency and management in the future, can be applied as a new approach for characterizing disasters. Looking for the special patterns in 311 service calls and correlating it with weather-related data may also reveal some information about time periods that were not necessarily recognized as a disastrous event by forecasts, but as a result of compound interactions of different events, might be experienced as a catastrophic situation for particular groups of citizens.

The main objective of the current study is recognizing the most emerging requests of citizens during extreme climatic events (specifically heat waves) and identifying potential requests for increasing preparedness and resiliency during future events. Another goal of this study is to explore the specific weather-related indicators that explain the variations in 311 service requests of citizens and identify the differential impacts of different climatic disasters on request calls. According to these objectives, throughout this study, we will address the following questions: What are the emerged service needs of citizens during extreme heat events? Is there any significant change in the frequency and the type of calls during heatwave stroke in 2021 compared to previous years? Is there any significant relationship between climatic conditions and the frequency of different 311 service needs during extreme climatic events? If so, can climatic predictors be used to predict 311 call volumes during climatic disasters?

Due to the higher global frequency and more severity of extreme heat, addressing the above questions can pave the road for better understanding the burdens of this climate-related hazard on the normal life of citizens, and thus the public service systems. This can ultimately lead to better preparedness of local governments in the face of future events and increase cities' resiliency toward the risk of extreme heat by incorporating extreme heat in hazard adaptation and mitigation plans and enhancing capacities for emergency and non-emergency responses. This study illustrates how an information technology-based government service system can be used to support a city's disaster management efforts by interpreting the emerging service needs of citizens during disasters. The results of this study can be useful for decision-makers and corresponding authorities to increase the required capacities or reutilize available resources in the face of future events. Prior knowledge on citizens' needs and requests during extreme heat events could raise preparedness level and resiliency and prevent the chaos and catastrophic situations during this climate-related disaster.

The remainder of the paper is structured as follows: First, we provide background information about the 311 System in Vancouver, British Columbia. Second, in the method section, we explain our methodological approach to examine the relationship between non-emergency call volumes and climatic conditions. This is followed by the

description of collected datasets. We then provide preliminary analysis results and discussions based on our findings. Finally, we conclude the paper by discussing how our approach of forecasting the non-emergency calls during extreme climatic disasters can improve the City's disaster preparation and mitigation.

CITY OF VANCOUVER 311 SYSTEM

The City of Vancouver, British Columbia 311 non-emergency service center has been providing residents a single point of access to the City's information and non-emergency services since 2009. 311 citizen service representatives deal with requests ranging from animal services to water services from 7 am to 10 pm every day. Currently, the system enables several contact channels for service or information inquiries, including phone lines, VanConnect app, online chat, and City's social media channels. The system also provides an interpretation service in 240 languages.

The City's non-emergency service center typically receives the lowest call volume over the Christmas holidays and the highest when adverse climate conditions hit the region (CBC News, 2018). Even though this system is designed for non-emergency needs, some people still call 311 about their emergency needs in a panic as well. Calling 311 for hazard-related reasons has a wide range, from a notice of smoke in someone's office or a need for help during extreme weather conditions. That is why, during emergencies like a natural disaster or a pandemic outbreak, 311 systems experience significant changes in the call volumes, especially for some request types related to the ongoing crisis (Pamukcu & Zobel, 2021).

TIME SERIES FORECASTING METHOD

Previously, researchers proposed several time-series prediction models to forecast daily request volumes of 311 services during extreme climatic events to help officials and decision-makers identify citizens' needs and thus better prepare for future disasters. For example, Zobel et al. (2018) propose a random forest model to predict the daily average number of requests based on five independent variables: average temperature, temperature range, the occurrence of snow, day of the week, and holidays. The authors used this prediction model to evaluate the effect of disaster events based on percent deviation from the historical expected number of requests. Differently, Madkour (2020) applies a decomposable time series model to estimate call volumes for the future hurricane season based on the historical hurricane seasons. However, none of these studies focus on a heatwave, which is another severe climatic disaster, to address the emerged service needs of citizens during extreme heat events and to identify the specific climatic indicators of daily non-emergency call volumes.

In this study, we conduct a time-series analysis to observe fluctuations in the non-emergency call behavior of Vancouver residents during an extreme heat event. By analyzing the number of different categories of calls during the heatwave period in 2021 and throughout the corresponding months (June and July 2021) and comparing it with call requests in similar periods in previous years, we are going to investigate whether the heatwave affected the number of those categories of calls in a significant way or not. Additionally, we examine the significant relationship between non-emergency call volumes and climatic conditions by conducting a time series regression analysis. In time series regression models, through analyzing the variance of corresponding weather-related parameters (maximum temperature, total precipitation, and maximum gust speed) and the model response (i.e., different categories of calls), we calculate a standardized regression coefficient (SRC) to quantitatively measure the influence of weather-related conditions on the specific categories of 311 call request volume during each month.

Data Description

For our analysis, we collected two main datasets. First, Vancouver 311 call requests, and second, Vancouver weather-related data. We obtained historical data of both needed datasets, the details of which are provided below.

Vancouver 311 data is obtained from the Open Data Portal of the City of Vancouver[1]. The portal provides multiple datasets extracted from the Vancouver 311 case management system, including 311 contact center metrics, case location details, case volumes, and interaction volumes datasets. These datasets include a variety of information such as the number of calls presented, the number of calls handled by Customer Service Representatives, the number of abandoned calls, the average speed of answer and service level, incident location, case type, responsible department, division, and intake channels. Investigations on these datasets revealed a total of 9,017,869 unique calls offered since 2009. Based on the records, in 2021, Vancouver 311 received 406,745 calls and handled 377,181 of these requests with an average answer speed time of 66.7 seconds.

[1]https://opendata.vancouver.ca/explore/?q=311&disjunctive.features&disjunctive.theme&disjunctive.keyword&disjunctive.data-owner&disjunctive.data-team&sort=modified

We also obtained the historical weather data for the area of interest from the Government of Canada's website[2]. Historical weather datasets available on this website provided us with daily and hourly weather information, such as temperature, precipitation, relative humidity, wind speed, and direction, as well as the monthly summaries, averages, extremes, and Climate Normals. Both hourly and daily datasets are available for the time period between 2014 and 2021. In this paper, we used the 2021 daily weather data, first, to show the extremity of the heatwave in 2021 and second, to discuss the significance of daily weather conditions on variations of citizens' daily non-emergency requests. We specifically used the West Vancouver station (climate id: 1108824), located 8.3 km away from the Vancouver city center, for extracting the needed daily weather-related data for our analysis. Choosing this station's dataset took place based on comparing different stations' reports during extreme climatic events. For example, for the case of the Summer 2021 heatwave, we noticed that the West Vancouver station captured the temperature extremity during the heatwave period more accurately compared to nearby stations.

To study the daily call volumes for each category of requests, we employed monthly case location datasets, which provided us with information such as the time and duration of each call, type of request, the pertained division and department of each request, and also the local area including the street name and the block that the request was asked for. We used these datasets, which are available for each month, to calculate the daily total number of calls in 2021 (and 2020, for exploring significant changes and trends) for each category of requests. We then merged this information with the daily weather-related dataset to build our regression model.

PRELIMINARY ANALYSIS RESULTS AND DISCUSSION

This study examines the effects of the 2021 heatwave on the City of Vancouver 311 non-emergency system. The Pacific Northwest United States and British Columbia province of Canada experienced the record-breaking extreme heatwave between June 25th and July 2nd of 2021, resulting in a death toll in the hundreds and hundreds of thousands of people seeking relief. A small town, Lytton in British Columbia, experienced the extreme and set Canada's new national record of 49.6 degrees Celsius. The heatwave was so far outside of the range of normal (Isai et al., 2021). The extreme climatic disaster brought a new public health concern while the authorities were still challenged by the ongoing coronavirus pandemic. The average number of daily sudden death incidents was severely increased, and extreme heat was reported as the contributing factor to most of those cases ("Canada Weather," 2021).

To show the extremity of the heatwave, we conducted a time series forecasting model - the Seasonal ARIMA model - to predict the daily maximum temperatures for 2021 based on the historical weather dataset. Specifically, we used the daily maximum temperatures of years from 2014 to 2020 and calculated the forecasted temperature in Celcius and resulting 95% upper and lower bounds for a model with RMSE=3.31. Figure 1. illustrates the actual and forecasted temperature values for the time interval from April 1st to September 30th of 2021. The estimates support that the heatwave far exceeds the historical records and predictions. The temperature was 20 degrees above the expected daily maximum temperature during the extreme heatwave, which was also above the statistical upper limits.

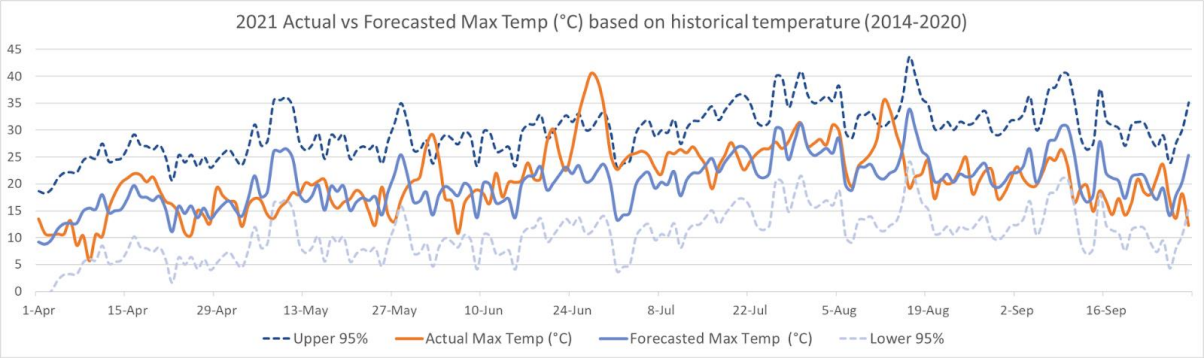

Figure 1. Forecasted maximum daily temperature in West Vancouver based on the historical data from 2014 to 2020

In order to respond to this situation, the emergency alarmed many City services to cope with the effects of the heatwave. The police and wildfire departments urged extra officers and personnel to deal with the crisis. Also, the city redeployed many additional officers to manage increased volumes of emergency calls that run out of available resources ("Canada Weather," 2021).

Although it is for the non-emergency needs of Vancouver citizens, the 311 system also experienced a significant increase in volumes of some call types during the extreme heatwave period. Figure 2 below illustrates the sudden

[2] https://climate.weather.gc.ca/

increase in 311 total number of calls during two consecutive extreme climatic events in Vancouver.

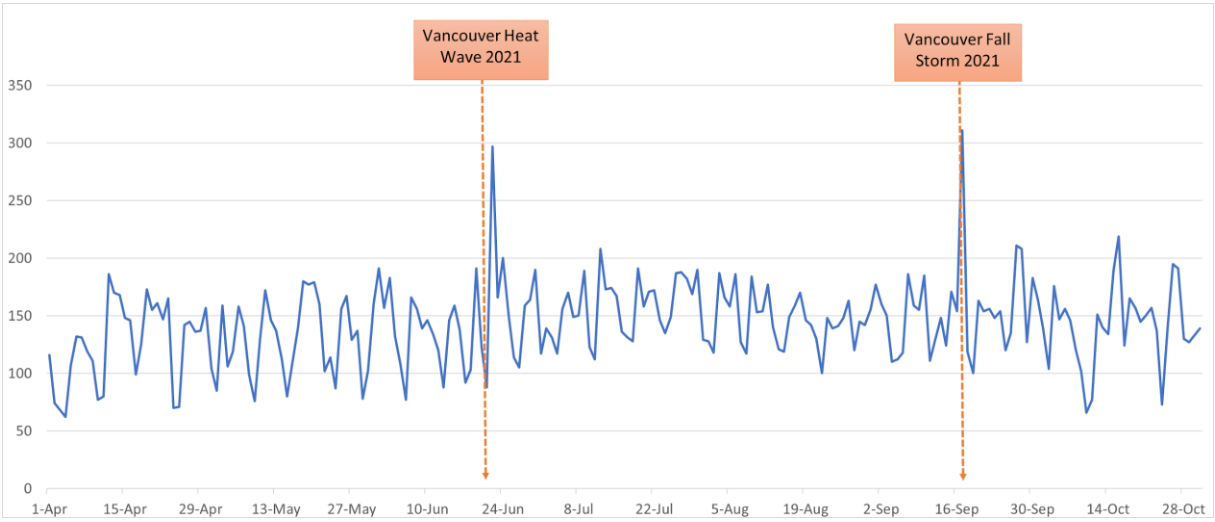

Figure 2. Daily total number of 311 non-emergency service requests in 2021 (from 04/01 to 10/30)

To gain a better insight into the categories of 311 call requests during the months with the highest temperature (June and July), we plotted the frequency tables of 311 calls based on the case types (Figure 3). According to this figure, in June and July 2021, the most frequent call requests were related to the noise complaints, abandoned vehicles, and dead animal pick-up cases that mainly were related to the streets, inspections, sanitation operations departments, and divisions. In July 2021, the number of noise complaint calls had a significant increase (compared to the previous months in the same year and the same month during the last year). Scrutinizing on the details of this category of calls showed that many noise complaints calls were concerned with noises from mechanical equipment (e.g., air conditioner or fan vent). An increase in the use of such equipment during days with high temperatures can explain the higher number of calls during this period. Moreover, throughout this month, water conservation violation calls also had a sudden rise. Such calls were mainly related to the reports of water usage violations such as water overuse or lawn sprinkling outside of the legal hours (4 am to 9 am). The higher sensitivity of citizens toward the water and water shortage concerns during days with extreme heat might be the main reason for such a spike in this category of calls.

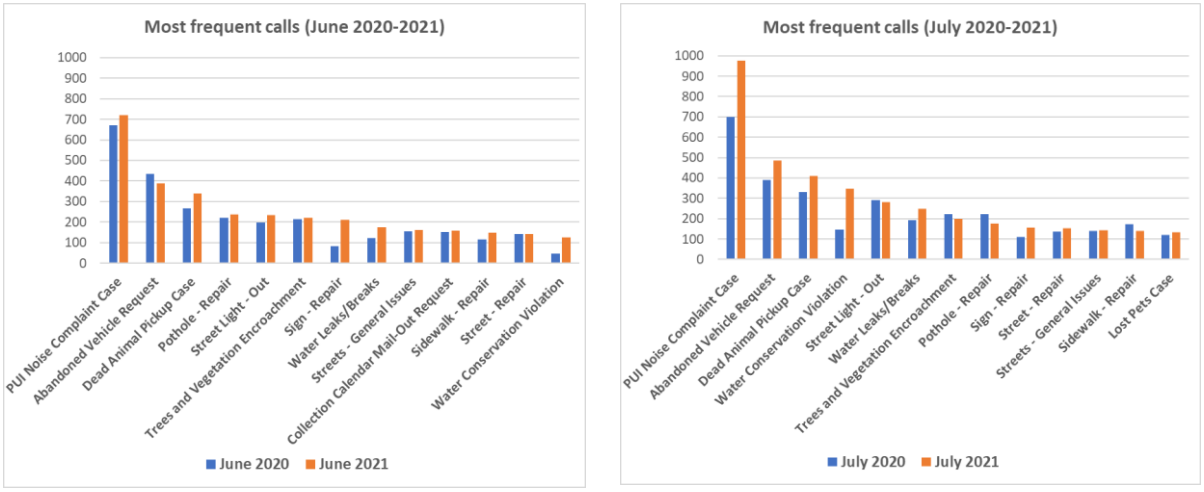

Figure 3. Vancouver 311 call volumes by case types in June 2020-2021 (left) and July 2020-2021 (right)

In table 1, we compared the daily number of calls for each type in June and July 2020 (using the student t-test), with the daily number of calls for each case type in June and July 2021. As it is reflected in this table, the frequency of the most common case type calls in 2021 (such as noise complaints, water conservation violations, and dead animal pick-up cases) was significantly higher than in the previous year.

To explore to what extent the call types and volumes are contingent on the climatic conditions, we also did a time-series analysis on the weather-related data and built a regression model to examine the meteorological parameters' impacts on changing the number of calls for two categories of calls which we found significant increase compared

to the previous year (i.e., noise complaint case and water conservation violation). For this purpose, we used the standardized regression coefficient (SRC) as a sensitivity index to quantitatively measure the influence of three weather-related variables (daily maximum temperature, maximum gust speed, and the total precipitation) in each month on the total number of noise complaints and water conservation violation daily calls. Regression analysis for each month for these two categories of calls is presented in Figures 4 and 5. As noise complaint and water conservation violation calls had the most net changes compared to the previous year (Table 1), and since we couldn't find a meaningful relationship between the annual standardized regression coefficients (SRCs) changes of three other case types (i.e., sign/repair, dead animal pick-up case, and water leaks/breaks) here in this study, we just reported the SRC changes of the first two call types (i.e., noise complaint and water conservation violation calls).

Table 1. The case types having most significant changes in the average number of daily calls in June and July (from 2020 to 2021)

	Average Number of Daily Calls		
Case Type	2021	2020	Net Change
PUI Noise Complaint Case	27.8	22.5	5.33*
Water Conservation Violation	7.7	3.2	4.54**
Sign - Repair	6.0	3.2	2.82**
Dead Animal Pickup Case	12.3	9.84	2.44*
Water Leaks/Breaks	6.9	5.16	1.72*

** p-value < .001, * p-value <.01

As it is shown in figure 4, the greatest influence of weather-related variables on the volume of calls related to the water conservation violations in 2021 happened during the summer. With the increase in temperature, the number of calls related to this category had an upsurge (positive SRC values). However, the increase in precipitation and wind speed had a negative impact on the volume of this category of non-emergency calls (negative SRC values). This issue confirms the strong contingency of citizens' non-emergency call requests on the climatic conditions.

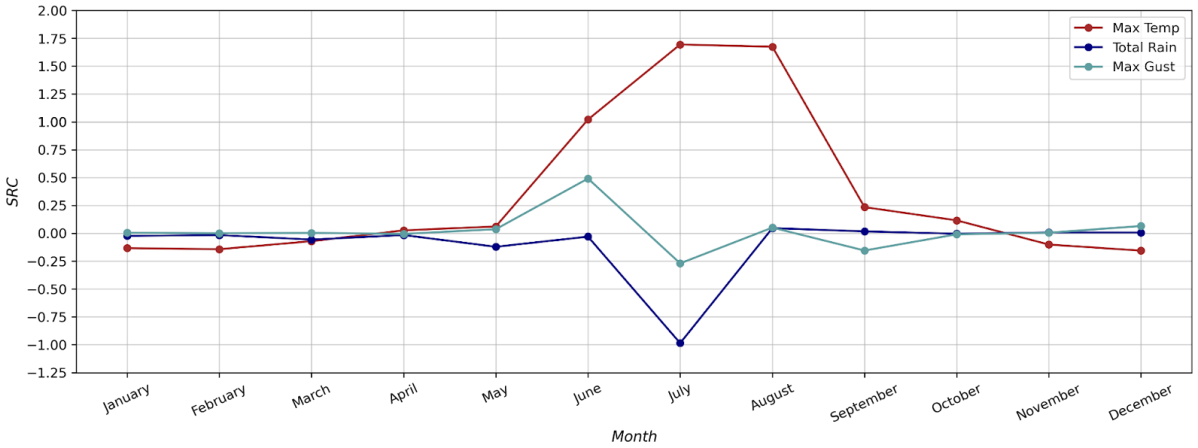

Figure 4. Influence of weather-related variables on the volume of calls related to water conservation violations

We also need to mention here that the out-of-range value of SRC during July and August happened due to the significant daily rise of this category of calls on certain days during these months. Those surges acted as outliers in our regression model. Our closer look at the water conservation call volumes showed that the spike in this category of calls exactly started with the beginning of the heatwave event in late June. However, this category didn't receive significant call requests during other seasons, which might be why the SRC values during other months are close to zero.

Another category of calls that we examined the impact of climatic situations on its volume was noise complaints. In figure 5, we plotted the SRC values of the three considered weather-related parameters in changing the number of calls in each month. According to this figure, in July 2021, the volume of noise complaints was strongly dependent on the temperature. Scrutinizing the datasets also showed that during this month, the number of this specific category of requests had a significant rise on specific days. As discussed earlier, this issue can be attributed to the air conditioning and fan equipment noise during days with high temperatures. It should also be noted that the small SRC value of temperature during June is due to the fact that the extreme heat event happened in the last days of this month, thus in the regression analysis, due to the limited number of observations, the impact magnitude of climatic situations didn't reflect well throughout this month.

Our exploration of other categories of calls revealed that water-related requests (such as water leak and repair) were significantly dependent on the weather-related variables. Moreover, we observed that different climatic variables such as maximum temperature and total rain usually had inverse impacts on the total daily calls of different categories, especially during the summer.

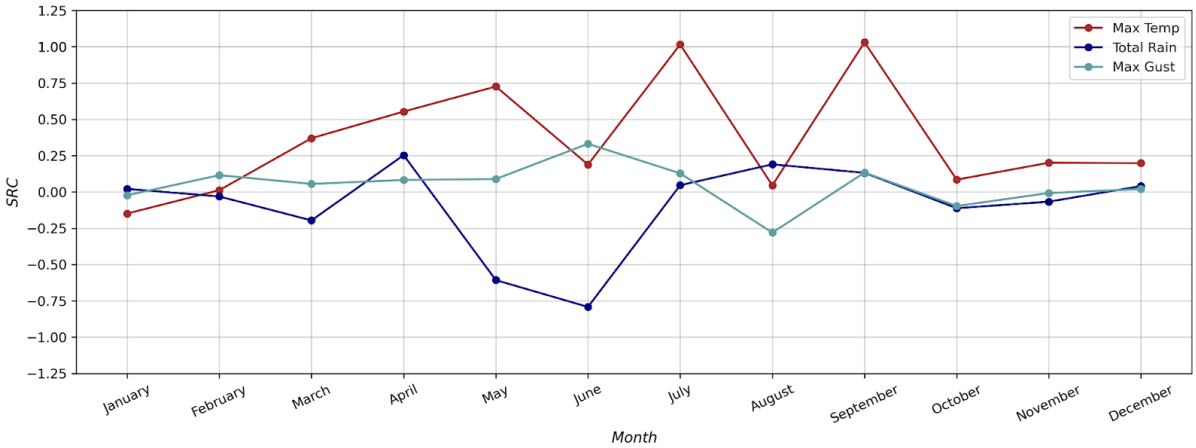

Figure 5. Influence of weather-related variables on the volume of calls related to noise complaints

CONCLUSION

In this study, we tried to analyze the most frequent non-emergency needs and requests during the heatwave in Summer 2021 in Vancouver and the period with high temperatures in this city. Our results revealed that specific types of 311 calls had significantly higher volumes during the heatwave period. The closer examinations showed that the frequency of these categories of calls notably depends on the weather-related variables such as temperature, precipitation, and wind speed. This issue further demonstrated why there were monthly and seasonal variations in the volume of different call categories.

Results of this study can be helpful for city officials and decision-makers for increasing preparedness and provisioning of essential capacities to respond to citizens' needs and requests during future extreme heat events. Moreover, as it seems extreme heat still has not been clearly identified and categorized as a high-risk climate-related disaster in the hazard mitigation plans and hazard management agencies of some cities, such analysis can help increase the awareness and sensitivity toward the calamity of this type of natural hazards. As a case in point for Vancouver, although the city has a public safety department responsible for addressing natural disasters and emergencies[3], this department didn't receive significant call volumes during the extreme heat in June and July 2021. Our initial investigations revealed that this issue was due to the fact that the heatwave is not still on the list of possible disasters and preparations of this department. Therefore, we hope the results of this study can contribute to the greater apprehension of extreme heat among public and officials as a disastrous event and lead to the increase of cities' adaptation capacities and resiliency toward the risks and consequences of such events.

FUTURE WORK

In this paper, we tried to introduce our research in progress for analyzing citizens' non-emergency requests during an extreme heat event. As a future research direction, to better understand the true causal relationship between 311 calls and extreme climatic situations such as heat waves, we plan to conduct a time-series analysis on historical service request data of 5 years duration. Such an analysis with the archived data would allow us to compare different call types and frequencies during an extreme heat event with the average of similar time in previous years. In this way, we would provide better insights into the emerging patterns of non-emergency calls during extreme heat events. Moreover, this study can be complemented with some qualitative content analysis on citizens' calls to scrutinize the details of those calls. This can be very helpful for exploring why some types of requests become more frequent during extreme events. This quantitative analysis will help recognize the underlying reasons of non-emergency calls during extreme climatic situations.

Furthermore, to compare citizens' needs during different climate-related disasters such as floods and heavy snowstorms, a comparative analysis can be performed to systematically gauge the application of 311 call analysis in elevating cities' resiliency levels during various climatic disasters. Exploring the specific request patterns during

[3] https://vancouver.ca/home-property-development/public-safety.aspx

particular climatic situations and comparing emerging call types and frequencies can help responsible authorities to identify the differential impacts of different climatic disasters. Such an analysis can further be extended to a multi-disaster context to uncover additional challenges due to the sequential occurrence of multiple climatic shocks.

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