

Urban morbidity in summer: ambulance dispatch data, periodicity and weather

Research Article

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Abstract: Over recent years the impact of weather on human health has become more severe, especially for people living in urban areas. Even though many studies have analysed the impact of weather on human mortality, few have quantified the impact of heat on morbidity, including ambulance response calls. In this study, 13,354 calls collected in the city of Florence (Italy) during summer were analyzed by month, day of the week, hour, and time slot of the day. An objective air mass classification was used to classify days and time slots with similar weather characteristics and a multiple variable analysis was applied to evaluate the relationship between emergency calls and weather. A positive trend was observed in the morning and a negative one during the night for all emergency calls, but only for food poisoning and alcoholic diseases. Calls for cardiovascular events increased in the morning and on hot days. Calls for psychiatric disorders rose significantly with temperature during the afternoon. The total number of calls and those for alcoholic diseases rose during the hottest nights. Our results, which show a clear relationship between ambulance response calls, periodicity, and weather, could contribute to an understanding the impact of weather on morbidity.

Keywords: *Biometeorology • Weather • Health • Periodicity • Summer • Italy • Emergency calls • Ambulance response calls • Morbidity • Urban health*

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1. Introduction

The negative impact of climate change on human health is higher during the summer period, when additional heat-related deaths outweigh the extra winter deaths [1]. This is particularly evident in urban environments resulting from the Urban Heat Island effect and because of the high number of people living there: people living in urban areas are more susceptible to heat than those living in rural environments [2,3]. Heat Related Illness (HRI) includes a broad spectrum of diseases [4]: from a public health perspective, detecting HRI in the early stages of illnesses before they lead to more serious outcomes could enable early intervention, thereby reducing the associated morbidity and mortality [5-8].

Many studies have investigated climate change and extremes on a very large scale or at national levels [9,10], but few have been done on a local scale [11,12]. It should be noted that healthcare systems usually deal with locals, so it is very important to study the adaptation of citizens to the local climate. Studies on the relationship between emergency department (ED) admissions and weather conditions could contribute to the organization of ED via the predicting of fluctuations in the rates of ED use [13-16]. Most of these studies have analyzed the effect of weather by taking only the impact of a single weather variable into account, generally the air temperature, and by considering the weather as a univariate phenomenon. Because weather is the result of complex interactions among different variables, some authors have proposed studies of the relationship

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between weather and health using a synoptic approach described as either “weather types” (synoptic events categorized by pressure patterns and wind fields) or “air masses” (based on a variety of ground weather elements), and by dividing the weather patterns into categories that are an expression of the weather conditions in a particular location [17]. This makes it possible to evaluate the potential synergistic impact of an entire series of weather elements on human health [18-20].

Most of the studies investigated the effect of weather/climate on hospitalizations or mortality for general or specific causes, while only a few considered the effect of weather on ambulance response calls [6,8,21]. Bassil and collaborators [4,5] suggested that 911 calls could capture a greater proportion of the burden of illness than ED admissions. Emergency call data were only analysed in very few studies, and there the main purpose was to investigate the circadian variation of emergency calls [8] or the relationship between weather and extreme health events [4,6,7,21,22]. Other studies investigated the relationship between weather and phone calls, especially to understand the relationship between weather and emotional states [23,24].

The aim of the present study is to analyse the summer emergency calls in Florence (circadian variation and periodicity) and the relationship with weather conditions using an air mass approach. Many authors have investigated the relationship between extreme weather events (heat waves) and health, underlining the benefits of heat-warning systems [22,25]: this study shows the relationship between weather and health during ordinary weather conditions, and the benefits of supporting health structures with biometeorological forecasts.

2. Materials and methods

2.1 Emergency call data

Emergency Call (EC) data were collected from the database of the EC Service of Florence (118 Firenze Soccorso). The total number of ECs during the study period (summer 2005: 1st June -31st August) was 13,354. The EC Service database records calls according to date, time of day, and type of disease (alcoholic disease – EC0; trauma events – EC1; cardiovascular disease – EC2; respiratory disease – EC3; neurologic disease – EC4; psychiatric disease – EC5; neoplastic disease – EC6; food poisoning – EC7; other/non-identified diseases – EC8).

EC data were grouped into daily, hourly, and time slot data. Time slot data were grouped into 4 categories: 1 - night (00:30:01-06:30:00); 2 - morning (06:30:01-12:30:00), 3 - afternoon (12:30:01-18:30:00); 4 - eve-

ning (18:30:01-00:30:00 next day). This was carried out for the total number of ECs and for each single type of disease.

2.2 Weather data

Fifteen minutes of data regarding air temperature (°C) and air pressure (hPa) were collected by a weather station located in Florence. To take the sudden impact of weather on ECs into account, daily weather data were grouped together with those of the previous day (lag 0–1), and the same was applied for the time slot data. The daily weather variables (maximum, minimum and average air temperature; daily temperature range; daily average air pressure and daily air pressure range) were then calculated considering the value collected between 00:00 on the previous day and 23:59 on the same day of the call. The same was applied for each time slot: e.g., the night-time slot values were collected from the previous time slot (evening) and from the same night-time slot. In addition, the climatological anomaly was calculated for the average air temperature as the difference between the daily values previously calculated and the monthly climatological data (1961-1990) of the average air temperature obtained from the website of the National Weather Service for Florence (<http://www.meteoam.it>).

2.3 Statistical methods

A preliminary descriptive analysis of the EC sample was produced by considering the entire sample and also separately according to the type of disease. The distribution of ECs according to the month, day of the week, single hours of the day and time slot was also analysed. In all cases, the statistical distribution of ECs followed a normal distribution and the significance between the mean differences was tested via the analysis of variance (one-way ANOVA) using the Fisher's Least Significant Difference Test (LSD test).

The second part of this study analyses the relationship between ECs and weather. Likewise in this case, EC data were analysed according to the disease classification. To consider the weather as a multifarious phenomenon taking into consideration the simultaneous and complex combination of weather variables, a partitional clustering analysis, the PAM (Partition Around Medoids- k-medoids) methodology was applied to the entire sample of daily and time-slot weather data [26]. PAM provides a graphical display; the silhouette plot proposed by Rousseeuw [27] was used in this study to select the number of clusters and assess how well individual observations are clustered. In this way, we were able to recognize different groups of days (and time slots) associated with specific weather type character-

istics (air masses) in terms of thermal and atmospheric pressure parameters. The General Linear Model Analysis (GLM) was used to analyze the relationship between EC data and the weather type according to the cluster analysis classification throughout the whole day and within each time slot. All the analyses were checked by months and days of the week.

All the analyses were performed using SPSS for Windows, version 15, and the R statistical environment version 2.8.1.

3. Results

The higher number of ECs in the period under examination was related to trauma events (3,668 calls), cardiovascular events (2,351 calls), neurological events (992 calls), and respiratory events (710 calls). ECs for psychiatric diseases reached 3.4% (448 calls), followed by ECs for alcoholic events (266 calls), ECs for food poisoning (180 calls), and ECs for neoplastic diseases (65 calls). ECs related to other/non-identified diseases represented 35% of the overall sample.

3.1 Month, day of the week, hour and time slot in the day, and Emergency Calls

The monthly analysis showed a significant difference between the mean values of the total number of ECs. The mean daily value decreased from June to August (Table 1).

Table 1. Analysis of variance (one-way ANOVA) of emergency calls between months. Values are expressed as mean $\pm$ standard error (SE). Values followed by different letters are significantly different according to the LSD test ($p < 0.05$).

Month	Mean ($\pm$ SE)
June	164.6 ($\pm$ 3.4) a
July	150.7 ($\pm$ 3.2) b
August	120.6 ($\pm$ 3.0) c

The day-of-the-week plots (Figure 1) show that calls drop to a minimum on Sundays and rise again on Mondays. The mean difference is significant between Sunday and all the other weekdays except Tuesdays, whereas there is no difference between ECs occurring on Tuesdays and all the other weekdays.

The hourly analysis of the total ECs (Figure 2) shows a positive trend from 7 am to 11 am, with the highest number of ECs for the day occurring at around 11 am, with 846 calls. After 11 am, the number of ECs decreases slightly until 4 pm. At 5 pm, there is another minimal increase after which the number of calls gradually decreases and remains almost the same until 8 pm. After

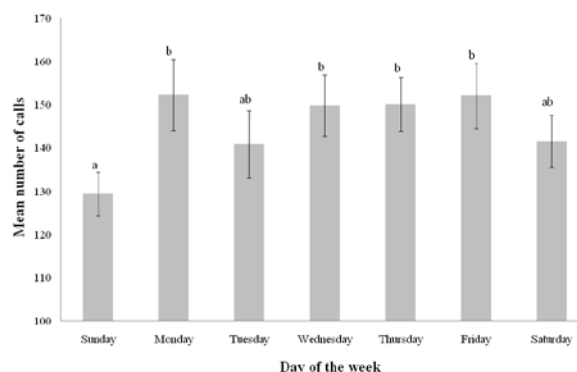


Figure 1. Mean number of Emergency Calls per day with standard error (light bars). Different letters indicate significant differences for $p < 0.05$ evaluated by the LSD test.

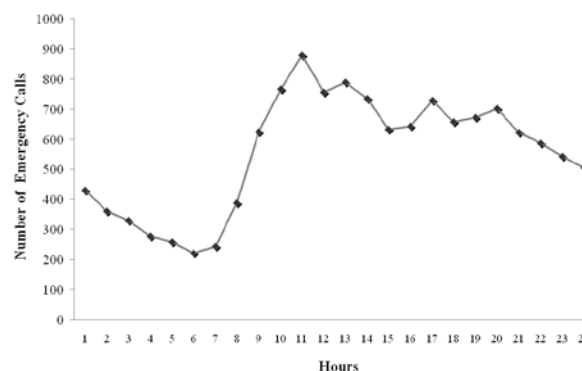


Figure 2. Hourly distribution of Emergency Calls during summer 2005 in Florence.

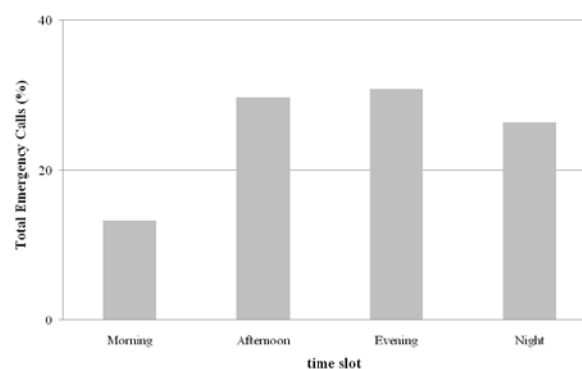


Figure 3 a. Time slot analysis of Total Emergency Calls.

8 pm, the number of ECs decreases again until 6 am when it reaches its lowest values, with 222 calls.

Each disease analysis was then performed by time slot. The time slot analysis of the ECs (Figure 3a) shows a common trend for the total number of ECs and for all the EC categories, with a minimum value in the night-time slot followed by the evening time slot, but only for ECs for alcoholic diseases and food poisoning. In the case of ECs for alcoholic diseases, the minimum

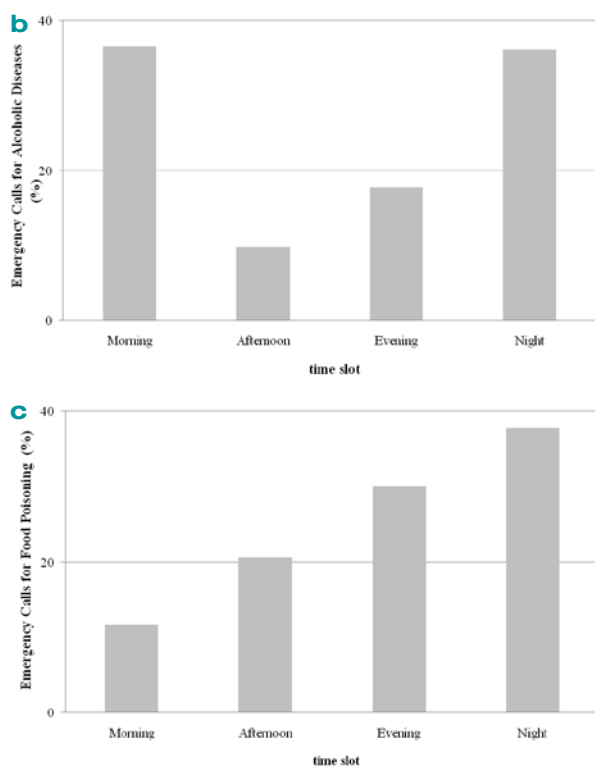


Figure 3 b,c. Time slot analysis of Emergency Calls for Alcoholic Diseases (b) and Food Poisoning (c).

value was observed during the mornings and again in the afternoons (Figure 3b). In the case of food poisoning, there was a positive trend from morning to night (Figure 3c).

3.2 Weather types

The cluster analysis classification grouped together the weather conditions of each time slot (night, morning, afternoon, and evening) and for the whole day. The first cluster (C1 – fresh and stable air mass) always grouped data with lower T_{max} , T_{min} and T_{ave} values, and the third cluster (C3 – hot and stable air mass) with higher values of the same variables. In all cases, C2 (warm and unstable air mass) was the cluster with the lowest air pressure values and the highest variability in the daily pressure range. The cluster analysis of the time slot weather variables showed the same trend (data not provided).

The cluster classification of variables relating to the whole day included the climatological anomaly of average air temperature. Likewise, in this case the highest anomaly was found in cluster no. 3 (C3 – hot and stable air mass) and the lowest in cluster no. 1 (C1 – fresh and stable air mass).

3.3 Weather and emergency calls

Considering the entire summer period (Table 2), ECs for cardiovascular events and psychiatric diseases increased significantly on days with hot and stable conditions. ECs for cardiovascular events increased by more than 3 calls per day, and ECs for psychiatric diseases increased by more than 1 call under the same conditions. By considering the time slots, and excluding the evening, significant relationships were observed between weather and ECs. All significant relationships were positive: with increasing hot conditions, there was an increase in the number of calls. In the morning, a significant relationship ($p < 0.01$) was observed between ECs for respiratory diseases and C2, with an increase of more than 1 call in this time slot on days characterized by warm and unstable conditions. No significant relationship was observed with ECs for respiratory diseases when the whole day or the other time slots were analysed. In the afternoon, a significant rise in the number of calls depending on hotter conditions was observed for neurological and psychiatric diseases. The rise was by almost 1 call both in C2 ($p < 0.01$) and C3 ($p < 0.5$) for neurological diseases, and by almost 2 calls in C3 ($p < 0.001$) for psychiatric diseases. As regards ECs for neurological disease, no significant relationship was observed when the whole day or the other time slots were analysed, whereas the results for ECs for psychiatric diseases confirm those observed for the whole day, with a rise in calls during the hottest conditions.

No relationship was observed between weather and ECs during the evening, whereas at night a significant increase was observed in the total number of ECs with the rise in air temperature. The total number of calls increased significantly in C2 and C3 ($p < 0.5$) with almost the same value of 4 calls, with slightly higher values in C3 than in C2 (4.4 vs. 4.1). Even other/non-identified diseases showed a rise in C2 ($p < 0.5$). ECs for alcoholic diseases showed a significant rise on hot and stable nights.

No relationships were observed between weather and trauma events, food poisoning or neoplastic diseases during the entire summer period or for each single time slot.

4. Discussion

In urban areas, the emergency service must always be on the alert for multiple types of diseases. The results of this study show that emergency calls are significantly correlated to periodicity and weather conditions, suggesting that meteorological forecasts might help local EDs in their daily management.

Table 2. General Linear Model Analysis. Results (mean number of calls) are expressed as parameters for each weather categories (the reference category for the categorical variable is C1). In round brackets 95% confidence interval is indicated.

	ECT	EC0	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	
Total	C2	-0.92 (-10.12;8.15)	0.24 (-0.88;1.36)	-4.29 (-8.73;-0.03)	0.66 (-2.26;3.51)	0.2 (-1.29;1.63)	0.99 (-0.75;2.67)	0.77 (-0.35;1.9)	-0.07 (-0.58;0.45)	-0.15 (-1.04;0.74)	1.01 (-3.72;5.66)
	C3	7.43 (-2.25;17.06)	0.77 (-0.33;1.86)	-0.05 (-4.85;4.68)	3.38* (0.22;6.51)	0.06 (-1.46;1.56)	1.55 (-0.27;3.36)	1.26* (0.16;2.37)	-0.05 (-0.55;0.45)	-0.36 (-1.23;0.52)	0.92 (-3.88;5.68)
	C2	2.39 (-2.81;7.22)	-0.09 (-0.41;0.22)	-2.82 (-6.15;-0.27)	1.58 (-0.38;3.54)	1.45** (0.44;2.46)	1.25 (-0.15;2.64)	0.33 (-0.28;0.95)	-0.28 (-0.63;0.06)	-0.21 (-0.68;0.26)	0.16 (-3.11;3.1)
Morning	C3	0.36 (-4.83;5.24)	-0.21 (-0.52;0.09)	-1.97 (-5.48;1.01)	0.75 (-1.15;2.65)	0.67 (-0.31;1.64)	1.24 (-0.11;2.58)	0.41 (-0.19;1)	-0.32 (-0.65;0.02)	-0.17 (-0.63;0.28)	0.19 (-3.3;0.4)
	C2	0.42 (-3.26;4.05)	0.14 (-0.25;0.52)	-0.91 (-3.03;1.2)	-0.62 (-1.92;0.64)	0.23 (-0.59;1.05)	1.27** (0.4;2.14)	-0.18 (-0.74;0.38)	-0.01 (-0.23;0.21)	0.04 (-0.35;0.44)	-0.09 (-2.17;1.95)
Afternoon	C3	3.81 (-0.96;8.68)	0.10 (-0.38;0.58)	-1.10 (-3.73;1.62)	1.37 (-0.42;3.27)	0.18 (-0.84;1.19)	1.16* (0.09;2.24)	1.56*** (0.87;2.25)	-0.11 (-0.39;0.16)	0.31 (-0.17;0.8)	-0.24 (-2.74;2.34)
	C2	1.99 (-3.4;7)	0.07 (-0.8;0.95)	0.42 (-1.94;2.6)	-0.22 (-2.15;1.71)	-0.29 (-1.37;0.8)	0.50 (-0.73;1.73)	0.60 (-0.22;1.42)	0.25 (-0.11;0.61)	-0.02 (-0.71;0.67)	-0.47 (-4.16;2.76)
Evening	C3	3.11 (-2.16;8.05)	-0.25 (-1.09;0.58)	0.30 (-2.09;2.51)	0.50 (-1.34;2.35)	-0.13 (-1.17;0.9)	0.69 (-0.48;1.87)	0.65 (-0.14;1.43)	0.06 (-0.28;0.4)	-0.62 (-1.28;0.04)	0.76 (-2.82;3.91)
	C2	4.05* (0.69;7.2)	0.29 (-0.5;1.08)	1.67 (-0.14;3.49)	0.33 (-0.62;1.29)	0.33 (-0.35;1)	0.03 (-0.51;0.57)	-0.02 (-0.53;0.48)	0.10 (-0.12;0.31)	0.01 (-0.31;0.33)	2.04* (-0.26;3.93)
Night	C3	4.38* (1.03;7.67)	0.88* (0.08;1.68)	1.48 (-0.34;3.3)	0.59 (-0.37;1.55)	0.21 (-0.46;0.89)	0.14 (-0.4;0.68)	0.08 (-0.42;0.59)	0.07 (-0.15;0.28)	-0.01 (-0.34;0.31)	1.15 (-1.01;3.11)

ECT=total emergency calls; EC0=Emergency calls for alcoholic diseases; EC1= Emergency calls for trauma events; EC2= Emergency calls for cardiovascular diseases; EC3= Emergency calls for respiratory diseases; EC4= Emergency calls for neurologic diseases; EC5= Emergency calls for psychiatric diseases; EC6= Emergency calls for neoplastic diseases; EC7= Emergency calls for food poisoning; EC8= Other/not identify disease. * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The decrease in monthly ECs from June to August highlights the relationship between the number of ECs and the presence of citizens in the city; in fact, the majority of citizens go on holidays in July and August. This result is also confirmed by the analysis of calls on different days of the week: the week analysis supports previous findings of a decline in ECs on weekend days, especially Sundays, with a rise on Mondays [15,24].

The hourly analysis showed the lowest number of ECs between 5 and 6 am, and the highest at 10 am; however, they were also high between 9 am and 7 pm. Similar results were observed in the time slot analysis, with the minimum value of total ECs in the night-time slot. The same trend was also observed when considering the ECs related to the other diseases separately, but only for ECs for alcohol-related diseases and food poisoning. For these two diseases, the highest number of calls occurred during the morning and night slots, respectively. This result underscores the higher probability of the occurrence of alcohol-related diseases and food poisoning after dinner and during the night. Furthermore, alcohol intake is higher during the night, when conditions are usually more relaxed than during the day. The results for cardiovascular diseases confirmed previous studies on ambulatory blood pressure monitoring [28] and the circadian rhythm of mortality for sudden cardiac death, with a primary peak in the late morning, between 9 am and 11 am, and a minor secondary peak in the late afternoon [29].

When considering the weather conditions during the entire summer period, an association was observed between the hottest conditions and the increase in calls, especially for cardiovascular and psychiatric diseases. Results for cardiovascular diseases are consistent with previous findings concerning a rise in hospital admissions during heat waves, especially in persons over 65, who are more susceptible to cardiac problems and less capable of increasing their cardiac output [30].

A significant association between hot conditions and calls for cardiovascular diseases was observed by considering the whole day, but not the single time slot: this suggests that hot conditions have an influence on the total number of calls for this type of disease throughout the whole day, and not at a specific time during the day. The rise in calls for psychiatric diseases in hot conditions is particularly evident in the afternoon: previous studies have revealed a relationship between weather and emotional states since about the middle of the 20th century, but the results have been inconclusive [31]. Nevertheless, seasonal and monthly studies have shown that hospital admissions for psychiatric disorders reach a peak in summer [23]. This analysis helps clarify the effects of extremely hot conditions on patients

with psychiatric diseases; more specifically, this study shows that the incidence of calls for this disease rises significantly during the hours of the day with the highest temperatures.

The relationship between ECs for respiratory diseases and weather was only observed during the morning and on days characterized by warm and unstable conditions. The rise in the morning can be linked to the weather conditions at night, as the weather-type classification includes the weather conditions for this period: this result is consistent with the well-known increased exacerbation of respiratory diseases during the night [32,33]. Generally, the morbidity and mortality peak for respiratory diseases occurs during the winter period [34]; however, these results show that summer days characterized by comfortable conditions might also have an impact on people with these diseases. Under these weather conditions, people tend to spend more time outdoors where they are more exposed to air pollutants and aeroallergens.

Calls for neurological diseases rise with hotter conditions in the afternoon: during the heat waves in Chicago in 1995, an increase in the number of hospital admissions was observed for several neurological conditions [30]. Patients with neurological diseases are in some cases unable to adequately care for themselves and consequently fail to drink sufficient amounts of fluid to avoid dehydration. The lack of a significant relationship between weather types and ECs during the evening could also suggest that extreme temperatures (generally recorded during the afternoon and considered in the weather-type classification of the evening) have an immediate effect on health in people with neurological and psychiatric diseases.

During the night, a rise in calls for alcohol-related diseases was observed in hotter conditions. The intake of alcohol leads to further dehydration [35], and the results of this study show that the alcoholic effects on humans are greater on hot nights.

Throughout the entire summer period, no increases were observed in the overall number of calls on hot days; this result is in contrast with previous findings that an additional strain is placed on human wellbeing during hot, oppressive weather [21]. However, the overall number of calls rose in hotter conditions during the night: this result is extremely significant because it demonstrates that night-time weather conditions are very important for human health and wellbeing. This also supports the results of a previous non-synoptic climate/mortality study suggesting that oppressive night-time conditions after a very hot day might be more stressful than the maximum temperature itself [36]. This result is also highly significant from a climatological point of view: research

conducted in Tuscany, the region where Florence is located, has shown a mean rise of 2°C in both maximum and minimum temperatures over the last 50 years [11]; moreover, minimum values generally occur during the night, with more evident consequences on public health.

In conclusion, the summer period represents an increasing risk for human health because of the increase in extreme weather events due to Climate Change, and public health measures need to be implemented to prevent heat-related illness, especially in urban areas. The results of this study show a clear relationship of weather on morbidity and could be useful for EDs in planning the presence of healthcare workers depending on the time

or time slot of the day, and also according to the weather forecasts. Future work should include a longer period of data collection in order to analyze the effects of both cold and hot conditions on ambulance response calls.

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