Predicting Demand for Government Services during Disaster Events

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ABSTRACT

Smart Service Queensland (SSQ) is the 'front door' to the Queensland State Government in Australia, providing services and information for citizens and businesses. Services are delivered through online channels, call centres and face-to-face service centres. Rostering to adequately staff the call centres during business as usual demand is well supported using existing workforce planning tools and content management systems alongside real-time telephonic monitoring. However, during times of large scale emergency events, such as floods and tropical cyclones, effective workforce planning heavily relies upon experienced SSQ personnel constantly monitoring and updating call centre staffing levels leading up to and during the disaster event to ensure customer demands are met. Achieving the right balance of call centre servicing without over provisioning is a challenging task.

We present a prototype analytics tool that supports the SSQ Forecast Analyst responsible for workforce planning during disaster events and provide initial results of modelling caller behavior during two recent tropical cyclones. The tool provides a single point of reference to a wide collection of relevant datasets, including population demographics and details of the natural and built environment, data feeds describing the emergency event under investigation, relevant social media posts and call centre operations metrics. The tool is an early proof of concept demonstrator highlighting the utility of data integration, web mapping, real-time event monitoring, and predictive modelling.

Keywords

Situation Awareness, Data Integration, Disaster Management, Crisis Coordination.

INTRODUCTION

Smart Service Queensland (SSQ) is the primary contact for customers to access government services in the Australian state of Queensland. SSQ provides access to government information and services 24 hours a day, 7 days a week via a single phone number: 13 QGOV (13 74 68). Calls are answered by experienced Customer Service Advisors (CSAs) who can either deliver government transactions on the phone, forward the enquiry through to the relevant state government department, or direct customers to the appropriate online resources.

SSQ provides a single point of entry to government services so that customers don't need to know which department or agency to contact. Governments are increasingly seeking efficiencies by providing services via online resources in preference to call centres or face to face contact centres. Further efficiencies are obtained by centralizing the citizen/government interface allowing government departments to focus on their core business.

Managing the SSQ call centre involves workforce planning to prepare the roster for CSA staff to answer calls. SSQ have government-imposed targets to ensure customer calls are answered within a reasonable time frame and to meet customer satisfaction objectives. During business as usual operations, rostering is well understood to meet these targets and in 2016/17 SSQ achieved good customer satisfaction results [DISITI 2018]. However, during times of large scale emergency events, effective workforce planning becomes more difficult. SSQ want to understand customer behaviour in times of disaster events and to incorporate this insight into the workforce planning process.

Communities across Queensland are thought to respond to disaster events differently. For example, rural and regional areas with a history of experiencing flooding or cyclone events are expected to be more self-reliant compared to urban areas that have not experienced such events. Demographic and socio-economic factors could also influence the resilience of different communities in times of disasters. A joint project was established with SSQ to explore these issues with the main objectives being to:

1. model SSQ customer call behavior during large scale disaster events; and
2. incorporate the customer modelling into the workforce planning forecasting process.

The rest of the paper is organized as follows. First we introduce background information about SSQ, the workforce planning process, two case studies of recent cyclone events and the SSQ call data. Then the prototype tool we have developed is presented along with a description of the data analysis undertaken. Preliminary results of this work are then presented. The paper concludes with a summary of our findings and plans for future work.

BACKGROUND

Smart Service Queensland during Disasters

In Australia, the states and territories manage emergencies with the police taking command during the response phase where safety and shelter is the main concern. Other front line response agencies are also involved such as Fire and Rescue, Ambulance, and the State Emergency Services. When the scale of the emergency event is beyond the capacity of the state or territory to respond adequately, they will request help from the Federal Government who provide financial and other assistance, such as sending in the army.

In the state of Queensland, SSQ are responsible for taking calls related to state emergencies and community response services. While the community can, and do, contact the front line response agencies directly as needed, most requests for assistance or information do not require direct contact with first responders. For example, as a cyclone or flood event approaches a region, people in the community contact the government to find out where they can collect sand bags to prevent or reduce flood water damage. They also want to determine the latest information about the event, such as where the event has been, where it is expected to go, how severe it is and what damage is expected. Post event enquiries are made about government financial assistance, the location of recovery centres, the status of infrastructure damage and repairs, information about road closures, and so on.

Workforce Planning

One of the tasks of the SSQ Forecast Analyst is to prepare the call centre rosters to allocate CSAs to manage customer enquiries. During times of business as usual, this process is well established and supported using existing workforce planning tools and content management systems in conjunction with real-time telephonic monitoring of calls. The Forecast Analyst has extensive experience of SSQ operations and understands the normal business activities as well as expected seasonal variations in caller demand. For example, during the flu season there is an expected increase in health related calls.

Modelling is done months in advance to predict caller demand, measured as the number of expected calls per 15 minute interval for the queues managed by SSQ. These queues correspond to the categories of customer enquires such as health, public housing, education, transport and motor vehicles, employment, and so on. For our investigation the queues of interest are the state emergency services (SES) and disaster recovery (DR).

One of the SSQ targets is to respond to 80% of calls within 20 seconds. Public demand can rise and fall during disaster events due to numerous factors such as the type and intensity of the event, the time of day, formal public announcements, media coverage, geographic proximity of the event, patterns in social media and telecommunications traffic, preparedness of partner agencies such as Emergency Services and local governments. Information on these factors is often unavailable or received inconsistently. Even when information is timely, it is difficult to determine confidently how or if it will influence demand. Despite this complexity, SSQ Workforce Planners successfully manage demand using capacity over supply and if required, suspension of non-core services. This however, may be accompanied by increased costs, reduced non-emergency related government services available to the public and risk of staff fatigue. Appropriate resourcing to meet customer service demands while not over-servicing is the aim of workforce planning.

Case Studies

The motivation for the project was partly based on the challenges of understanding the public demand for government services via SSQ during two tropical cyclone events: Marcia and Debbie.

Tropical Cyclone (TC) Marcia formed as a category 1 cyclone on 15 February 2015 and went on to become a category 5 event on 20 February which eventually reduced to a tropical low the next day. During this time strong winds, heavy rainfall, flooding and storm tides caused extensive damage across the coastal regions of central Queensland. The Federal Government provided $AU13.77 million in assistance to affected communities and the Insurance Council of Australia estimated the insurance costs to be $AU404 million [ADRKH].

TC Debbie formed on 25 March 2017 and progressed to a category 4 cyclone as it made landfall near Airlie Beach on 28 March having previously devastated resorts on the Whitsunday Islands. It then tracked inland reducing in strength and on 29 March it was no longer considered a cyclone. However it continued inland as a tropical low bringing strong winds and flooding across southern Queensland and northern New South Wales resulting in over ten fatalities. The impacts included damage to more than 2300 residential properties of which almost 1000 were declared uninhabitable. Recovery grants exceeded $AU25 million and damage estimates to infrastructure and industry exceed $AU1 billion [ADRKH].

These large scale disaster events are anticipated by Bureau of Meteorology (BOM) weather warnings which are closely monitored by the SSQ Forecast Analyst to gain an insight into where and when the cyclone is expected to make landfall and at what intensity. This information is used along with call centre data from previous cyclone events to model expected public demand for workforce planning. This modelling is regularly revised in conjunction with weather updates from the BOM and feedback from real-time call centre metrics.

SSQ Data

SSQ provided extensive call data from the SES and DR queues during the period Dec 2012 – Dec 2017. Figure 1 shows the number of distinct calls per day with the three large spikes corresponding to Tropical Cyclones Oswald, Marcia and Debbie. The other smaller spikes relate to large storm or flooding events. Unfortunately TC Oswald could not be included in our analysis due to known data inconsistencies within SSQ.

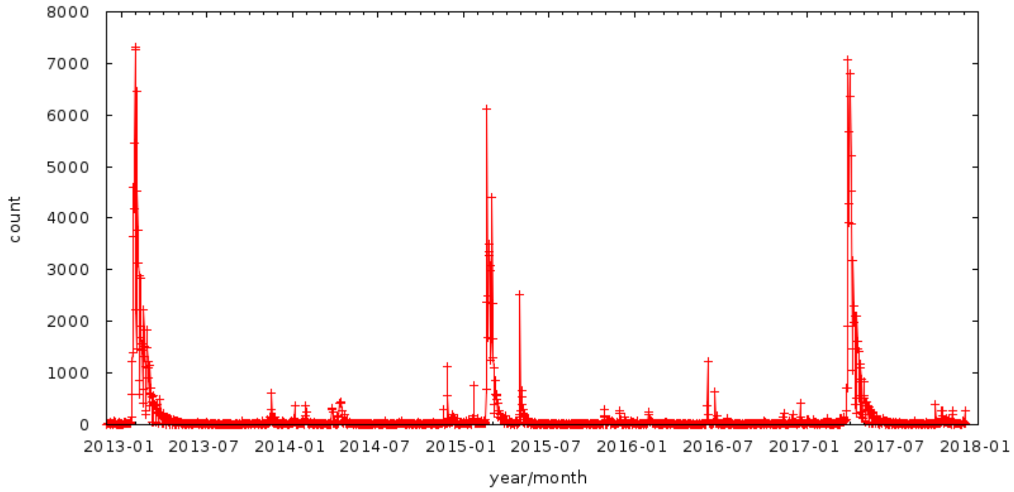

Figure 1: SSQ encounters per day.

This call data includes details of the CSA who took the call, the queue the call came on, how long the call was on hold, abandoned calls (hang ups), call duration and a breakdown of the reasons for the call, termed interactions. Approximately 20% of calls identify the postcode of the caller. This data reflects the SSQ IT systems which include Interactive Voice Response to direct calls to the right queue, a forms based Content Management System (CMS) capturing the caller interactions and real-time call centre phone monitoring.

Related Work

This work is motivated to develop a greater understanding of how different community groups respond in times of disasters. Our focus is to use such insights to model demands for government services while others have explored the same issues for different purposes, for example to reduce disaster risk and loss of life and property [Sendai 2015], increase community resilience [Majchrzak et al. 2018], to inform government policy [Parsons and Morley 2017] and to allocate limited resources more effectively. Our other focus is to explore how to effectively combine various datasets into a single point of view, or common operating picture, also known as decision support systems or system of systems for emergency managemet. [EM-COP, Majchrzak et al. 2018].

THE TASK

Preliminary Work

The initial phase of the project consisted of a number of face-to-face meetings with SSQ to conduct user requirements gathering and needs analysis, in order to understand the business processes of SSQ during disaster events and to refine the project goals. A data gap analysis was also undertaken, where complementary datasets were identified that could be useful for modelling caller behaviour. This data includes weather warnings [Power et al. 2013], BOM Cyclone tracks [BOM], Australian Bureau of Statistics (ABS) demographics and socio-economic data [ABS 2018], building data [NEXIS 2017] and relevant social media content [Power et al. 2014].

Web Portal

The SSQ analytics tool is a map based web application developed by CSIRO Data61 for use by SSQ which integrates information from the numerous data sources noted above using ABS statistical regions [ASGS]. The tool is available at http://ssq.csiro.au/ and requires access credentials which are available by contacting the authors.

The Cyclone interface, shown in Figure 2, provides a cyclone event replay facility where cyclone warnings and call data can be examined in detail. The top left panel contains an interactive timeline of events which can be navigated left or right to more forward or backward in time. It can also be zoomed in/out, which is useful when there are numerous short events within a small time frame. The top Cyclone timeline events are the map-based forecasts that are periodically produced by the BOM when there is an active cyclone. The map on the right automatically displays the "current" forecast map depending on the visible time period within the timeline. Text based cyclone warning information is shown in the Warnings row of the timeline. These are selectable so that the full warning text is displayed. SSQ call data is displayed in the Calls section where each horizontal bar represents an individual answered call. Where possible the call is assigned to one of seven Queensland regions, colour coded to the small map legend on the bottom left. Individual calls can be selected to show more details, including a city if available and the type of call, one of preparing, responding, recovery and other. The type of the call is determined using a rule-based classifier which examines the sequence of CMS pages visited by the CSA during the call. This sequence provides insight into the reason for the call. For example, in Figure 2, the caller is requesting SES assistance, a "responding" call type, and they are enquiring about sandbags.

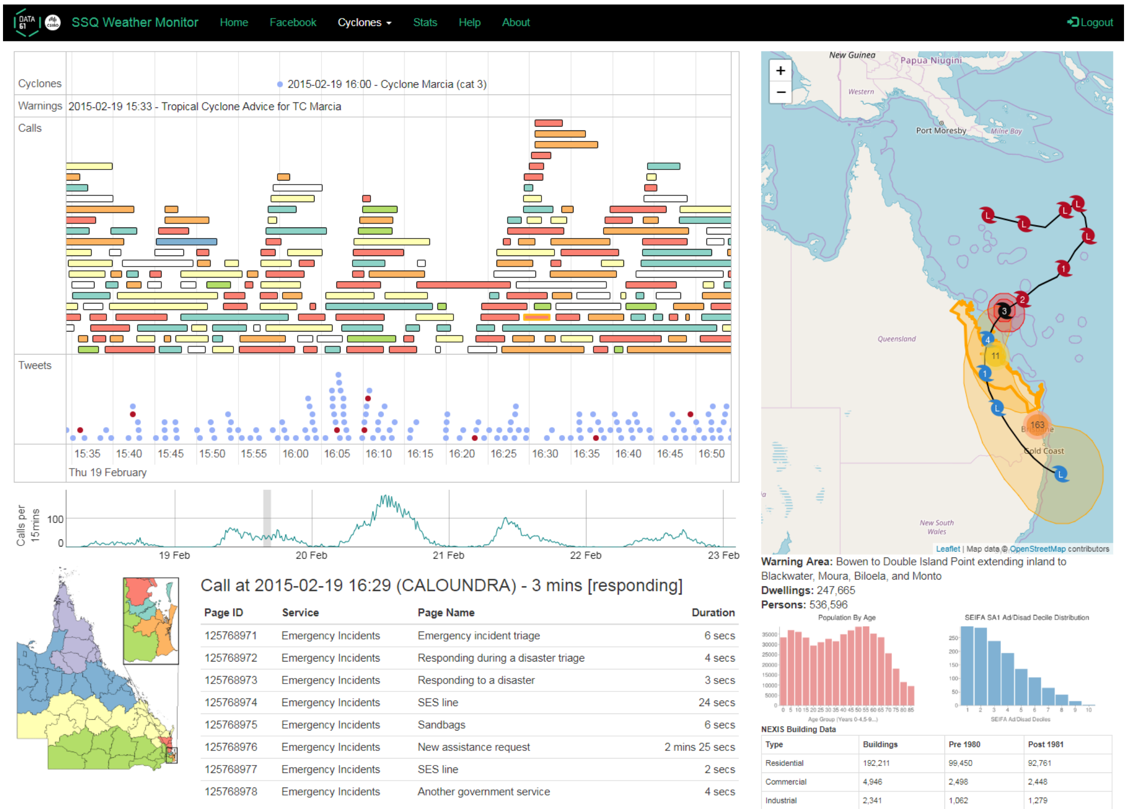

Figure 2: SSQ Analytics tool for TC Marcia.

Below the call data is a Tweets section where each dot represents a Queensland based tweet that contains a cyclone related keyword. Red dots represent tweets that originate within the current cyclone warning and/or watch areas. Each tweet may be selected to view the message, including any associated pictures or videos.

An overview of call volumes over the five day period is displayed below the main timeline showing the number of calls for each 15 minute time window, which can be used to quickly navigate the main timeline. The vertical grey bar highlights the currently visible time period.

The cyclone forecast map on the top right shows the cyclone track (historical locations, current position and forecast path) along with warning/watch areas shown in orange and forecast high wind areas shown in red. Each area on the map may be selected to view more information about the warning, watch or wind area, along with summary information about the population within that area. Demographic data such as the number of people and dwellings, the age distribution and socio-economic status of the potentially affected population is displayed. Building data is also available, including the number of residential, commercial and industrial buildings and the number of those that were built before 1980 when the Australian building codes were strengthened.

METHODOLOGY

Data Analysis

The BOM cyclone data for Debbie and Marcia was combined with the SSQ call data and the other datasets into two large CSV files and processed using the R statistical programming environment [R]. The SSQ SES and DR queue data for the period between 10 days before and 60 days after the cyclone event was combined with the cyclone track information showing the event's location and expected path. Various impact regions can be selected, for example the current cyclone watch area; the current warning area, and so on. Data is also available on the areas currently experiencing damaging or destructive winds, and those expected to experience them within 24 or 48 hours. The corresponding ABS demographics and socio-economic data and details of the built environment for each of these various cyclone impact regions were then calculated, producing a large dataset that was explored in various ways to identify correlations. The two datasets, one for each cyclone event, consisted of approximately 7000 rows and were about 4 MB in size.

As the cyclone track makes landfall and higher population densities are exposed to destructive winds, there is a corresponding increase in calls to SSQ. However, it is difficult to confidently locate these calls due to the lack of supporting caller location data.

The first plot in Figure 3 shows the number of calls per 15 minutes to SSQ during Cyclone Debbie. Note that the axis tick marks represent midnight on the morning of the labelled day. The grey shaded areas show weekends and public holidays; the number of calls was generally much lower on these days (even though CSAs were still available), particularly across the Easter long weekend of Friday 14 April to Monday 18 April, though a spike of call activity did occur on Sunday 2 April. The red line shows the daily trend.

The overall pattern of recovery calls is of a peak followed by approximately exponential decay. Lower numbers of calls are received on weekends and public holidays, while the following workday – usually a Monday – shows a slight increase in calls.

There is a clear pattern of variation within each day: disaster recovery calls fall to zero overnight and peak the following morning, remaining high for most of the day. Very similar variation of call intensity within days was seen on all days, even though the actual number of calls on each day varies widely.

The lower plot in Figure 3 shows the number of calls per 15 minutes, as a percentage of the daily average for cyclones Debbie and Marcia, referred to as the daily seasonality. Most calls occur between 9 am – 6 pm, but calls continue into the evening. There is a gradual decline from 10 am – 5 pm. The patterns are very similar across both cyclone events, especially for disaster recovery calls (black and green lines). More disaster response calls (the SES queue) were made after 6 pm, especially during Cyclone Debbie.

For each call category, the daily seasonality for each 15 minute period is calculated as the ratio of calls to the daily average, averaged across all days:

$$\text{seasonality} = \frac{\sum_{\text{days}} \left(\text{weighting} \frac{\text{calls}}{\text{daily average}} \right)}{\sum_{\text{days}} \text{weighting}}$$

Setting the weighting equal to one gives a simple average across each day, but better results are found by weighting according to the daily average number of calls, so that call patterns on busier days carry more weight in the calculation. The seasonality for each 15 minute period is thus simply $\frac{\sum_{\text{days}}(\text{calls})}{\sum_{\text{days}} \text{daily average}}$.

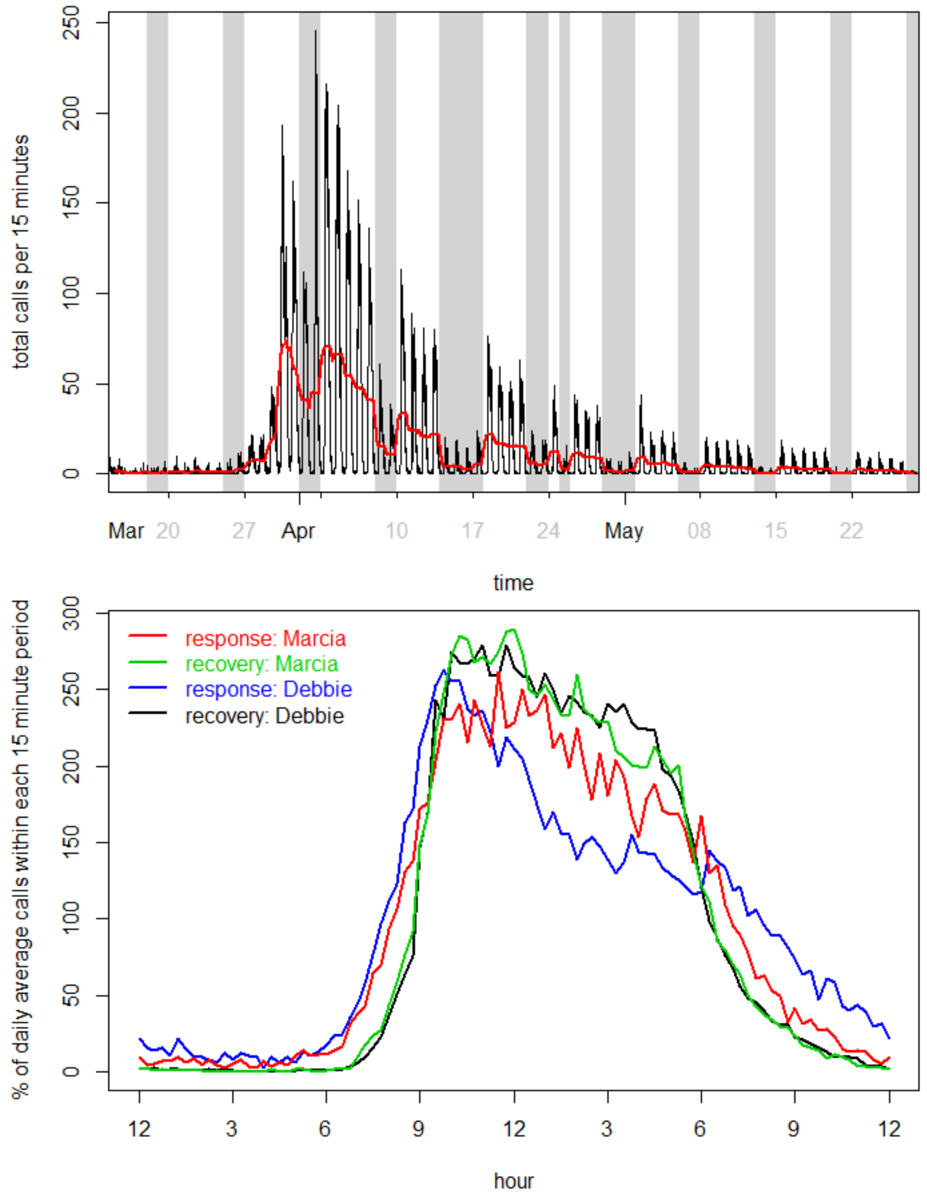

Figure 3: TC Debbie calls with trend line (top) and seasonality (bottom).

Modelling

The long decline in calls during April and May in Figure 3 consists almost entirely of disaster recovery calls. An exponential decay model is suggested, allowing for the daily seasonality as shown in Figure 3 and defined above, as well as variation caused by weekends and public holidays. The model is thus

$$\text{calls} = S \times \text{trend}$$

where S is daily seasonality and the trend is the red line plotted in Figure 3, modelled as

$$\text{trend} = cWMe^{kT}$$

Here W and M represent the 'weekend' and 'Monday' effects noted above, T is time, and c and k are regression constants.

Taking logs, the model can be fit by ordinary least squares regression. This was done in R.

RESULTS

Predictions

Figure 4 shows the model for Cyclone Debbie. Predictions were much too low over the first two days, perhaps in part due to their falling on a weekend; it is hard to judge when the peak is truly reached. However, for the rest of the period an exponential decay model fits well; model errors have a standard deviation of 6.5 calls per 15 minutes (or 9.2 calls, including the errors on the first two days). All modelled effects are statistically significant (p values < 0.001).

The model shows a decline in the number of calls from day to day of 7.6 %. Weekends and public holidays are modelled to reduce by a further 77.6 % from the trend, whereas calls on the following workday increase by 5.6 %.

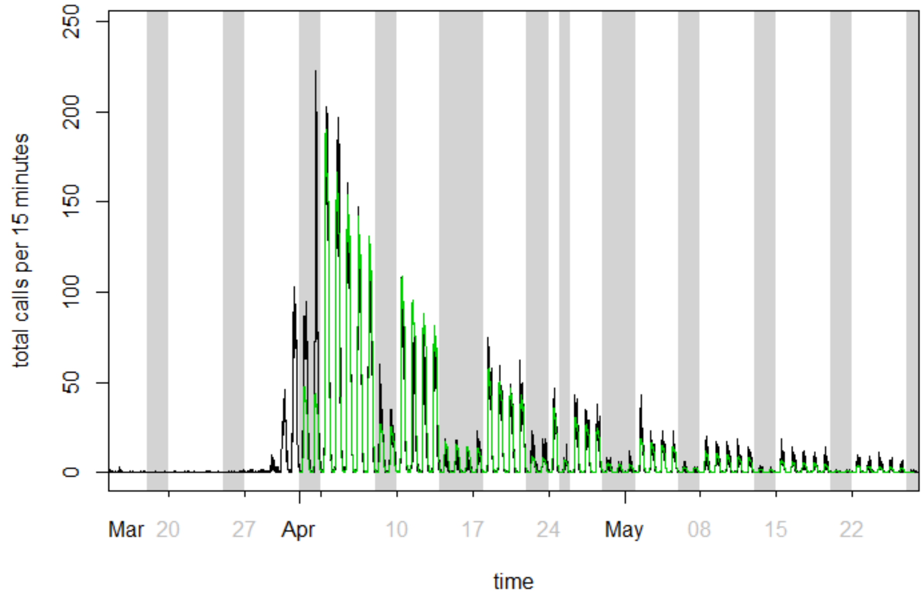

Figure 4: TC Debbie disaster recovery calls with predictions.

Observations

There are two large categories of calls: response (the SES queue) and recovery (DR). They follow different patterns and were analysed separately; DR calls peak later and take far longer to subside. The majority of calls are from unknown regions, which makes analysis by region of call currently impractical.

Disaster response calls peaked a day after the damaging winds had subsided in the case of Cyclone Marcia, and two days later in the case of Cyclone Debbie. Disaster recovery calls commence later. This makes direct correlation between the cyclone path over time and numbers of calls challenging; winds have subsided before calls commence. While there is a lot of data across time for the two cyclones, allowing interesting analysis of call behaviour over time, there are only two cyclones, which is too small a sample to allow reliable quantitative prediction of the peak call intensity and the rate of decline over time across different cyclones.

Direct correlations could be calculated in the case of Cyclone Marcia, where more calls were received during the period of damaging winds. As might be expected, disaster response calls are affected predominately by actual damaging winds, rather than forecasts of them.

CONCLUSIONS AND FUTURE WORK

The prototype SSQ analytics tool supports the work practices of the Forecast Analyst to help monitor emergency events as they unfold, allowing intelligence to be gathered faster to support the process of workforce planning in exceptional circumstances. The initial development was focused on features supporting the map interface. The simple task of combining information from various data sources, saving it in a database for later use, and providing a single map based web site interface is a productivity improvement for the purposes of quickly accessing relevant information for decision making.

The model is based on the daily seasonality of the call centre data. When applied to the trend line we can accurately predict the number of calls per 15 minute interval. This model can be used to estimate the number of expected calls for the remainder of the event, once the initial call peak has occurred. The remaining task is to determine beforehand what this peak will be. We are currently exploring Twitter data for this purpose.

There are a number of areas of future work that we are exploring. The current tool uses historical data and has focused on previous large scale cyclone events. While incorporating publicly accessible real-time data feeds, such as weather warnings and cyclone tracks from the BOM, is straightforward, obtaining the real-time call centre metrics from a proprietary software management system is not. While this is technically feasible, as demonstrated by the provision of call centre data from SSQ, the technical details are yet to be realized. We are also investigating large scale storm and flooding events to see if similar correlations exist for this data.

We need more data to develop a robust model. Rather than wait for these events to occur over time, we would like to develop a self-updating modelling system. As new cyclone events occur, the existing model is updated using the call centre metrics. Such a system would require oversight by a knowledgeable forecast analyst to ensure the model improves over time. Similarly, the prototype system could be extended to be a scenario planning tool to investigate situations that could occur in the future, informed by data from previous cyclone events. For example, it could predict the expected call volumes for an event similar in size to TC Debbie, but instead making landfall in Cairns or Brisbane.

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