PLANNING EQUITABLE FIRE AND RESCUE SERVICE DELIVERY BASED ON INFORMED DECISION-MAKING

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ABSTRACT

Maintaining equity of service delivery and planning for the future needs of a rapidly growing population can provide significant challenges. The current project utilises GIS mapping to match data from the latest Census of Population and Housing to station and brigade areas of responsibility, and provides an estimate of the emergency response requirements for that location. Evaluation of this method has demonstrated an extremely high correlation (0.8) with actual emergency response requirements. This technique is currently being used by the QFRS State Operations, Risk and Planning Unit to identify areas in which current resourcing may not be well-matched with current requirements, and assist in service delivery planning up to 15 years in the future.

INTRODUCTION

In the past thirty years, considerable research in the area of fire risk to communities has focussed on socioeconomic characteristics of individual communities (National Fire Data Center 1997; Nicolopoulos, Murphy, and Sandinata 1997; Jennings 1999). Factors such as poverty, building vacancies, education and age have all been associated with increased rates of fire (that is, number of fire incidents per unit of population). The results of these types of studies can be extremely useful in applications such as targeting risk groups within a community for fire prevention and public education initiatives. However, these analyses are sensitive to inter-city variation in the explanatory power to different socioeconomic variables (National Fire Data Center 1997). In addition, analyses comparing entire cities are affected by large variations in socioeconomic indicators and fire rates within cities (which are obscured when cities are analysed as single entities), and significant variations in fire rates in given cities from year to year.

Sustained population growth in Queensland, particularly in the south-east corner of the State, has seen considerable changes in both urban and rural communities. Between 2001 and 2026, the population of the south-east Queensland region is projected to increase by over

50%. (Planning Information and Forecasting Unit 2003). In the latest residential developments, less land per capita of population increase is being consumed (Queensland Department of Local Government and Planning 2003). This increases the overall population density, although this increase is not uniformly distributed. Recent migration trends, although volatile (Planning Information and Forecasting Unit 2003), indicate that similar processes are occurring in a number of regional centres elsewhere in the State while other areas (particularly the Central West and North West Statistical Divisions) are likely to experience declines in population.

As a result, maintaining an equitable and effective level of fire and rescue service delivery requires monitoring of a number of potential causes of population change, including expansion of areas in which urban fire services are required, increases in population density, and net positive and negative migration trends. The purpose of this paper is to demonstrate the use of basic demographic data to guide the process of ensuring equality in service delivery between communities, and to show how the same method can be used to assist in the planning of future needs.

METHOD

The Queensland Fire and Rescue Service (QFRS) delivers fire and rescue services to the entire community of Queensland, with an estimated resident population of 3,840,000 people (Australian Bureau of Statistics 2004) in an area of over 1.7 million square kilometres (Australian Bureau of Statistics 2003). Operational response is provided by three distinct groups of personnel (permanent firefighters, part-time auxiliary firefighters, and rural volunteer firefighters) based at urban stations and rural brigades. There are four classes of rural brigades (Queensland Fire and Rescue Service 2001), as shown in Table 1. Combinations of personnel types and shift hours at urban stations are extremely varied, however these stations are generally amalgamated into three classes (Queensland Fire and Rescue Service 2003).

Data relating to attendance at incidents are collected separately from urban and rural personnel. For incidents attended by urban personnel, incident reports are required to be completed by the officer-in-charge of the first attending urban appliance. These reports are collated into a State database. Incidents attended by rural personnel are subject to voluntary reporting only, and are entered (where available) into a separately maintained database. As a result, there are two potential issues in the analysis of incident data. Firstly, incidents occurring in rural areas may be underreported, and to an undetermined extent. Secondly, incidents attended by both urban and rural personnel may be somewhat overreported, since they are recorded in two separate databases with no reliable method of linkage.

Table 1 Classes of urban station and rural brigade in the Queensland Fire and Rescue Service

Station or Brigade Type	**Personnel**
Traditional Rural Fire Brigade Class 1	Rural volunteer firefighters
Mixed Rural and Rural Residential Brigade Class 2	Rural volunteer firefighters
Rural Residential Brigade Class 3	Rural volunteer firefighters
Transitional Rural Fire Brigade Class 4	Rural volunteer firefighters
Auxiliary Station	The attendance of auxiliary firefighters is required to crew appliances, whether or not one or more permanent firefighters are based at the station
Composite Station	Staffed by at least one full crew of permanent firefighters at some times, but at other times requires the attendance of auxiliary firefighters to crew appliances.
Permanent Station	Staffed by at least one full crew of permanent firefighters at all times. Auxiliary firefighters may also be assigned to a permanent station.

For the purposes of simplicity for this research paper, the number of incidents occurring within a station or brigade's area of responsibility was approximated by the average number of incident reports filed by that station or brigade per financial year between July 2001 and June 2003 (a two-year period). This averaging was performed to take account of fluctuations from year-to-year in the numbers of incidents, but minimise the impact of the overall growth in numbers of incidents. Additional accuracy in the count of numbers of incidents (at the cost of more data pre-processing) can be obtained by GIS comparison of reported incident locations (AMG Grid Reference or latitude/longitude) with the boundaries of station/brigade areas of responsibility. In addition to the total number of incidents, counts of individual types of incidents were also considered: structural fires, landscape fires, mobile property accidents, unwanted alarm activations and other incidents.

The size of the area of responsibility for each urban station and rural brigade was calculated from map boundaries using MapInfo (MapInfo Professional 2002). Population values for each station and brigade area were then calculated from data collected for the 2001 Census of Population and Housing (CData 2001 - Full GIS 2002). Since Census Collection Districts do not correspond directly with station and brigade area boundaries, initial estimates of population were based simply on proportional areas of coverage. However, a later refinement involved weighting the contribution of Collection Districts by the property density within that Collection District.

STATISTICAL TECHNIQUES

Inspection of the range and distribution of variables such as numbers of incidents, population and area of responsibility for brigades and stations revealed a large range of values and a significant skew towards lower values. Logarithmic transformations ($\log_{10}$) were therefore applied to each affected measure, in order to be able to apply parametric analysis methods (such as correlations and linear regressions) to the data.

Statistical measures employed in this research included correlations (which determine how closely two or more variables relate to each other), cluster analyses (which automatically classify data according to relationships between specified variables) and scatter plots (which in this study have been used to provide a visual tool for determining similarity between stations and brigades according to selected variables). Statistical analyses were undertaken using SPSS 12.01 for Windows (2003).

MODELLING EQUITY IN SERVICE DELIVERY

Relationship between station/brigade type and number of incidents attended

The existing classes of the 237 urban stations were found to be strongly related to the overall number of incidents attended by the stations, with a Spearman rank correlation value of 0.81. A discriminant analysis of the numbers of different types of incidents attended by these stations was then conducted, to determine if analysis of variations in numbers of different types of incidents (structural fires etc) attended by stations could construct a classification algorithm to mirror station classifications. This was reasonably successful. Of the 65 permanent stations, 59 were classified as such by the automated algorithm, with the remaining six being classified as composite. All 10 composite stations were classified as composite, along with 18 auxiliary stations. The remaining auxiliary stations were identified by the algorithm as auxiliary.

The existing classes of the rural brigades were also found to be significantly correlated with to the average reported number of incidents attended for those brigades that reported incidents, although the Spearman rank correlation value of 0.50 was considerably lower than that for urban stations. Discriminant analyses of rural brigade data were deemed impractical, due to the low total numbers of incidents reported by individual brigades each year.

Relationship between station/brigade area of responsibility, population, and number of incidents reported each year

In order to determine if demographic variables could be used to predict numbers of incidents occurring in a geographical area, the two-year-average number of incidents attended by the stations and brigades were compared with a range of demographic variables for the corresponding area, including population, socioeconomic advantage/disadvantage, number of passenger vehicles registered, remoteness and the geographic area of responsibility of the station/brigade. The Pearson correlation between the average number of incidents and population was strongest at 0.79, with the correlation between average number of incidents and area of responsibility next most significant at –0.36. Even after the relationship between population and area was taken into account (large areas of responsibility tend to have low populations living within them), area of responsibility of the station/brigade remained significantly correlated with the number of incidents reported ($r = -0.19$).

A linear regression model was then constructed from the available demographic variables to predict the number of incidents. Only two demographic variables (population and area of responsibility) were included in the final regression model, as other measures made no additional significant contribution. The results of this final model correlated highly (0.85) with the actual number of incidents observed over the two-year period, and explained 73% of variance. While this is not an exceptionally high proportion of variance explained, it should be noted that the linear regression model is more predictive of number of incidents attended than the current urban station classification (correlation coefficient = 0.81) and rural brigade classification (correlation coefficient = 0.50) systems.

Figure 1 demonstrates the outcome of using population and area of responsibility to model service delivery needs. This scatter plot shows these demographic variables for each station and brigades of the Queensland Fire and Rescue Service, with the various classifications of station and brigade indicated by different symbols. It can be clearly seen that Permanent stations are quite similar to each other in terms of these demographic measures, whereas Auxiliary stations and Class 1 and 2 rural brigades notably differ in terms of population and size of area of responsibility. Graphical displays such as these can be used to identify outliers in a well-ordered system, or quantify degree of overlap in a classification system which is not as clear-cut.

EVALUATING OTHER OPTIONS

As a result of analyses such as those conducted above, or other factors, proposals may be made for redefined station and/or brigade boundaries. Effective evaluation of these options can be performed by defining new station or brigade boundaries after the proposed redistribution, calculating their geographical areas and estimating the probable population. The same model is then applied to the new data to assign a service delivery level consistent with similar areas and populations.

This procedure could be performed for any desired geographical areas (for example, local government areas). However, care should be taken when selecting small areas, since the equity of the model depends on each station/brigade covering some combination of residential, commercial, industrial and/or open space zoned land. If too small an area is selected, the estimated resident population of that area may end up substantially biased.

PLANNING FOR THE FUTURE

While the analysis outlined above compares data on current population, area and service delivery requirements for existing stations and brigades, this method can also be applied to predictions of future population. The in-built assumptions are that population will remain proportional to service delivery requirements, and that no large discrepancies in risk will develop between communities in the State. Under these assumptions, even if the number of fires, rescues and other incidents per person changes over time (for example, through the successful introduction of new community intervention programs), the overall method of determining areas of greatest future service delivery need remains valid.

Population projections for the Statistical Divisions of Queensland can be obtained from the Office of Economic and Statistical Research for up to 2026, and for up to 2051 for Queensland as a whole (Office of Economic and Statistical Research 2004). More than one set of projections is generally produced, in order to take account of the large number of possible outcomes in population factors (such as birth rate, migration and mortality). However, while these figures can provide long-range predictions regarding future population as a whole and in specific age groups, these predictions are extremely broad in terms of geographic area. More localised population projection data is available from the Department of Local Government and Planning, with projected population values readily available for the years 2006, 2011, 2016 and 2021 (Queensland Department of Local Government and Planning 2001).

An additional source of information that is extremely valuable in projecting future service delivery requirements is broadhectare data, which in Queensland is available through the Department of Local Government, Planning, Sport and Recreation. Broadhectare data indicates location and timing of likely future residential growth, by identifying land that is "suitable, potentially available and serviceable for future residential development", and also the timeframe when the land will potentially have water and/or sewerage services. When overlaid with details of existing and/or proposed emergency response infrastructure, broadhectare data can give a useful visual indication of the extent of the additional geographical area that will require urban fire services. An example of broadhectare data for a small area of south-east Queensland is shown in Figure 2.

CONCLUSION

The analysis above demonstrates that demographic data may be used to provide a model of the extent of fire and rescue service delivery requirements for a given geographic area. This modelling capacity can be applied in other ways, such as to consider the impact of altering existing service delivery arrangements, or help predict future service delivery requirements.

However, it should be noted that this method was designed to help indicate an appropriate level of <u>base</u> resourcing for fire and rescue services. What it does not do is give consideration to the appropriate location for more specialised equipment (for example, emergency tenders for road accident rescue or HazMat appliances) which may be held at a more limited number of sites. However, GIS-based mapping of data such as the past locations of specific types of incidents, or properties where particular risks are higher (e.g. industrial premises) may be used in these cases to further inform service delivery planning decisions.

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Figure 1 Scatter Plot of Station and Brigade Populations and Areas of Responsibility, by Station and Brigade Classification

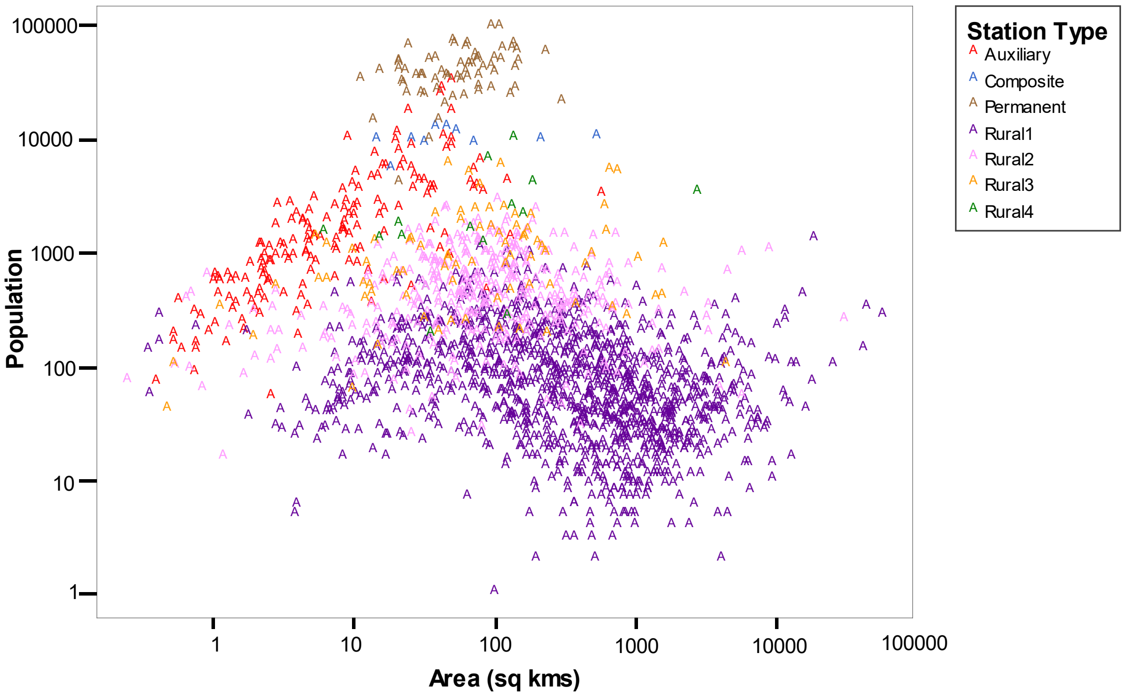

Figure 2 Example of Broadhectare Map-based Data for a Section of Southeast Queensland