Predictive Models for Apportioning 911 Fund

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Abstract

The current funding practice of the North Carolina 911 Board is based on the five-year rolling average of previous calls and the receipts of the 911 fee charged by all telephone (wireline, wireless & VoIP) providers. The practice has received increasing criticisms because of unfair funding allocations and constant human intervention, which have resulted in an increased operational cost. To automate the 911 Fund allocation process in a fairly and equitable manner, a business analytics team was formed to identify and analyze potential antecedents that can better predict the number of 911 calls. A stepwise regression analysis was conducted to assess the potential contribution of each variable to the dependent variable of the number of 911 calls. Suggestions were made to the Board to improve upon the current funding allocation method and to ameliorate public perception of each PSAP. Theoretical and practical implications were made to conclude the study.

Keywords: Analytics, Funding Models, Public Safety Answering Points (PSAPs), 911, Business Analytics

1. INTRODUCTION

The state-level 911 Board (hereinafter referred to as "the Board") was initially established to consolidate enhanced 911 systems under a single board with a uniform 911 service charged to integrate the State's 911 system and enhance efficiency and accountability. The General Assembly is often the body to oversee the operations of PSAPs (Public Safety Answering Point, aka 911 centers) and to fund the centers from receipts of the 911 fee charged by all telephone providers according to legislative directives.

The current model for distributing funds to PSAPs in North Carolina is based on a rolling five-year average of eligible expenses incurred and funding provided to PSAPs. This current model has shortcomings, namely, lack of incentives to spend money wisely and be as economically sound as possible. As the growing population demands increasingly enhanced 911 systems, the Board needs to develop a more effective funding model to fulfill its mission of "professionally taking, processing and dispatching calls in a timely manner while ensuring callers are receiving the best possible emergency services" (Caldwell County Government 2017, p1).

An analytics team (hereinafter referred to as "the Team") is comprised of one faculty supervisor, and five data analytics students. The Team derived options that proved compatible for the Board seeking a solution to optimize the current funding model being used. In general, options derived from statistical analysis be categorized into descriptive, predictive, and prescriptive classifications. Each has the potential of addressing various aspects of the funding concerns raised by the Board and are examined in the literature.

Additional potential variables that may impact the number of emergency calls to the PSAPs are also examined and hypothesized. A research model is then developed based on the proposed hypotheses, followed by the research methodology section. Analysis results are then reported, preceding a discussion of theoretical and practical implications based on the findings. Limitations and future research directions conclude the study.

2. CONCEPTUAL FORMATION

Analytic Solutions for the 911 Funds Allocation Problems

The Board was facing three fundamental problems: (1) fund allocation is primarily based on historical data at a uniform rate, therefore could not account for the increasing demand for enhanced services, (2) a decreasing allocation of federal funds to the Board at the state level, and (3) misalignment between funding incentives and the Board's mission.

The proposed use of descriptive analytic solutions can offer insights into the current problems faced by the Board while predictive analytics allows us to build a model based on statistical methods and forecasting techniques to predict required amount of funding for PSAP operations. Lastly, Prescriptive analytics aim to optimize or simulate algorithms of the predictive model.

Data Analytics Challenges Faced by the 911 Board and PSAPs

Data collection is an ongoing issue for the Board, as there is no unified definition of a "call" between PSAPs. As such, there is no universal approach to collect and categorize them by text message, VoIP, emergency, non-emergency, and administrative calls. Lack of resources also discourages data sharing across jurisdictions as PSAPs vary in their organization and filtering processes. The number of calls received was an integral component of the new data analytics methods.

Internal and External Variables Related to the Number of 911 Calls Received by Each PSAP

The structure of PSAP operation affects the costs generated. PSAPs can offer up to four services: law enforcement, fire department, rescue/EMS, and emergency medical dispatch. The combination of services offered correlate with the number of calls. Processing and cleaning the different types of data poses challenges for analysis.

External factors that may have an impact on call data include population, unemployment, education, and crime index rates. As the team discovered various PSAPs conducting personal calls on the monitored lines, these external factors may prove useful in determining the proportion of critical calls and thus directly impacting the funding model.

Rural-Urban Continuum codes distinguish metro and non-metro areas, and may have an impact on call volume. Economic typology indicates if a county is dependent upon factors such as manufacturing, farming, state/federal government, etc. and could also impact call volume. Demographic profile, age group, and household income could also correlate with the number of calls and type of calls to an area's PSAP. Cost per call is impacted by the type of call incurred.

Research Methodology

While the Board is responsible for setting the rate charged by telephone providers and allocating the funds collected, this project was specific to the distribution of those funds and not the actual rate-setting.

Data Analytics Lifecycle Approach

The Team conducted the following steps to implement the data analytics lifecycle approach: identify the problem, design data requirements, preprocess data, perform analytics of data, and visualize data (Figure 1). After the process was initially completed, the Team repeated the steps four additional times before reporting their final insights to the Board.

ISSN: 2167-1508
v10 n4524

3. ANALYSIS METHOD

The Team ran various models to determine the correlation of data parameters to the number of calls by PSAP or to the existing funding structure. Time Series and Multiple Regression emerged as the best possible models for allocation. Time Series allowed the Team to forecast the potential funding requirements and call volume. Multiple regression helped determine correlation between the independent variables and the number of calls received. Using regression analysis, the Team could find a relationship using key variables and the number of calls to act as an estimate of the number of calls without using the manipulative number as the funding metric.

The Team used multiple linear regression to estimate the number of calls to each PSAP. We used SAS Enterprise Guide and a STEPWISE procedure to determine the most appropriate model, and forced the inclusion of the population variable for each PSAP because using simple linear regression we found that this variable alone explained 87.29% of the variance in the number of 911 calls (R^2= 0.8729). None of the variables included exceeded $p < 0.1$. The STEPWISE procedure determined that there were four additional variables to include in the model creating a final R^2 of 0.8874. For the final model, please see table 1. The variables are defined as:

***POPULATION (NCOSBM 2015 est.)-** population under each PSAP's jurisdiction
****Violent Crime Rate 2012-** violent crime rate for each NC county
*****Rur_Code_3-** if the Rural/Urban Continuum code is 3 the value =1, otherwise value = 0
******PercBet25_34-** percentage of the population that is between age 25 to 34
*******PercGreat75-** percentage of the population that is greater than 75

This model shows the variables that influence call volume incurred by each PSAP. The problem with this model is the difficulty for the Board to utilize the data in the future to create funding models. As one of the criteria for the model was simplicity, we could not entrust that this model would be sustainable and useful for years to come.

A final model was proposed to simplify the process by using just the population under jurisdiction of each PSAP as the sole predictor of call volume (Adj. R^2 = 0.8729). For the simple linear regression results, see table 2.

4. ANALYSIS RESULTS

Using this model, we could create a funding proposal to allocate funds based on the proportion of calls each PSAP is estimated to receive. Due to the negative intercept, however, allocating funds strictly based on this model would yield some PSAPs to have a negative amount of calls, and thus no funding. This created the argument for a consolidation method in which some PSAPs are so inefficient that they are should not exist independently.

We also identified an opportunity for an increase base amount of funding. Due to varying PSAP costs, the exact dollar amount required for base operation is unclear, so we simply used the amount of the lowest funded PSAP. After allocating this base amount, the additional funds are dispersed based on predicted call volume.

5. PRACTICAL IMPLICATIONS

Analytical solutions adopted in this study are primarily predictive and they can directly address the funding issues faced by the North Carolina 911 Board. Another benefit is to provide insights into the external factors that are pertinent to the decision of allocating the limited 911 funds to each PSAP. These findings could possibly transform the current funding model into a fair and equitable one. With the formula-based allocation model, the funding method can endure continual changes in economic and demographic dynamics in the jurisdiction of each PSAP. More importantly, the funding model is easily calculated and difficult to manipulate.

An unexpected benefit is the possibility of improving the efficiency of PSAPs based on a calculated model. For example, based on funding and the number of calls received by each PSAP, Charlotte-Mecklenburg had the lowest cost per call at $3.21 while Beech Mountain had the highest at $259.75. This could be improved by various methods proposed, namely, consolidation. It is possible to have a singular call center that services various geographic areas and routes the dispersed calls to one physical location reducing costs, and thus cost per call. This new information discovery may encourage jurisdictions to begin discussing innovative approaches of data sharing and cooperation for the improvement of operational effectiveness.

6. THEORORETICAL IMPLICATIONS

Predictive models (e.g. regression) have often been adopted to optimize the distribution of budget across departments within an organization (Baker et al. 2017). Budget allocation examined in previous predictive analytics study, ranges from marketing (Fischer et al., 2011) to departmental budgeting (Luna and Brennan, 2009). Predictive models can help improve certain aspects of operational performance, such as avoiding unnecessary budget spending (Aubry et al. 2013), and managing budget maintenance activities (Flores-Colen & de Brito, 2017). This study builds on previous research of the effective allocation of 911 funds for PSAPs by using predictive models. Our findings corroborate with previous ideas that predictive models, including Time Series and Regressions, could enhance the decision-making process for the 911 Board.

Business analytics solutions have the potential to explore business problems and transform current management practices (McAfee & Brynjolfsson 2012). The example provided in this case uses a real study to affirm the possibility via predictive analytics solutions. In the face of data explosion challenges, the shift from intuition-based to data-driven decision-making is unavoidable. Academia should continue exploring new data-related tools and validate their usefulness in raising awareness of the importance of making business decisions based on data (Brynjolfsson & McElheran, 2016). More importantly, academia should strive to make recommendations for traditional institutions like the 911 Board to improve current management practices.

7. LIMITATIONS AND FUTURE RESEARCH

If able to obtain more data involving the operations of a PSAP, we would likely be equipped to develop more rigorous models that could help obtain a better understanding of which PSAPs are operating more efficiently than others. The Time-Series model would be more accurate at forecasting the number of 911 calls if we were able to obtain more data from years past. As more data is collected, it would likely be a good idea to develop a new Time-Series model. Cluster analysis would be a great tool in deciding how to consolidate PSAPs. It would be necessary to have a better insight into the operations of PSAPs and have an idea as to which ones cannot be eliminated.

8. CONCLUSIONS

This paper addresses the issue with fund allocation which can be applied for all local governments and law-enforcement agencies in different metropolitan areas and not just PSAPs in North Carolina (focus base of this research). Thus, it has rich value of content and research topic since it addresses issue with funding of 911 PSAPs.

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ISSN: 2167-1508
v10 n4524

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ISSN: 2167-1508
v10 n4524

APPENDIX

TABLE 1

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-133756	53429	10229780822	6.27	0.0138
POPULATION (NCOSBM 2015 est.)*	0.71789	0.02846	1.04E+12	636.11	<.0001
Violent Crime Rate 2012**	64.82215	25.31616	10701416607	6.56	0.0119
Rur_Code_3***	-24459	12340	6413128480	3.93	0.05
PercBet25_34****	589793	347705	4696407683	2.88	0.0928
PercGreat75****	560955	240622	8871017807	5.43	0.0216

TABLE 2

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-5002.66427	4526.92008	-1.11	0.2714
POPULATION (NCOSBM 2015 est.)	1	0.72825	0.02578	28.25	<.0001