Improving REMS Service Plans Based on Time Series Predictive Modeling

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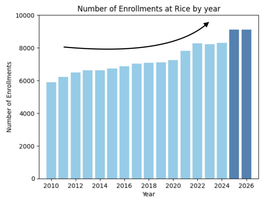
Introduction

Rice Emergency Medical Services (REMS) serves the Rice community and provides them with **accessible medical care.**

Due to an **expected addition of around 700 students** to the student body in the next 3-5 years, Rice plans to build two new residential colleges to accommodate demand.



REMS would like to predict the expected increase in demand for the next 3-5 years, since this would allow them to be more prepared for the future. With our help, REMS can foster a safer and healthier Rice campus.

Objectives

After discussion with REMS, our team determined there were **three primary objectives** that our project aimed to solve. Each objective was approached separately, with its own data and modeling sections.

1. **Objective 1**: Use past call data in order to predict *call volume (number of calls)* in the next 3 years.
2. **Objective 2**: Use data on personnel to predict future *staff growth* in all areas as well as future *training needs*.
3. **Objective 3**: Use financial information, including equipment and educational budgets, to predict *future expenditures*.

Data Description

The data was given to us by REMS in many different formats, sizes, and shapes. We **extracted the data** and separated relevant information, based on the different objectives.

	Time Range	Data Volume (# periods x # features)	Important Features
Obj 1 Call Volume	2006 - 2023	139 x 6	Call Volume, Special Events
Obj 2 Staff Growth	2016 - 2023	8 x 7	Volunteer, Paid Staff, Employees
Obj 2 Training Needs	2010-2023	14 x 3	Total Staff
Obj 2 OC Room Usage	2017 - 2023	84 x 5	N/A
Obj 3 Expenditures	2016 - 2022	9 x 7	Call Volume, Staff Count, Enrollment

Modeling

1. Time Series Models

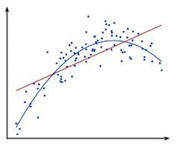
ARIMA(p,d,q): catching trends and forecasting
- p: influence of past values
- d: difference in the data to make it stationary (mean, variance remain constants)
- q: smoothing past errors

SARIMA(p,d,q)(P,D,Q)$_m$: (Seasonal ARIMA)
- Seasonality: cycles that occur at regular intervals
- p,d,q: same as ARIMA
- P,D,Q: seasonal p,d,q
- m: frequency; number of observations per cycle

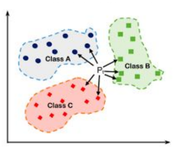
2. Regression Models

Due to the low data volume for select datasets, in particular for Objectives 2 & 3, we applied:

Polynomial Regression (d)
d = degree of polynomial



K-Nearest-Neighbors (n)
n = number of neighbors



3. Parameter Tuning

ACF: correlation of a time series with itself at different lags
PACF: correlation of a times series with itself at different lags after removing the influence of correlated lagged values in between
***AIC:** estimation of prediction error of a given model

Number of model parameters

$$AIC = 2k - 2\ln(\mathcal{L})$$

$\mathcal{L} = \mathcal{L}(\hat{\theta})$ = maximum value of the likelihood function of the model

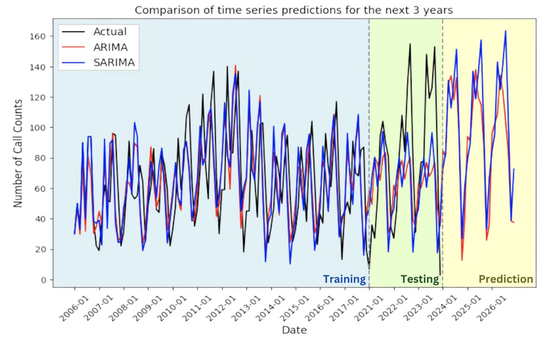
4. Model Evaluation

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}}$$

Data Split

Result — Objective 1

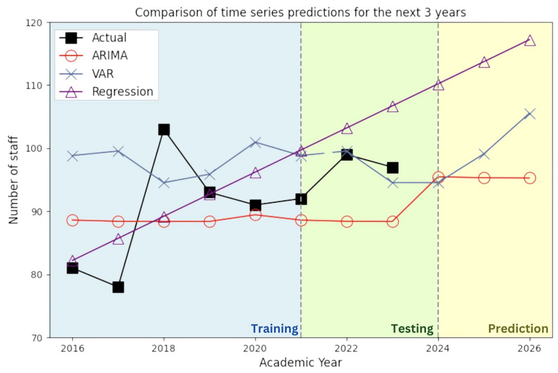
Time Series Models like ARIMA and SARIMA were trained and **predictions for call volume were made for the next 3 years.**



	ARIMA (10, 0, 1)	SARIMA $(0, 1, 2)\ (0, 1, 1)_9$
Training RMSE	**28.61**	31.89
Testing RMSE	**39.39**	41.85

Result — Objective 2

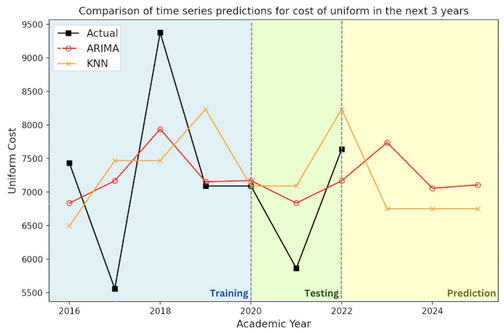
Comparing the results predicted by 3 models, we expect a **steady increase in the total number of staff for the next 3 years** that will lead to increased budgetary needs due to the cost of training, staff paychecks, and off-campus rooms..



	ARIMA (1, 1, 1)	VAR (2)	Polynomial Regression (d = 1)
Training RMSE	9.09	13.87	**7.46**
Testing RMSE	7.08	**4.21**	7.55

Result — Objective 3

Models analyzed and predicted five different kinds of expenditures, including **uniform**, **insurance**, **IC (In Charge staff) housing**, **vehicle maintenance**, and **medical supplies**. Below is the sample modeling result of **uniform's** cost:



	ARIMA (2, 0, 1)	KNN Regression (neighbor = 2)
Training RMSE	**1002.45**	1377.11
Testing RMSE	**764.05**	964.40

Conclusion

The project predicts an expected increase in demand for REMS services over the next 3 years, highlighting the need for enhanced resources to continue REMS' quality services and ensure a safer and healthier Rice campus that should be reflected in **increasing budget estimates**.

Objective 1
- **Higher call volume** for months with higher call counts like **October and April** when there are more special events
- Call volume for other months will stay **relatively constant**

Objective 2
- Rising need for training and resources based on 3 models
- **Budget increase to accommodate additional training hours and staff paychecks**

Objective 3
- Might **not need to largely increase the budget** for the five kinds of expenditures **except medical supplies**
- Due to the small dataset, **the predictions for all kinds of expenditures will become more accurate as time goes on**

Acknowledgements

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