

RADIOLOGY ASSOCIATES SENIOR PROJECT REPORT

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ABSTRACT

Radiology Associates Senior Project Report

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After discontinuing their subscription with Shinyapps and relying on a manual forecasting process, Radiology Associates needs a new method to forecast the number and types of scans that will be executed at each site location. Radiology Associates utilizes Quinsite, which incorporates a live link to their database, as a host for all their Tableau dashboards. This project will create an accurate forecasting model utilizing complex forecasting methods to be hosted by Quinsite which is accessible by all management within Radiology Associates. To begin this process, an exponential smoothing model was created in Tableau to solidify dashboard and storyboard design. Additionally, ARIMA and SARIMAX models were built using TabPy and RServe. Using a MASE score each forecasting method was tested. Using the MASE score and feedback from Radiology Associates during a mock forecasting meeting, exponential smoothing was selected as the most accurate to be in the final design. With the final forecasting method selected the dashboard went through several rounds of slight alterations based on feedback from project stakeholders before being officially handed over to Radiology Associates.

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1. Introduction and Background

Radiology Associates is a medium-sized company with three sites, located in the central coast area. Radiology Associates provides premium, full-spectrum medical imaging and interventional radiology services for patients, physicians, and healthcare organizations. For the purposes of this project, Marci Miller, Radiology Associates' Chief Administrative Officer, will function as the team's primary liaison with Radiology Associates. In addition, Jill Speece, former Director of Business Optimization for Radiology Associates, is the project supervisor and may also act as a liaison with Radiology Associates.

In the past, Radiology Associates has used a forecasting platform called Shinyapps. Shinyapps allowed Radiology Associates to forecast using the ARIMA method which will be discussed later in this paper. Radiology Associates recently decided to stop using Shinyapps due to the platform costing \$99 a month while only providing one employee with access to the program. Radiology Associates used Shinyapps to forecast sales and revenue so their team could budget out quarters in advance. Due to the loss of their forecasting dashboard on Shinyapps, Radiology Associates has been relying on a manual process to calculate their forecast and requested a new forecasting model be built. For the solution to be compatible with current Radiology Associates platforms, the team will design a forecasting model in Tableau as Radiology Associates currently uses the program company-wide.

In the future, the forecasting model developed could be used for revenue projection and budgeting by Radiology Associates. This project is important to Radiology Associates as it should allow them to accurately budget for future quarters, leading to higher profit and a more organized business. More importantly, the model created will have a direct live link to Radiology Associates' database. This will allow for real-time forecasting without having to upload new data for a new forecast. In addition, since the forecasting model will be hosted on Quinsite, Radiology Associates' data dashboard, it will be accessible to everyone in the business. This allows for more flexibility with managers looking to forecast. Overall, the new forecasting model will make Radiology Associates' forecasting simple, accurate, and accessible.

2. Problem Description

The previous solution that Radiology Associates used was hosting their forecasting dashboard on Shinyapps which they no longer have access to. Shinyapps cost \$99 per month and only gave one employee access to the Radiology Associates forecasting dashboard. This situation was deemed unacceptable by Radiology Associates because the forecasting information stored in the dashboard is used by several managers to budget and plan out future quarters.

To understand where the forecasting model will be used, and in what capacity, a process flow map was constructed of the current state of forecasting meetings. The

forecasting meetings entail going over the projected number of tests and the revenue associated with those tests for the following year. In the process flow map (Shown in Appendix IV), there is a tall column of steps on the left of the chart which are all associated with preparing the forecasting model before a meeting can begin. These steps include manually moving data between databases as well as manually constructing graphs and tables to check over in the meeting. Forecasts are done manually on a spreadsheet utilizing pivot tables. In the meeting, the forecasted report counts and expected revenue are checked location by location and modality by modality. Should a specific modality not meet revenue goals, potential changes are discussed to increase revenue and put into the spreadsheet to check again. Once all locations and modalities are projected to meet revenue goals, strategic initiatives are set and the meeting ends. Data from the meeting is sent to all locations and managers so each site is informed about the budget for the year.

The data from the forecasting model and meeting can be used to set budgets and hiring requirements, meet revenue goals, and help schedule tests. Having an accurate and accessible forecasting model will allow Radiology Associates to operate smoothly. To achieve this, Radiology Associates requested a forecasting dashboard that is compatible with current company software, $\geq 90\%$ accuracy, ergonomic, linked to live data updates, accessible by all approved employees, and adaptable to future changes. Using the project requirements, some project key performance indicators shown in Table 1 were created.

Table 1: Key Performance Indicators

Key Performance Indicators	Current	Target
Compatibility	No Access	Built on Tableau and hosted by Quinsite.
Forecasting Accuracy	Current accuracy is unknown	An accuracy level $\geq 90\%$
Accessibility and Ergonomics of Forecasting Dashboard	One employee has access	All approved employees will have access. Dashboard will be simple to use
Linked to live data updates	Data is manually selected to run forecasting models	Automatically use historical data stored on Quinsite to run forecasting models
Adaptable	Hard to change	Easily updated/adapted to new changes

Using the key performance indicators, some immediate decisions became evident. To meet compatibility, accessibility, and ‘linked to live data’ requirements, the forecasting model will be built in Tableau and hosted on Quinsite, both of which are programs already used by Radiology Associates. While using these programs helps meet several of the key performance indicators, it does not automatically address the accuracy and ergonomics key performance indicators.

3. Literature Review

a. Introduction:

For the literature review of the report, research was conducted to further the solution ideation and development. A fishbone diagram shown in Figure 1 was created to find root causes of the problem. The root causes helped guide the major topics researched for this project.

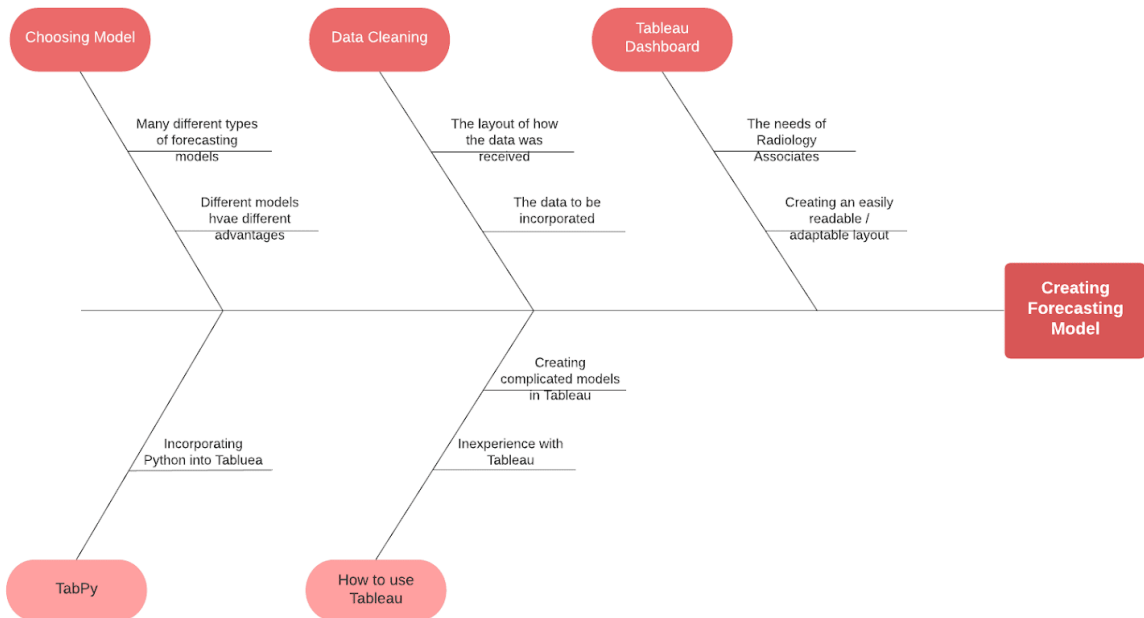


Figure 1: Fishbone Diagram

b. The Importance of Forecasting:

In a study from 175 companies summarized by Herbig, P., Milewicz, J., and Golden, J. E. in *Forecasting: Who, What, When and How*, 92% of companies responded that forecasting was essential for their company’s success. Forecasting allows a company to plan for the future and guide their decision-making process. Furthermore, forecasting allows a company to plan their production, sales force, advertisement campaign, general wellness of the company, and many more

aspects of the business. In addition, forecasting improves as a company continues to perform it since the company will be able to identify certain, repeatable errors (Herbig, Milewicz, & Golden).

When forecasting, there are many aspects of the forecast which must be considered. One of the main aspects is the time horizon of the forecast. The longer timeframe that the forecast is predicting, the chance of errors to occur increases. This is due to changes in technology, environment, business growth, etc. It is good practice to use forecasts with these outside factors in mind (Herbig, Milewicz, & Golden).

c. Exponential Smoothing:

The main influencing factor for forecast performance is the model. Exponential smoothing is Tableau’s standard forecasting option. The methodology behind exponential smoothing includes applying exponentially decreasing weights to historical data as that data gets older. As compared to moving average forecasting, which applies the same weights to all data points. The idea of exponential smoothing is the foundation for the more complicated models which will be implemented (Hyndman, Koehler, Ord, & Snyder, 2008). Mathematically, the formula incorporated with exponential smoothing can be seen in Figure 2.

$$F = \alpha A + (1 - \alpha)B$$

Key:

F: forecast, A: actual sales data, B: forecast sales from previous periods, α : the smoothing constant that is set as a value between 0.1 and 1.0.

Figure 2: Exponential Smoothing Equation

d. ARIMA Forecasting Model:

The possible models to be implemented are based on ARIMA and SARIMAX forecasting. The ARIMA model, “AutoRegressive Integrated Moving Average,” uses past values including lags and errors to forecast future values. This model does not include seasonality, which is why SARIMAX may be the better option; more on that later. Furthermore, the ARIMA model can be characterized by three terms: p, d, and q. The p and q terms refer to the linear combination of past values and errors. The d term refers to differencing and the number needed to make the model stationary. Since the ARIMA model is used when the time series data is non-stationary, differencing using the d term converts

the non-stationary data to stationary data. The ARIMA model will be implemented through TabPy which is Tableau's Python extension (Prabhakaran, 2022). Mathematically, the formula incorporated with ARIMA can be seen in Figure 3.

$$\Delta y_t = c + \phi_1 \Delta y_{t-1} + \theta_1 \epsilon_{t-1} + \epsilon_t$$

Figure 3: ARIMA Forecasting Equation

e. SARIMAX Forecasting Model:

SARIMAX or “Seasonal AutoRegressive Integrated Moving Average with exogenous factors,” includes seasonality and external factors which is why it builds upon and is more accurate than ARIMA. Moreover, SARIMAX takes in four additional numbers to ARIMA's p, d, and q parameters which build the seasonality trends. These include seasonal AR (Autoregressive) specification, seasonal integration order, seasonal MA (Moving Average), and seasonal periodicity. Mathematically, the formula incorporated with SARIMAX can be seen in Figure 4.

$$\phi_p(L)\bar{\phi}_P(L^s)\Delta^d\Delta_s^D y_t = A(t) + \theta_q(L)\bar{\theta}_Q(L^s)\epsilon_t$$

Figure 4: SARIMAX Forecasting Equation

These extra factors allow SARIMAX to build upon ARIMA’s model with higher accuracy (Goled, Gopani, Verma, & Choudhary, 2021; Elamin & Fukushige, 2018).

f. Tableau:

Tableau was created in 2003 and has been utilized in organizations ranging from retailers to hospitals to federal organizations, making it the data analytics industry leader (Murray, 2016; Patrizio, 2021). Unlike other analytics software, information is not entered directly into Tableau; instead, it is gathered from a separate connected database. Databases can have one of two connection styles: live or extract. Live connections will allow for the most up-to-date information to be analyzed while extracts will provide a snapshot of data and use less processing power. For this project, the model will be connected live to a large database maintained by Quinsite, a healthcare analytics company. This allows for the forecast to be always up to date and easily accessible. Once data is connected, users can create custom calculated fields using functions referencing different columns within the data, which can in turn be used in graphical visualizations

(Best practices for effective dashboards, 2021; Nandeshwar, 2013; Batt, Grealis, Harmon, & Tomolonis, 2020).

g. TabPy:

Tableau is a useful piece of analytic software; however, on its own, it does not cover all workflow associated with data analytics (Schmidt, 2020). TabPy is an analytics extension that combines the visualization of Tableau with the processing power and libraries of Python. According to Schmidt, TabPy works on a “shared” interface model, meaning that Tableau, the standalone program, allows for scripts to be run directly from within it (Schmidt, 2020). Python code can be executed in custom formulas with SCRIPT functions (Tableau/TabPy: Execute python code on the fly and display results in tableau visualizations, n.d.). Within a SCRIPT function, users can write python code to be read and executed by the console. Instead of hard coding variables in these functions, Tableau parameters can be utilized for adaptability and are especially helpful to adjust accuracy while forecasting (Rafferty, 2021). Both ARIMA and SARIMAX models can be constructed via python libraries, bypassing numerous in-Tableau calculations, and providing a more comprehensive analysis and forecast.

h. Tableau Dashboards:

The Tableau dashboard is one of the most prominent features being focused on for this project. A well-designed dashboard allows for convenient data tuning, organizing efforts, identifying key performance indicators, and aiding in the decision-making process. Having a goal in mind whilst producing a dashboard is essential. The goal for the forecasting dashboard is to be a main hub where many types of forecasts can be made and customized. This includes having sliders, different input parameters, and adjusting timelines. All of this has been included to promote a high-level of interaction from Radiology Associates. Furthermore, including different scales and color schemes help to identify key points and make the visual aid better (Best practices for effective dashboards, 2021).

i. Storyboard Design:

Rather than having a single dashboard, Tableau allows users to create a “storyboard.” Storyboards allow users to show how certain aspects of the model are connected and how they can be altered. It also shows how certain decisions impact the output of the model (Creating a story, 2021). Moreover, the storyboards in Tableau are a series of data plots which help to portray a cohesive story to the user. This can make outcomes more understandable, especially for an

audience who do not have experience in data analytics (Kaur, 2021). Being able to tell a story using data aids the general audience in understanding how you reach a conclusion. Having multiple visual aids separated by tabs, like a window browser, helps with creating the story (How to tell a story with data and analytics in Tableau, 2021).

j. Verification and Validation of Methods:

To validate the forecasting methods, statistics are needed to measure the accuracy of forecasting models. The accuracy methods used are Mean Absolute Scaled Error (MASE) and Root Mean Squared Error (RMSE). MASE was invented by Hyndman and Koehler (2006). They proposed this method to be a general method, applicable to many forecasting accuracy tests without the obstacles that come with other models. MASE is based on the Mean Absolute Error and scales those errors based on the naïve forecast. A MASE value of less than one shows that the forecast is better than a naïve forecast while a value above 1 shows the naïve forecast is better than the forecasting model. As a result, the closer the MASE score to zero, the better. Mathematical formulation of MASE can be found in Figure 5.

$$q_t = \frac{e_t}{\frac{1}{n-1} \sum_{i=2}^n |Y_i - Y_{i-1}|} \quad \text{MASE} = \text{mean}(|q_t|)$$

Figure 5: MASE Equation

The main advantage of using MASE over another method such as MAD is that MASE is applicable to data which has trend, seasonality, or other patterns which arise in complex datasets (Shcherbakov, et al., 2013; Hyndman R. J.).

Root Mean Squared Error (RMSE) is a common measure for determining the quality of predictions from a model. RMSE computes how far predictions are from true values. RMSE also places weight on large errors, unlike MASE. Since RMSE is so commonly used, it is recommended to calculate RMSE values to evaluate the performance of future ARIMA and SARRIMAX models (Chai & Draxler, 2014; Root Mean Square Error (RMSE), 2021). Mathematical formulations of RMSE can be found in Figure 6.

$$RMSE = \sqrt{\frac{\sum_{i=1}^N \|y(i) - \hat{y}(i)\|^2}{N}}$$

where N is the number of data points, y(i) is the i-th measurement, and $\hat{y}(i)$ is its corresponding prediction.

Figure 6: RMSE Equation

4. Design and Evaluation of Proposed Solutions

The potential solutions for the project were decided based on the given parameters and constraints of the project. Due to Radiology Associates' current use of Tableau and Quinsite as a means of hosting their dashboards, the solution platform needed to be both in Tableau and compatible with Quinsite's platform.

Within Tableau, the model used a given static dataset to create worksheets with various useful views to display the historical data in an easy-to-understand format. The necessary views were the number of tests administered at each of the three sites broken down by the modality of the test (See Appendix I); then, using the average insurance reimbursement for each modality by site defined in the control sheet (See Appendix III), a view was created to display the breakdown of revenue across the three sites (See Appendix II). Each site and modality can be added or removed from the view as needed.

Within Tableau there is a forecasting function using exponential smoothing to display the estimates of the number of tests administered or revenue accrued. However, Tableau has the functionality to use Python and R to access more advanced forecasting models using the TabPy and RServe extensions. Through these programming extensions, ARIMA and SARIMAX models were constructed. The final solution was then selected by testing each solution to calculate which model is most accurate. The solution that is the most accurate will be implemented in the final dashboard.

a. Impact Analysis of Proposed Solutions

All three of the proposed solutions will have economic, ethical, diversity, and environmental impacts. Economically, the forecasting model will have four major impacts. The first economic impact is that it will eliminate the \$99 monthly cost Radiology Associates paid for Shinyapps. Secondly, by automating the forecasting and linking the data to live updates, it will require very minimal maintenance. Additionally, the time required to perform strategic forecasting planning will be reduced from the current day and a half. To test this (and to receive further feedback on the entirety of the dashboard), a mock forecasting meeting was conducted with Radiology Associates. From the mock forecasting meeting it was demonstrated that five manual steps were eliminated from the forecasting meeting setup (see Appendix V). This will save time and therefore

save money. Finally, the model will be linked to each scan modalities average revenue values, allowing for better overall budgeting.

The Tableau forecasting model will also ethically preserve patient privacy. Firstly, the forecasts will only be seen by qualified professionals in Radiology Associates for internal purposes. On top of that, the data supplied to the forecasting model is not directly linked to patients.

The forecasting dashboard design took into consideration accessibility by making the dashboards interface ergonomic and the text easily readable. Present and future members of Radiology Associates may have diverse levels of vision or motor skills, so it is vital to structure the dashboards to be accessible.

Environmentally, the solution will use less energy than manually computing the forecasting every year, as the database is automatically connected to the forecasting model. In addition, the automation of the forecasting will lead to less screen time associated with every forecasting meeting, saving energy.

b. Verification and Validation of Proposed Solutions

To test the solution designs, the mean absolute scaled error (MASE) was calculated for each solution. MASE is the mean absolute error of the forecast values divided by the mean absolute error of the one-step naive forecast, or a forecast which is essentially using the data from the last time period as the forecast of the next time period with no consideration of trends or seasonality. The calculated MASE score of each solution is shown in Table 2. Using the MASE scores, the team was able to recommend and implement Exponential Smoothing as the most accurate forecasting method. Unfortunately, due to the timeline of the project and the complexity of coding new forecasting methods, the SARIMAX method was never fully implemented and could not have a MASE score calculated.

Table 2: Forecasting Method Accuracy Testing Results

Forecasting Method	MASE Score
Exponential Smoothing (ES)	0.536
ARIMA	1.190
SARIMAX	Undetermined

To test the dashboard's usability and functionality a mock forecasting meeting was conducted with Radiology Associates. At this meeting, the dashboard was used to provide the forecasted data that Radiology Associates uses to make their decisions for the year. The data from the dashboard was compared

against the forecast and decisions that Radiology Associates made at the start of the year to gain insight into the functionality of the dashboard. The mock forecasting meeting served as a very preview into how the dashboard would be used in the future by Radiology Associates and validated the dashboard's usability and functionality.

5. Conclusions and Recommendations

Using the results from the accuracy testing shown in Table 2 and feedback from Radiology Associates, the team implemented the Exponential Smoothing method. With the verification of the selected forecasting method complete and the Exponential Smoothing method implemented, the dashboard completes all the performance indicators listed in Table 2. By using Tableau to build the dashboard and Quinsite to host it, the forecasting model meets several key performance indicators. Both Tableau and Quinsite are already used by Radiology Associates so the dashboard will be compatible with existing systems and access will be given to all authorized employees. Additionally, by using Quinsite, the model will be linked to live updates. This allows the dashboard to be self-sustaining with minimal maintenance while also leaving the dashboard open for future adaptations and adjustments.

6. Implementation Plan

Timeline

1. Meet with Quinsite Rep to establish upload plan. (1/12/22)
2. Email & Upload initial, non-live model to test upload plan. (4/20/22)
3. Mock forecasting meeting with RA to receive feedback. (4/22/22)
4. Update model based on feedback. (4/23-28/22)
5. Meet with Quinsite Rep to establish live link. (4/29/22)
6. Email & Upload model with live link & Test it. (4/30/22)
7. Receive final feedback from RA. (5/12/22)
8. Update model based on final feedback. (5/22/22)
9. Email Quinsite representative the final model. (5/31/22)
10. Quinsite uploads the final model. (Pending)
11. Final model is tested and confirmed functional. (Pending)

Required Resources – In order to implement our model, we conducted multiple meetings with Quinsite to publish our dashboard to their hosted website. We also conducted a mock forecasting meeting with Radiology Associates to discover needed changes which we incorporated into our final forecast.

There are no additional costs associated with implementing this forecasting model. The model is hosted by Quinsite, which Radiology Associates is already paying for.

7. Future Directions

Future suggestions focus on the implementation of an ARIMA and SARIMAX model. These models will need to be coded into Tableau using either RServe or TabPy. Once one or both models are built within Tableau, they should be evaluated using MASE and RMSE evaluation metrics to determine each model's accuracy. Once these metrics are developed, the MASE or RMSE scores of all models should be compared and the model that is the most accurate should be utilized.

In addition, as any new sites or modalities are added, the dashboard should be updated to reflect this. It will be necessary to complete annual calibration checks of key variable parameters (SARIMAX's p , d , q , etc.) to ensure the most accurate forecast; however, in time, there is room to write additional code to automate this calibration process. For now, the model's parameters are kept as manual entry so the forecasting team can utilize their insight and personal knowledge of trends to influence the forecast.

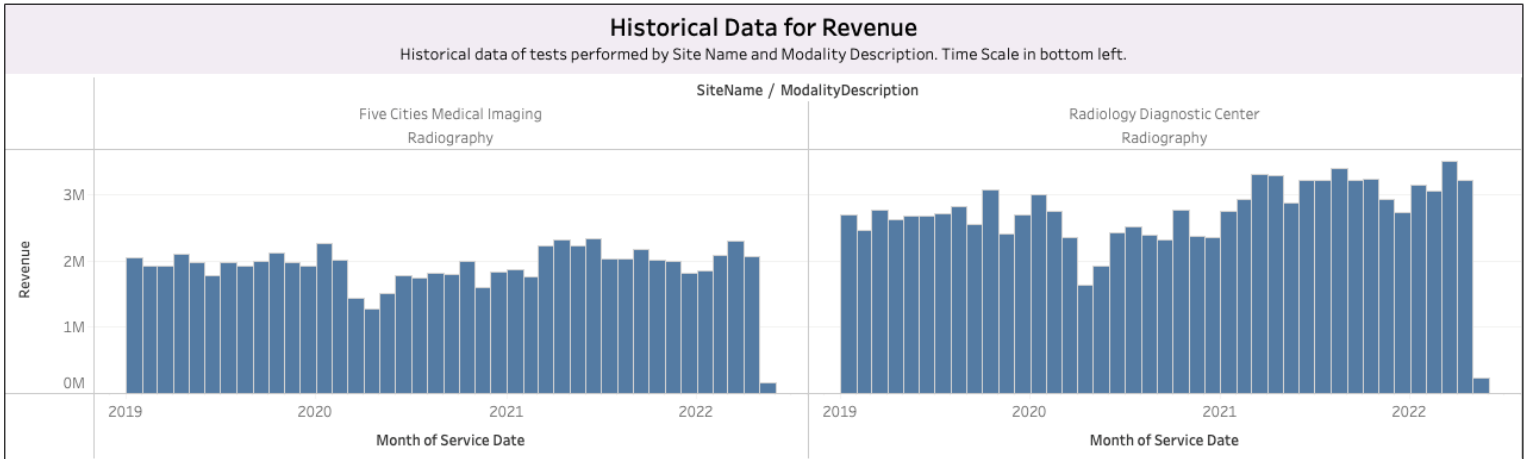
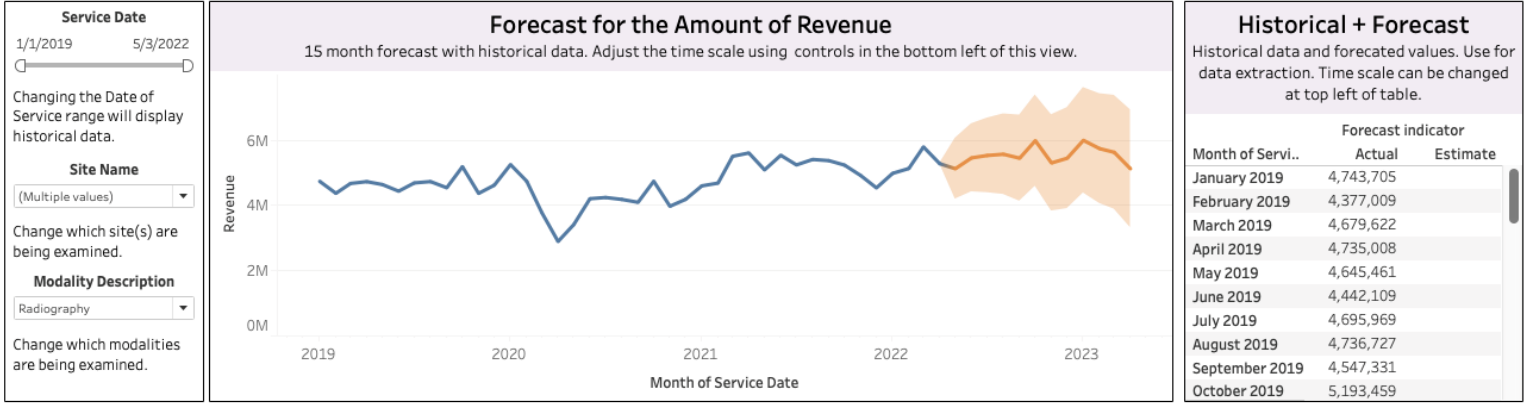
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Appendix II: Revenue Dashboard

Revenue Dashboard



Appendix III: Reimbursement Dashboard

Reimbursement Dashboard

Click to show the reimbursement rates for editing and click again to hide. Only have ONE site and year shown at a time.

Arroyo Grande Community Hospital CT Reimbursement (\$)	273
Arroyo Grande Community Hospital Mammography Reimbursement (\$)	273
Arroyo Grande Community Hospital MRI Reimbursement (\$)	273
Arroyo Grande Community Hospital Nuclear Medicine Reimbursement (\$)	273
Arroyo Grande Community Hospital Radiography Reimbursement (\$)	273
Arroyo Grande Community Hospital Ultrasound Reimbursement (\$)	273

2019

- Hide Arroyo Grande Community Hospital
- Show Digital Medical Imaging
- Show Five Cities Medical Imaging
- Show French Hospital Medical Center
- Show Marian Regional Medical Center
- Show Matthew Will Memorial Center
- Show Radiology Diagnostic Center
- Show Selma Carlson Diagnostic Center
- Show Sierra Vista Regional Medical Center
- Show Twin Cities Community Hospital

2020

- Show Arroyo Grande Community Hospital
- Show Digital Medical Imaging
- Show Five Cities Medical Imaging
- Show French Hospital Medical Center
- Show Marian Regional Medical Center
- Show Matthew Will Memorial Center
- Show Radiology Diagnostic Center
- Show Selma Carlson Diagnostic Center
- Show Sierra Vista Regional Medical Center
- Show Twin Cities Community Hospital

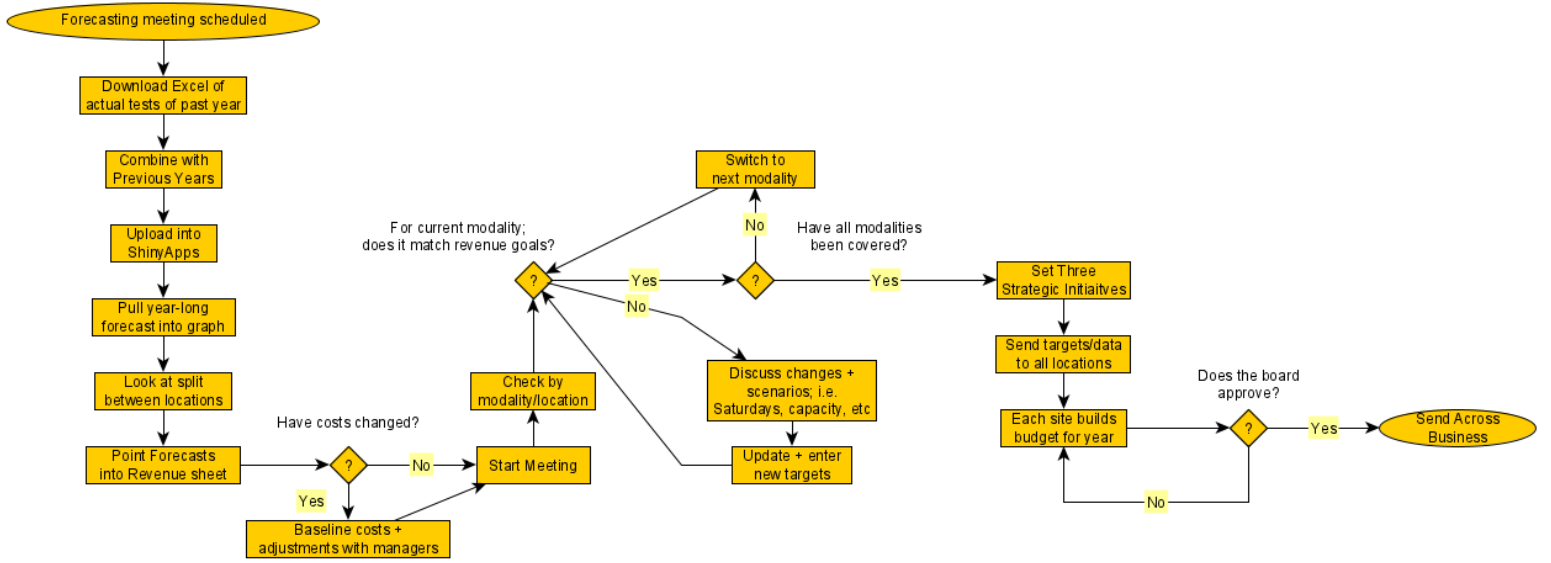
2021

- Show Arroyo Grande Community Hospital
- Show Digital Medical Imaging
- Show Five Cities Medical Imaging
- Show French Hospital Medical Center
- Show Marian Regional Medical Center
- Show Matthew Will Memorial Center
- Show Radiology Diagnostic Center
- Show Selma Carlson Diagnostic Center
- Show Sierra Vista Regional Medical Center
- Show Twin Cities Community Hospital

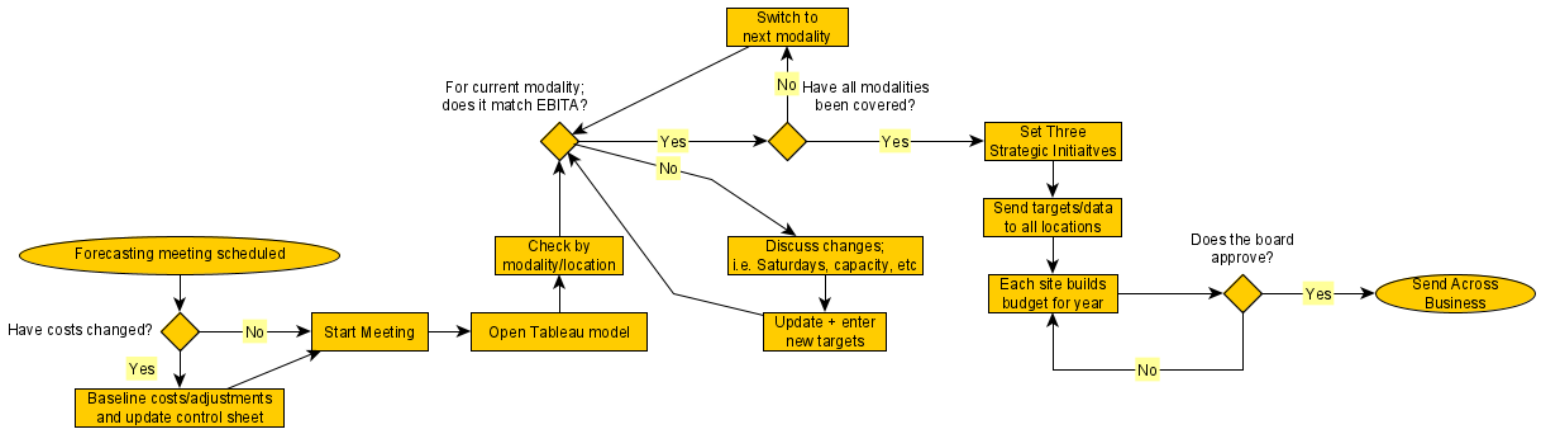
2022

- Show Arroyo Grande Community Hospital
- Show Digital Medical Imaging
- Show Five Cities Medical Imaging
- Show French Hospital Medical Center
- Show Marian Regional Medical Center
- Show Matthew Will Memorial Center
- Show Radiology Diagnostic Center
- Show Selma Carlson Diagnostic Center
- Show Sierra Vista Regional Medical Center
- Show Twin Cities Community Hospital

Appendix IV: Current State Process Flow Map



Appendix V: Improved State Process Flow Map

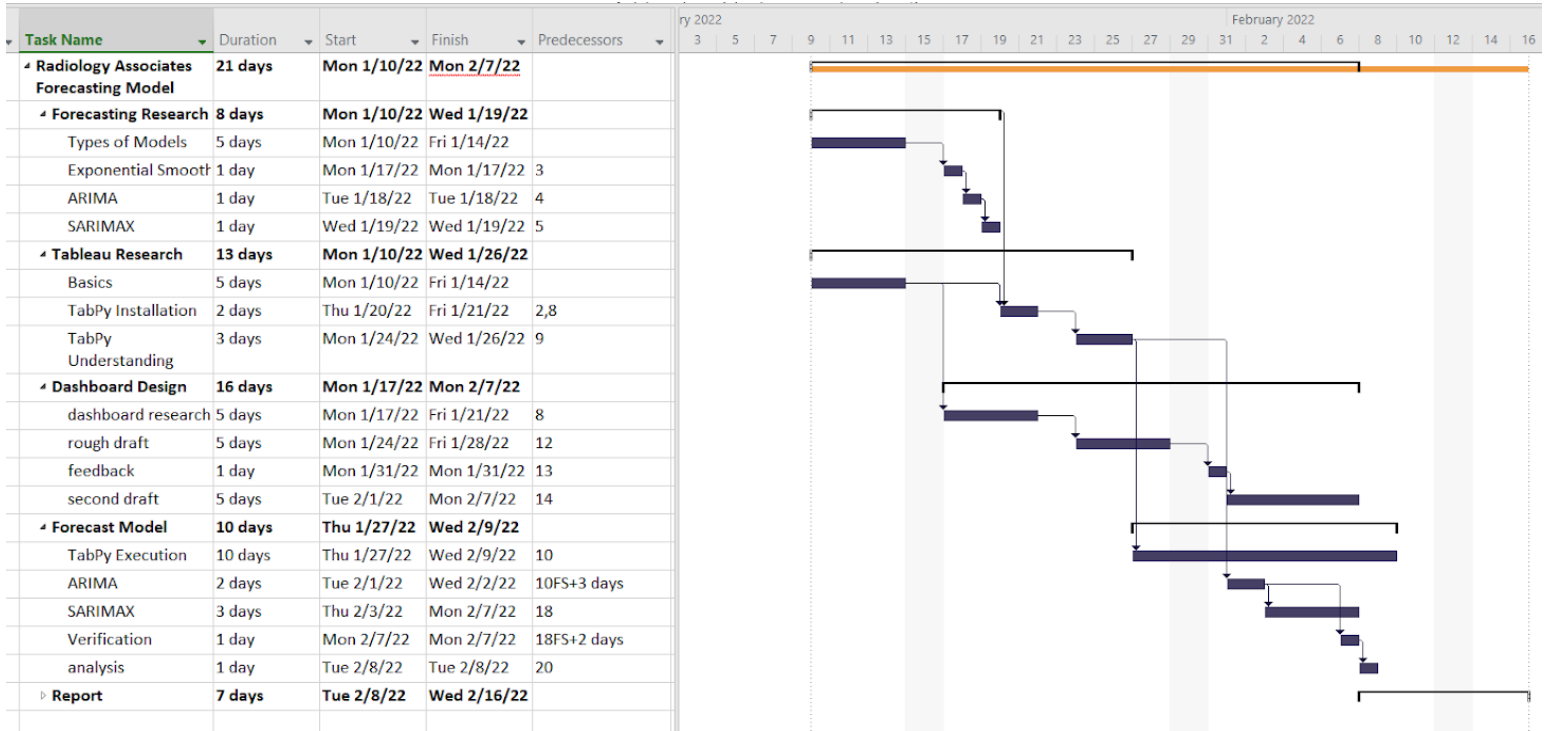


Appendix VI: Video User Guide

The video user guide/demo can be found at the following YouTube link or QR code:
<https://youtu.be/NaaCiEcvdjQ>



Appendix VII: Project Management Analysis



Appendix VIII: Communication with Client

Date	Location	Purpose	Comments
1/12/2022	Zoom	Initial Meeting with Quinsite: Established project compatability and feasibility to host forecasting dashboard	Met several member of Quinsite and learned about how to make our forecasting dashboard compatible to Quinsites system. Confirmed Radiology Associates live data will be linked to the forecasting dashboard.
1/18/2022	Zoom	Initial Meeting: Establish Current State and Background	Meet Marci, learned about Radiology Associates and the nature of the problem.
3/23/2022	Radiology Associates Templeton	Initial site visit: See the location and testing modalities. Meet Marci in person.	Scheduling mistake. Site visit did not happen.
3/2/2022	Radiology Associates Templeton	Initial site visit: See the location and testing modalities. Meet Marci in person.	Met Marci and toured Radiology Associates. Showed Marci current forecasting dashboard design and received feedback.
3/9/2022	Zoom	Final presentation to Marci and class	Presented our final presentation.
4/18/2022	Zoom	Current State Process Flow Meeting	Met Marci and Jill to gain a better udnerstandign of the current state process flow.
4/22/2022	Radiology Associates Templeton	Mock Forecasting Meeting	Conducted a mock forecasting meeting to demo the dashboard in use and gain feeback from Radiology Associates.
4/29/2022	Zoom	Establish Live Link Data Connection	Met with Mark at Quinsite to link the dashboard to the live data.
5/6/2022	Zoom	Radiology Associates Interview	Interviewed Marci to get feedback on dashboard.
6/1/2022	Zoom	Final Meeting with Radiology Associates	Showed video to Marci and officially handed off the project to Radiology Associates.

Appendix IX: Teamwork Analysis

Our team worked well together with everyone performing their roles as laid out in the team contract. Over the year our team had to make a lot of decisions and we benefited from having a defined decision and team interaction policy.