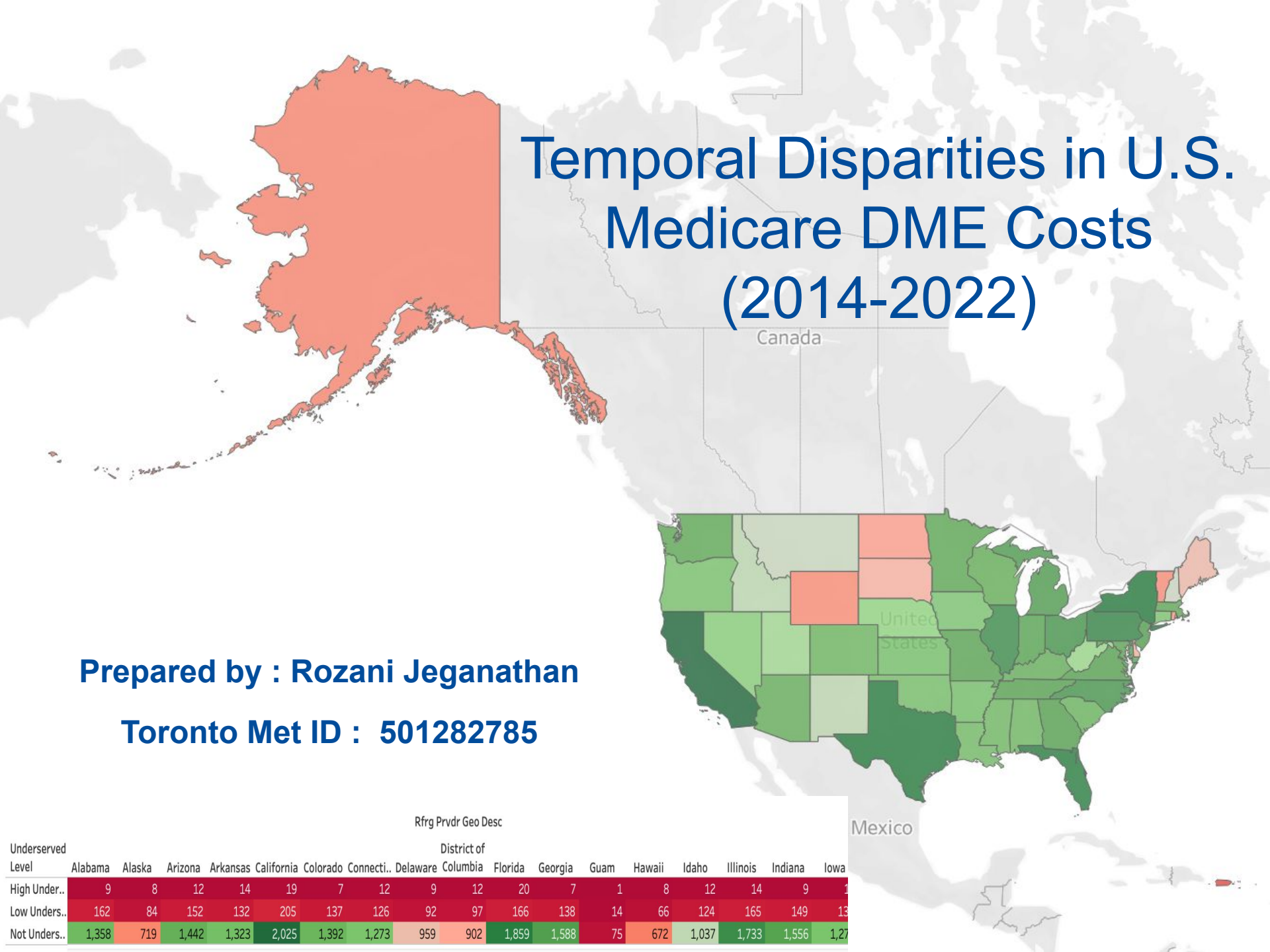
Temporal Disparities in U.S. Medicare DME Costs (2014-2022)



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Rfrg Prvdr Geo Desc

Underserved Level	Alabama	Alaska	Arizona	Arkansas	California	Colorado	Connecti..	Delaware	District of Columbia	Florida	Georgia	Guam	Hawaii	Idaho	Illinois	Indiana	Iowa
High Under..	9	8	12	14	19	7	12	9	12	20	7	1	8	12	14	9	1
Low Unders..	162	84	152	132	205	137	126	92	97	166	138	14	66	124	165	149	13
Not Unders..	1,358	719	1,442	1,323	2,025	1,392	1,273	959	902	1,859	1,588	75	672	1,037	1,733	1,556	1,27

Temporal Disparities in Medicare DME Costs

The Issue: Medicare's $31.2 billion in improper payments in 2023, including a 22.5% rate for DMEPOS, highlights inefficiencies. Regional disparities, with states like Texas exceeding spending averages by 10% and Alaska falling below by 10%, underscore the need to address inequities and optimize resource allocation.

Objective: Use machine learning and time-series analysis to uncover disparities and inform cost optimization strategies.

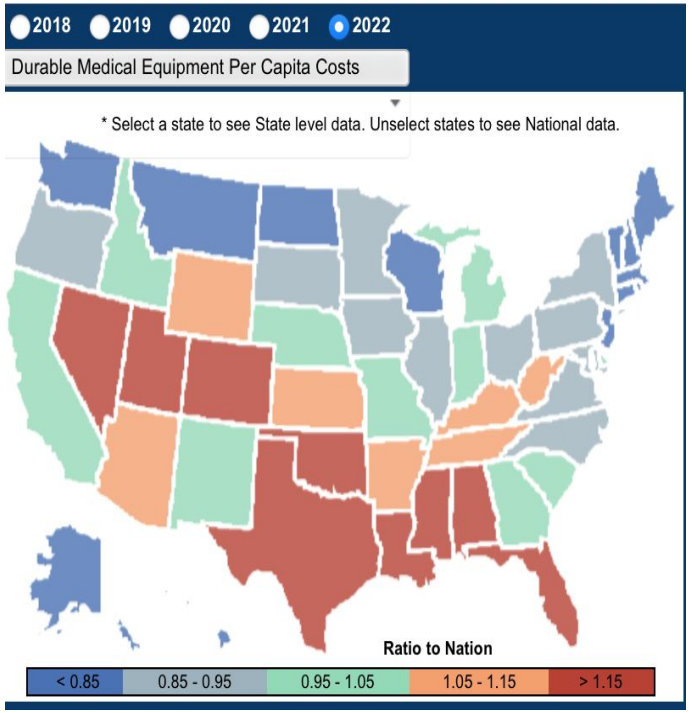

Image Source: Geographic Variation in Standardized Medicare Spending - State | CMS Data

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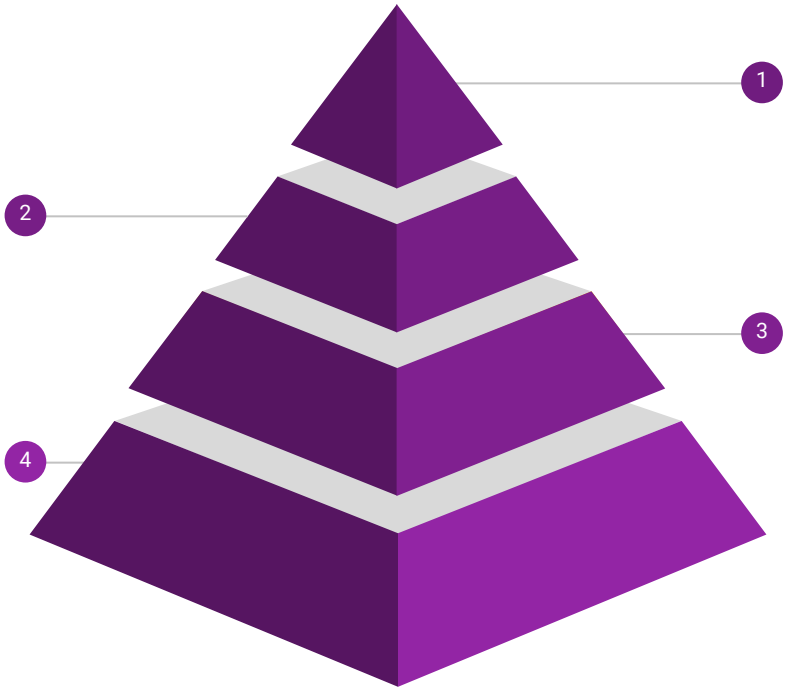
Project Goals

Inform policy decisions

Support equitable healthcare delivery and cost optimization through actionable insights.

Analyze long-term billing trends

Uncover key trends and disparities in DME spending over time.



Identify underserved regions

Pinpoint areas with high charges and low service volumes for targeted interventions.

Detect anomalies and inefficiencies

Identify irregular supplier behavior and systemic inefficiencies.

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DATA

Dataset Name: Medicare Durable Medical Equipment, Devices & Supplies - by Geography and Service

Timeframe: 2014 – 2022

Size: 295,052 observations, 19 variables

Processing Details:

- Address missing values (median imputation, placeholders).
- Transformations (one-hot encoding, PCA)

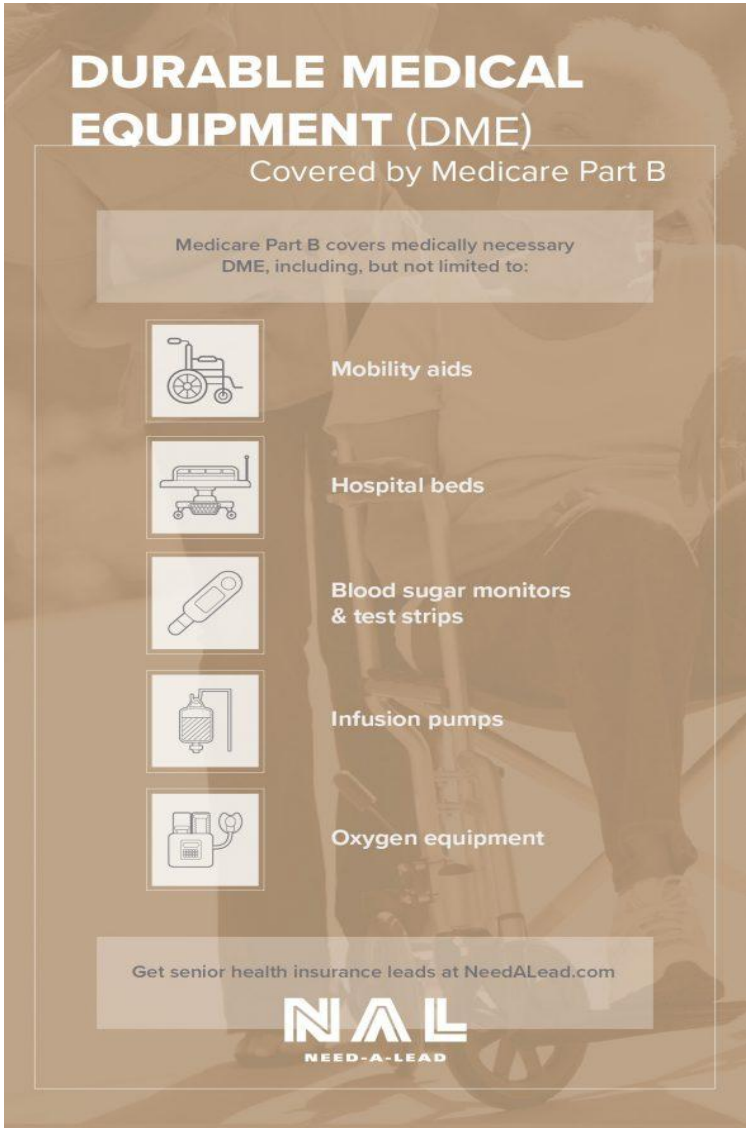
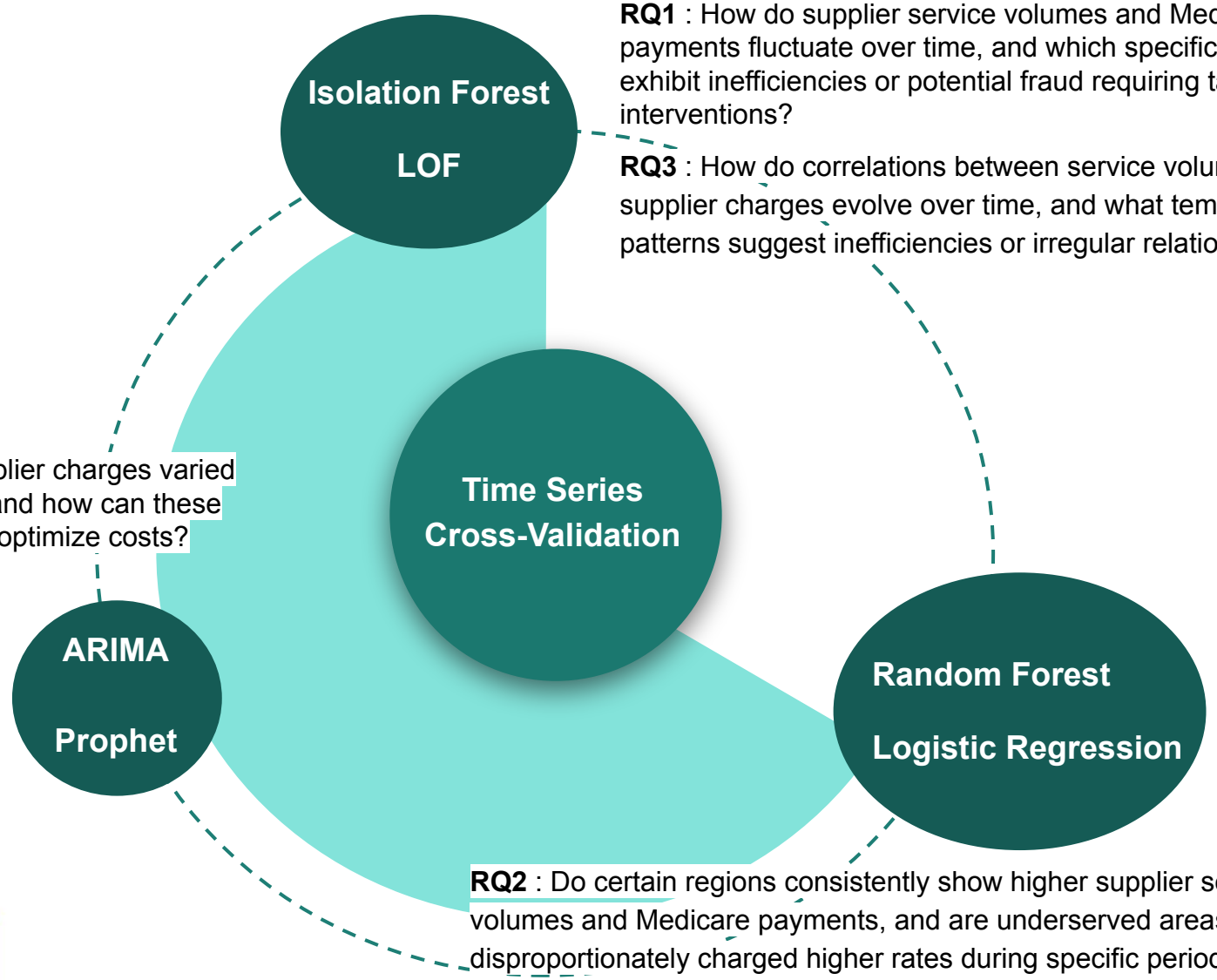


Image Source : https://needalead.com/what-is-durable-medical-equipment-dme/

Research Questions and Methodology Framework

RQ1 : How do supplier service volumes and Medicare payments fluctuate over time, and which specific periods exhibit inefficiencies or potential fraud requiring targeted interventions?

RQ3 : How do correlations between service volumes and supplier charges evolve over time, and what temporal patterns suggest inefficiencies or irregular relationships?



RQ4 : How have supplier charges varied by region over time, and how can these temporal trends help optimize costs?

RQ2 : Do certain regions consistently show higher supplier service volumes and Medicare payments, and are underserved areas disproportionately charged higher rates during specific periods, which could support targeted policy interventions?

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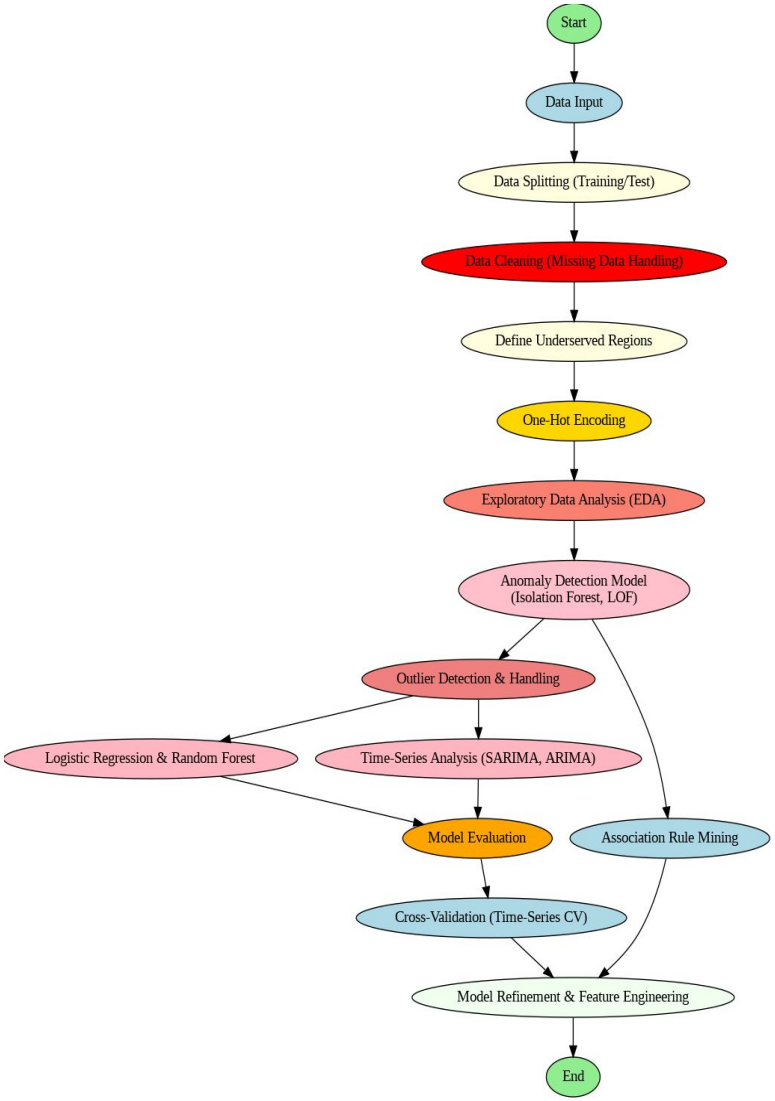
Methodology Framework



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Models Performance

Anomaly Detection:

- Isolation Forest outperformed LOF with a lower risk of over-detection and robust anomaly identification.

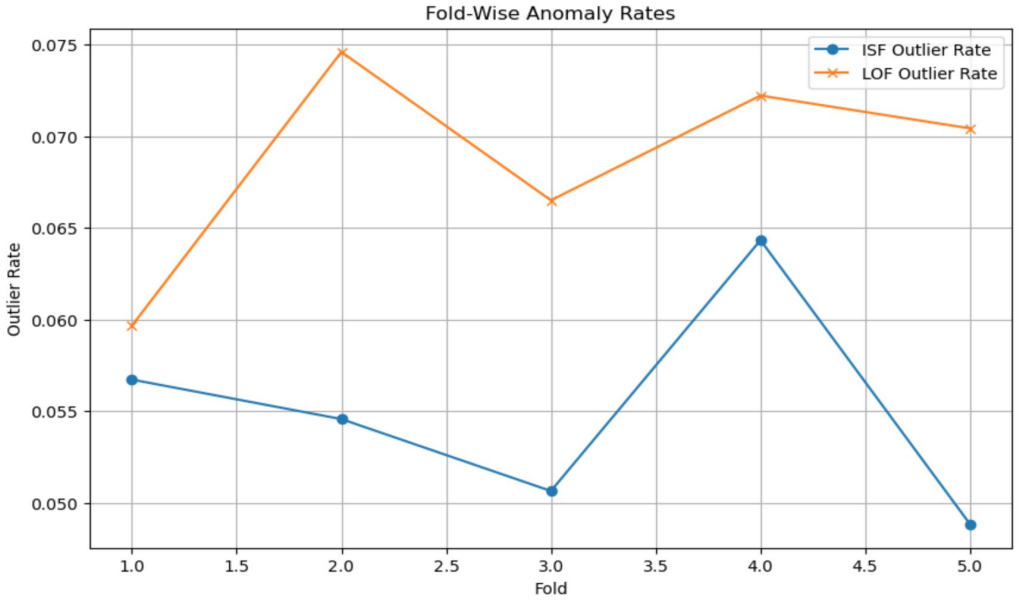

Figure : Fold-wise Anomaly rates of ISF vs LOF

Models Performance

Classification:

- Random Forest achieved near-perfect metrics (AUC = 1.0; F1-score = 1.0).
- Logistic Regression showed good accuracy but struggled with recall.

Model Performance Metrics:

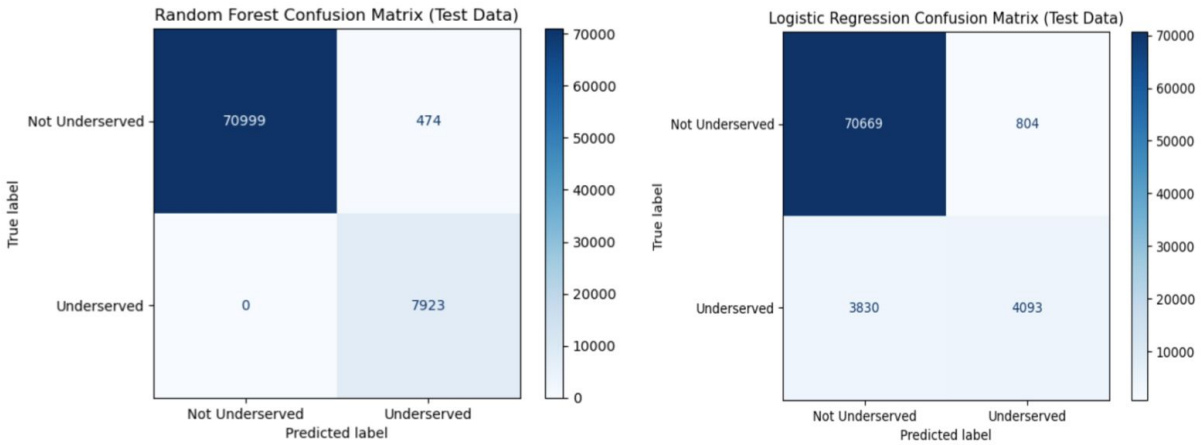

Figure : Confusion Matrix Random Forest vs Logistic Regression

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Models Performance

Time-Series Forecasting:

- Prophet generalized better for unseen data, particularly for anomalies and non-linear trends.
- ARIMA fit historical data well but lacked consistency in test performance.

Metric	ARIMA (0,1,1)	Prophet
RMSE (Train)	1718.82	1737.69
RMSE (Test)	2211.22	1737.69
MAE (Train)	534.26	689.65
MAE (Test)	614.74	689.65
MSLP (Train)	2.54	3.32
MSLP (Test)	2.15	2.72

Table - ARIMA vs Prophet Avg Submitted Charges

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Interpretability and Insights

Key Insights:

RQ1: Anomalies indicate potential inefficiencies in 2020, likely influenced by external factors like COVID-19.

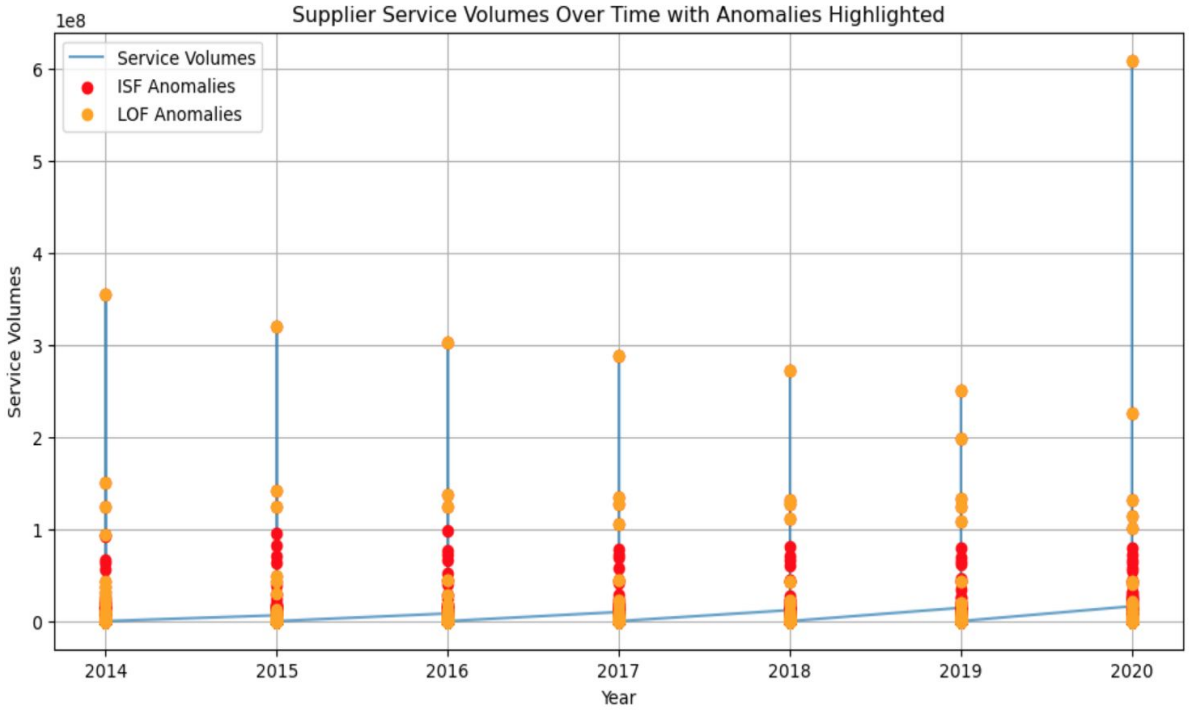

Figure : Feature Contributions for Anomalies vs. Normal

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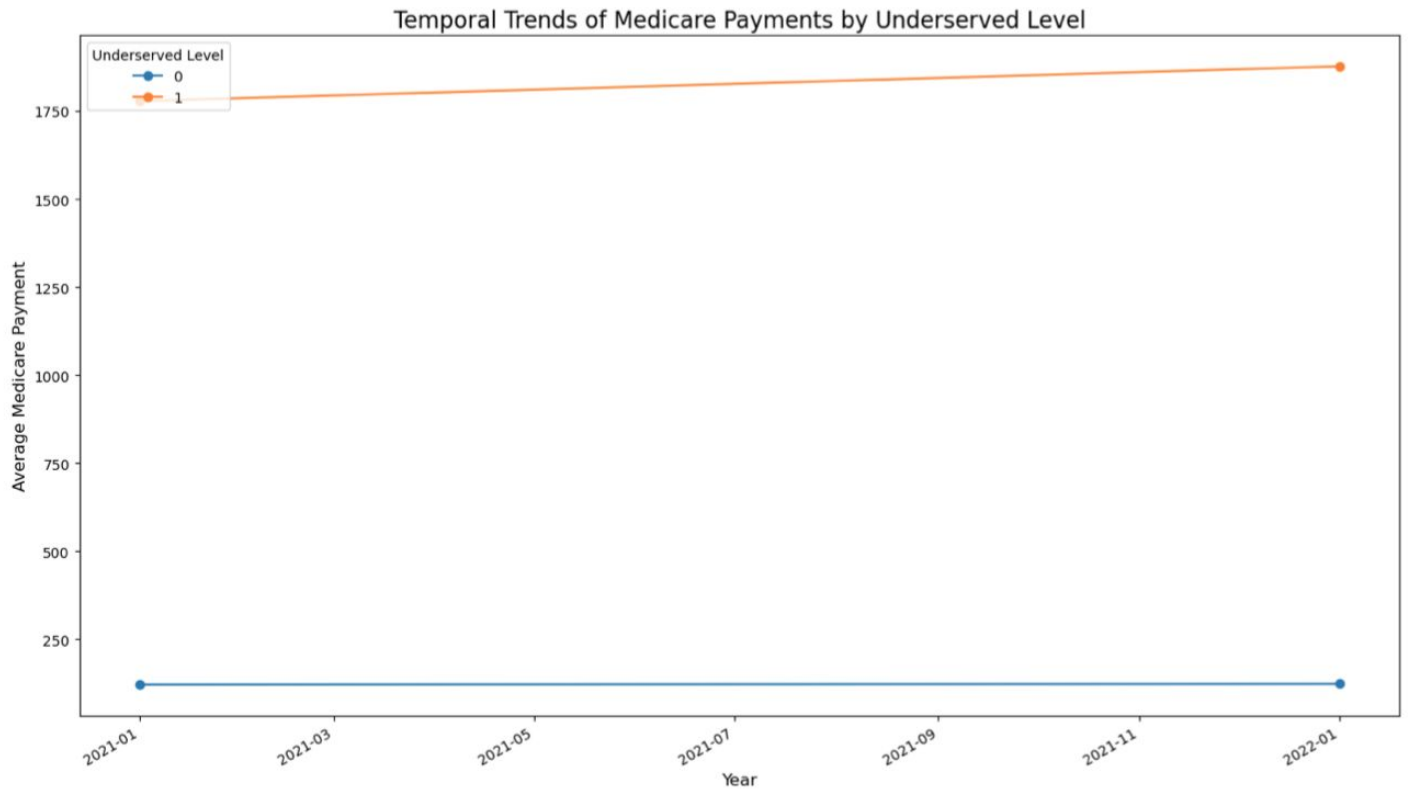
Interpretability and Insights

RQ2: Underserved regions face higher costs with lower service volumes.



Underserved Level : 1 - Underserved regions 0 - Normal regions

Figure : Temporal trends of Medicare payments by level

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Interpretability and Insights

RQ3: Negative correlations between service volumes and charges suggest systemic inefficiencies.

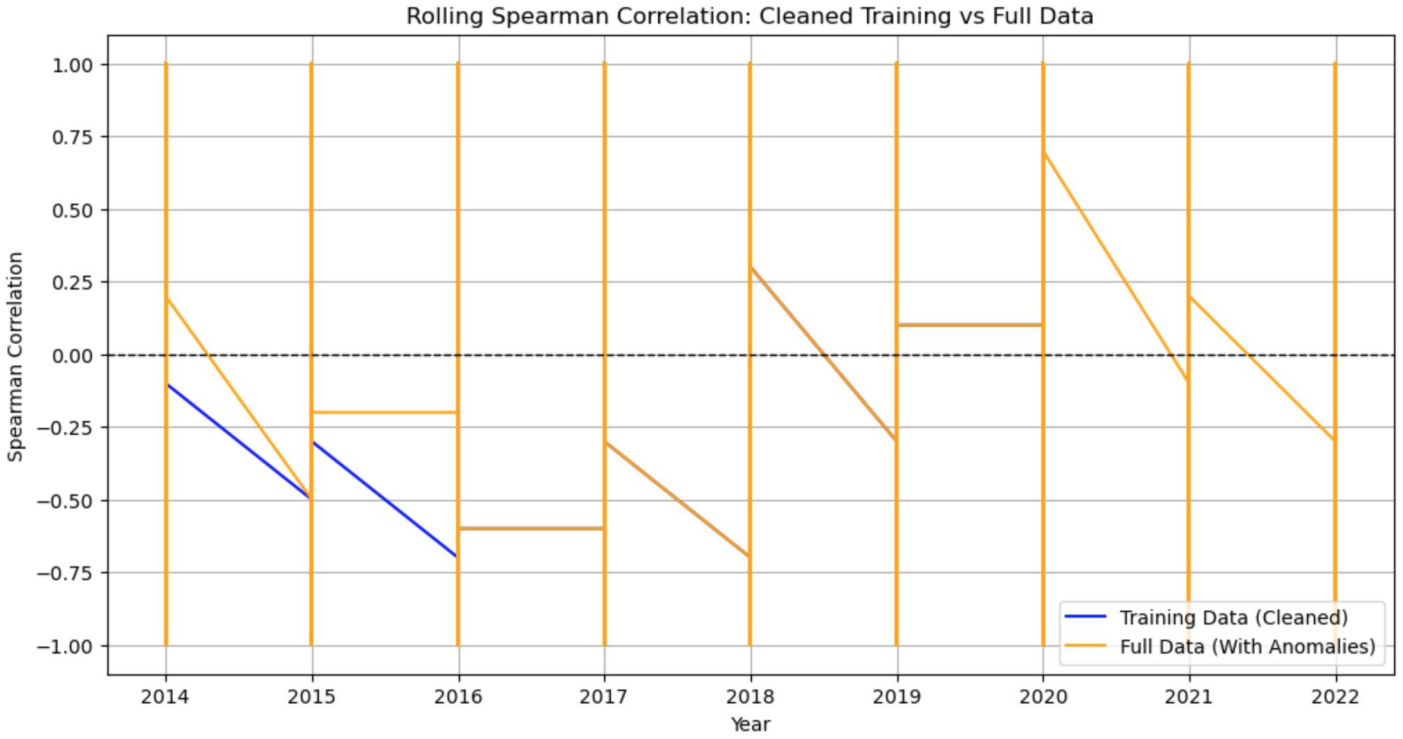

Figure : Rolling Spearman Correlation Between Cleaned Training Data and Full Data

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Interpretability and Insights

RQ4: Supplier charges show significant regional differences and fluctuating trends, emphasizing the need for region-specific cost optimization strategies

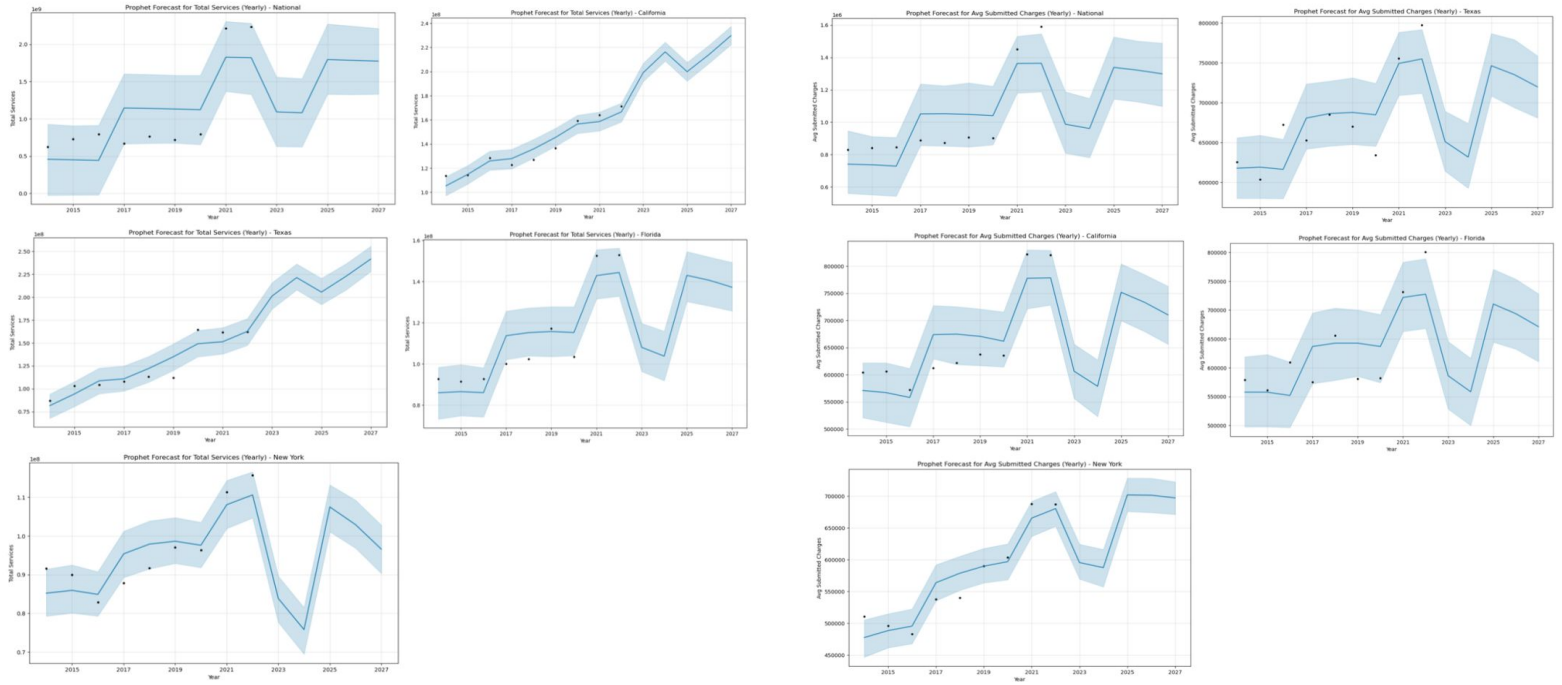


Figure : Forecast Total Services and Avg Submitted Charges for the Top 5 Regions

Limitations and Challenges

- ➔ Lack of labeled data for anomaly validation.
- ➔ Data Quality and Completeness (Right-Skewness)

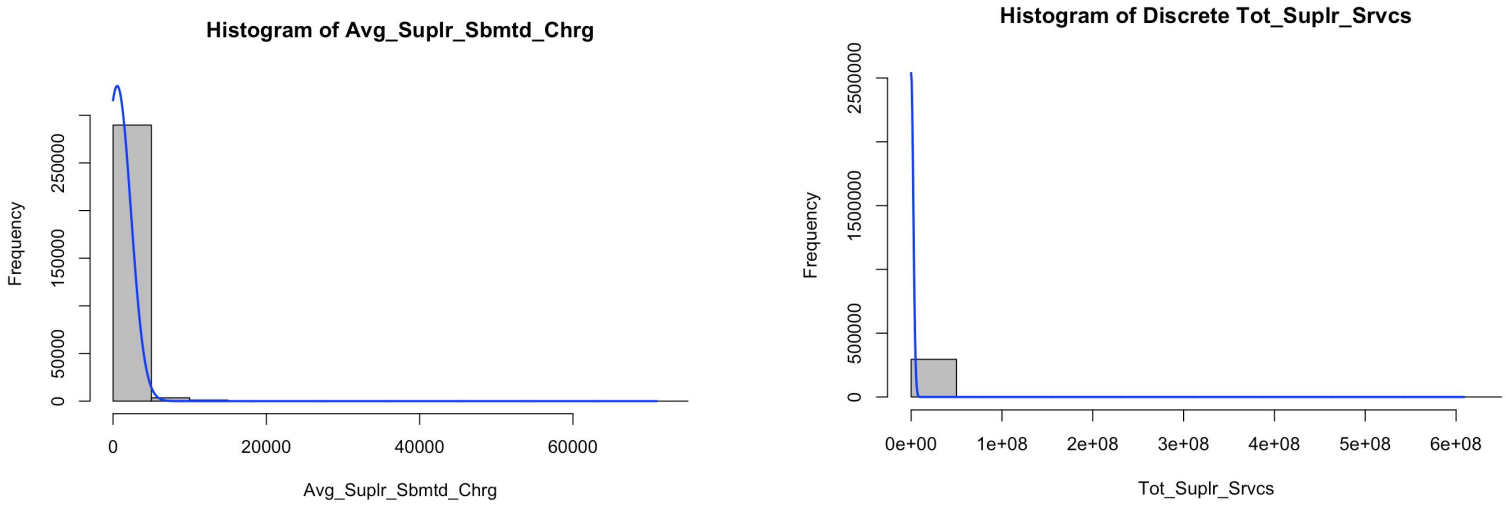
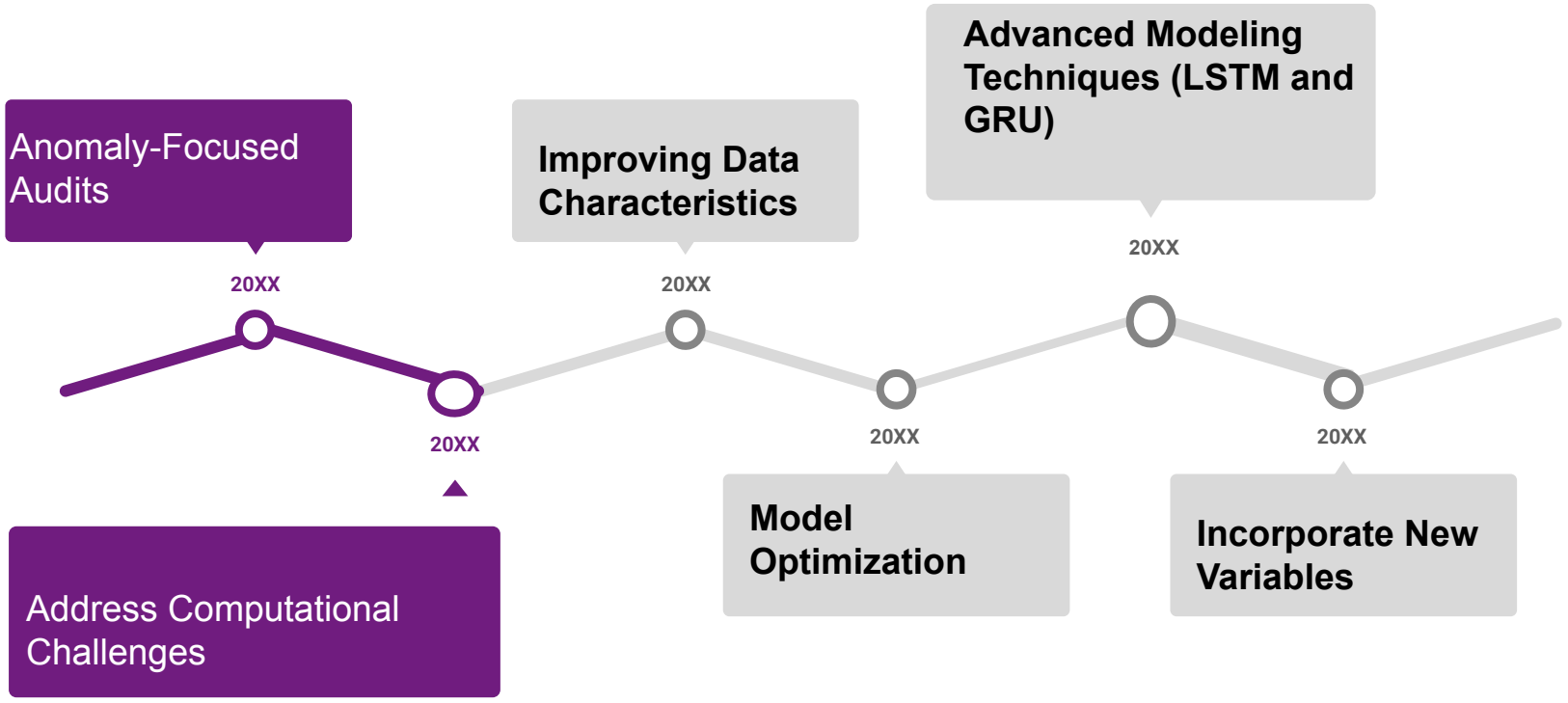


Figure : Histogram of Total Services and Avg Submitted Charges

Limitations and Challenges

- ➔ Computational Overhead (TSCV , Scalability)
- ➔ Temporal Trends and Seasonality
- ➔ Model Sensitivity
- ➔ Scalability
- ➔ External Factors

Future Directions



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Policy Implications

- ➔ Real-Time Detection Systems
- ➔ Targeted Resource Allocation
- ➔ Addressing Inefficiencies and Cost Spikes
- ➔ Benchmarking Best Practices
- ➔ Enhancing Billing Oversight
- ➔ Localized Interventions for Fluctuating Regions
- ➔ Incentivizing Efficiency in High-Volume Services

Conclusion

Insights

This research identifies Medicare inefficiencies and highlights opportunities for improvement through targeted strategies and machine learning applications.

Impact

Tackling temporal and regional disparities can improve cost-efficiency and ensure better accessibility, particularly for underserved regions.

Next Steps

By leveraging data-driven approaches and addressing inefficiencies, this study supports equitable resource allocation and enhanced healthcare delivery.

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Questions, Comments & Feedbacks

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Thank you!

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