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Articles

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Benchmarking and analysis of machine learning models to predict used car prices

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Abstract

The United States used car market represents a complex ecosystem in which vehicle valuations are influenced by numerous interconnected factors. This study develops a comprehensive machine learning framework to analyze and explain the pricing dynamics of used cars in the U.S. market, employing SHAP (SHapley Additive exPlanations) values to interpret feature contributions. Our methodology integrates regression, ensemble, and neural network–based models to capture nonlinear relationships between vehicle attributes and market prices. The model incorporates multiple determinants, including make, model, year, mileage, drivetrain, and transmission, while SHAP values are used to quantify and visualize both individual and interactive feature effects. The results indicate that mileage, make, and year are the most influential predictors of price. SHAP analysis further reveals complex feature interactions, with mileage and base model emerging as dominant drivers of valuation. This research enhances understanding of used car pricing mechanisms in the United States and provides a robust, interpretable framework for pricing strategy development in the secondary vehicle market.

Keywords: SHAP; Price Prediction; Used Car Prices; Regression; Nonlinear Relationships

1 Introduction

The dynamic nature of the automotive market makes car price prediction a critical component for various industry stakeholders, particularly in an era of rapidly evolving consumer preferences and market conditions. In today's digital economy, where information accessibility strongly influences consumer behavior, accurate price predictions serve as essential tools for enhancing market transparency and efficiency. Consumers rely on reliable price estimates to make informed purchasing decisions and negotiate effectively, ensuring they receive fair value for what is often their second-largest financial commitment after housing. This predictive capability is especially important given that price variations can be substantial across regions and timeframes. Dealerships depend on precise vehicle valuations to maintain competitive pricing strategies, optimize inventory management, and maximize profitability while preserving customer satisfaction. Accurate price predictions support informed decisions regarding trade-in values, optimal selling prices, and inventory turnover management. For manufacturers, understanding price trends and their underlying determinants is essential for strategic planning, product development, and market positioning, enabling alignment of production and marketing strategies with evolving market demands. Such insights are particularly valuable for long-term planning, allowing manufacturers to anticipate market shifts and adjust their product portfolios accordingly. The ability to accurately predict vehicle prices has become increasingly vital as the automotive industry continues to evolve through technological advancements and changing consumer expectations, influencing decisions across the value chain. In an industry characterized by tight margins and intense competition, success often depends on the ability to accurately assess market values and anticipate price movements.

The complexity of car price prediction arises from the multitude of factors that influence vehicle values in today's market. This research focuses on eight key determinants: make, model, year, exterior color, interior color, drivetrain, transmission, and mileage. These fundamental characteristics form the backbone of vehicle valuation, each contributing uniquely to a car's market worth in ways that often interact with one another. The intricate nature of the automotive market means that these factors cannot be evaluated in isolation, as their combined effects frequently produce non-linear impacts on vehicle prices that vary across market segments and geographical regions. A vehicle's make and model serve as primary indicators of value, reflecting not only the manufacturer's reputation but also the market positioning and historical performance of a specific vehicle line. Premium manufacturers such as BMW, Mercedes-Benz, and Lexus typically command higher prices due to strong brand equity and perceived quality, while mainstream brands often offer more moderate pricing and, in some segments, better value retention. Within each make, models can differ substantially in their value propositions; flagship models and limited editions often maintain stronger resale values than base variants. The year of manufacturing plays a dual role by capturing both age-related depreciation and technological relevance in an increasingly advanced automotive landscape.

Newer vehicles equipped with advanced safety systems, improved fuel efficiency, and modern connectivity features tend to retain higher values than older models lacking these innovations. Although exterior and interior colors are included in the analysis, recent research (Bergmann & Feuerriegel, 2025) suggests their impact on vehicle pricing is more nuanced than traditionally assumed. These findings challenge conventional assumptions about the role of color in price determination and suggest that color influences market liquidity more than final transaction value. In contrast, drivetrain and transmission specifications have a more direct effect on vehicle pricing by shaping performance characteristics and appeal to specific consumer segments. Mileage remains one of the most intuitive yet critical indicators of vehicle condition and expected remaining lifespan. The interaction of these variables creates a complex network of relationships that traditional pricing models struggle to capture effectively, underscoring the need for more sophisticated analytical approaches. This complexity is further intensified by regional market differences, seasonal demand fluctuations, and evolving consumer preferences, making the development of accurate car price prediction models both challenging and essential for the automotive industry.

2 Literature Review

2.1 Historical Approaches to Car Price Prediction

Historically, the prediction of used car prices has relied heavily on statistical methods, particularly regression-based techniques. Multiple linear regression has been widely employed because it enables the estimation of vehicle prices using several independent variables, such as mileage, age, and engine size. For example, Kuiper (2008) developed a multivariate regression model to predict used car retail prices, highlighting the relationship between price and factors including mileage and engine specifications (Agokei & Afa, 2019). Similarly, spline S-regression models have demonstrated promising performance in used car price prediction, in some cases outperforming traditional linear regression approaches (Salim & Abu, 2018).

Heuristic models have also been applied to car price prediction, typically relying on expert judgment to establish price ranges based on observed market trends. However, these models generally lack the robustness and adaptability of statistical and machine learning–based approaches. The limitations of heuristic methods become evident when compared with data-driven techniques, which can dynamically adjust to new information and changing market conditions. In addition, advancements in data collection methods have significantly improved the accuracy of price prediction models. The emergence of online databases and valuation platforms such as Kelley Blue Book has enabled access to large-scale datasets, thereby enhancing the predictive performance of regression-based models (Venkatasubbu & Ganesh, 2019). Nevertheless, while these historical approaches have laid a strong foundation for understanding key price determinants, they often struggle to capture the complex and nonlinear relationships that characterize used car pricing.

2.2 Emerging Techniques Leveraging AI and Machine Learning

The emergence of artificial intelligence (AI) and machine learning (ML) has revolutionized the field of used car price prediction. Recent studies have demonstrated the effectiveness of advanced algorithms such as Random Forest, Support Vector Machines (SVM), and XGBoost in forecasting prices with greater accuracy than traditional methods (Guo & Zhang, 2024; Zhu, 2023; Chen et al., 2022). For instance, Li highlighted the efficacy of Random Forest Regression, which utilizes ensemble learning to improve prediction accuracy by aggregating the results of multiple decision trees (Li, 2024). Additionally, hybrid models that combine various machine learning techniques have shown promise in enhancing prediction accuracy. For example, a hybrid forecasting model utilizing a BP neural network and stochastic algorithms has been developed to evaluate used car prices based on multiple indicators, achieving high accuracy in predictions (Xu et al., 2023). Furthermore, the integration of deep learning techniques, such as convolutional neural networks, has been explored, indicating a trend towards more sophisticated models capable of analyzing complex datasets (Dutulescu et al., 2023). The use of feature engineering and data preprocessing has also become critical in improving model performance. By selecting relevant features and transforming data appropriately, researchers have been able to enhance the predictive power of their models significantly (Varshitha et al., 2022). This trend underscores the importance of not only the algorithms used but also the quality and relevance of the input data in achieving accurate price predictions.

2.3 Comparative Studies on Algorithmic Efficiency in Price Predictions

Comparative studies have been instrumental in evaluating the efficiency of various machine learning algorithms in predicting used car prices. Research has shown that ensemble methods, particularly Random Forest and XGBoost, often outperform traditional regression techniques due to their ability to handle nonlinear relationships and interactions among variables (Longani et al., 2021; Chen et al., 2021; Chen et al., 2022). For instance, a study comparing Random Forest, Decision Tree, and Gradient Boosting Regression found that Gradient Boosting provided superior predictive performance in the context of used car pricing in India (Chen et al., 2022). Moreover, the application of supervised learning techniques has been extensively documented, with studies indicating that Random Forest and Support Vector Machines yield competitive results in terms of accuracy and reliability (Venkatasubbu & Ganesh, 2019; Amik et al., 2021). The performance of these algorithms is often assessed using metrics such as Mean Absolute Error (MAE) and R-Squared values, which provide insights into their predictive capabilities. In addition, the exploration of hybrid models that integrate multiple algorithms has gained traction. For example, the combination of neural networks with other machine learning techniques has shown to enhance prediction accuracy, demonstrating the potential benefits of using ensemble approaches

(Liu et al., 2022). Such comparative analyses are crucial for identifying the most effective methodologies for used car price prediction and guiding future research directions.

2.4 Existing Limitations and Research Gaps in Car Price Prediction

Despite the advancements in machine learning techniques for used car price prediction, several limitations and research gaps persist. One significant challenge is the availability and quality of data. Many models rely on historical data that may not accurately reflect current market conditions, leading to potential biases in predictions. Furthermore, the dynamic nature of the used car market, influenced by economic factors, consumer preferences, and technological advancements, necessitates continuous model updates and refinements (Zhu, 2023). Another limitation is the interpretability of complex machine learning models. While algorithms like Random Forest and XGBoost provide high accuracy, they often operate as "black boxes", making it difficult for stakeholders to understand the underlying decision-making processes. This lack of transparency can hinder trust in the models, particularly among buyers and sellers who rely on these predictions for financial decisions (Dutulescu et al., 2023). Additionally, there is a need for more comprehensive studies that incorporate a wider range of variables influencing used car prices. Many existing models focus on a limited set of features, potentially overlooking critical factors such as market trends, regional differences, and economic indicators (Costa et al., 2020). Future research should aim to develop more holistic models that consider these variables to enhance predictive accuracy. Finally, the integration of real time data and the application of online learning techniques could significantly improve the adaptability of prediction models. By continuously updating models with new data, researchers can better capture shifts in market dynamics and consumer behavior, ultimately leading to more accurate price predictions (Huang, 2023). Addressing these limitations and research gaps will be essential for advancing the field of used-car price prediction and ensuring that models remain relevant in an ever-changing market landscape.

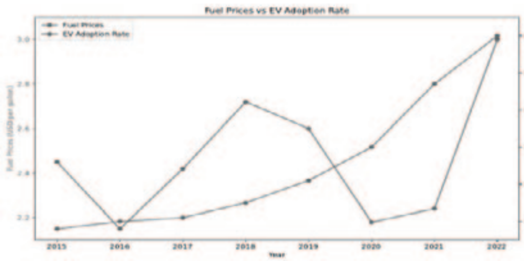


Figure 1: Impact of Fuel prices on Electric Car Adoption from 2015 to 2024

3 Car Price Prediction Methodology

3.1 Understanding Market Trends

Fuel prices have a significant influence on car pricing as shown in Fig. 1. The influence mechanism can be broadly categorized into shaping consumer demand, impacting production cost, and market dynamics. A time series analysis of the data shows the impact of the fuel price on car pricing. Impact on consumer demand: In 2008, when the oil price surged and reached $\$145$ per barrel, the demand for fuel-efficient vehicles like Toyota Prius increased dramatically. This, in turn, impacted the price of hybrid vehicles, which rose by $10 - 15$ percent. Between 2014 and 2016, when the oil price dropped to an average of $\$45$ per barrel, there was a 25 percent increase in sales of SUVs and trucks with a corresponding price increase of $8 - 10$ percent for these models (Maersk, 2022). Impact of Production Cost: Higher fuel prices impact transportation costs, which increase production costs. In 2022 the fuel price surged, and the price of diesel increased by 55 percent year-over-year. This caused a 3.5 percent rise in vehicle costs (Ke et al., 2014). In 2023 when the traditional automakers shifted part of their production to electric and hybrid vehicles the production cost was higher for these vehicles as compared to their traditional counterparts. The impact of market dynamics: According to the Kelley Blue Book data, the price of fuel-efficient vehicles retains 58 percent of their value whereas less-efficient vehicles retain 48 percent of their value during the same period. Technological investments by some automakers do have an impact on the price of vehicles. Tesla Model 3, with significantly more investment in technology and corresponding higher range per charge had a price premium over its counterparts (Kelley Blue Book, n.d.).

Inflation in the economy had a great impact on car prices. Inflation impacts the raw material cost including that of steel, aluminum, and plastic which includes a big component of the raw materials. This increase in the cost of raw materials caused hikes in the manufacturing cost which is finally passed on to consumers. Inflation also has an impact on labor wages which moves up with the cost of living (Vilchez et al., 2019) This higher labor cost caused vehicle prices to surge. Automobile manufacturing depends on a stretched-out global supply chain. Inflation often has a disruptive effect on the supply chain by sharp increases in shipping and logistics costs. This disruption in the supply chain can cause shortages in critical components and drive up the price. The pandemic had a big impact on the global supply chain which caused a shortage of semiconductors which are in great demand for new cars and hiked up the car price. Central banks often raise interest rates to combat inflation. This higher interest rate increases the cost of auto loans, and it makes the car purchase more expensive for consumers (Foohey, 2020; CNBC, 2023). Inflation also impacts on the cost of vehicle maintenance and repair. The higher price of parts and labor because of inflation makes car ownership more expensive. The cost of insurance also rises with inflation and adds another layer of expense for car ownership. While these macroeconomic factors--such as fuel price fluctuations and inflation--clearly influence the broader pricing landscape, the current study focuses specifically on vehicle-level attributes. The integration of these broader economic indicators into predictive modeling is reserved for future research iterations.

3.2 Selection and Processing of Critical Attributes

The make and model of the car are the fundamental attributes that have significant influence on its price. Different car brands and models have varying levels of reliability, reputation, and demand. This in turn reflects the market price. These categorical variables can be encoded into numerical formats which are suitable for machine learning models (Brucks et al., 2000). The year of car manufacture is also crucial as it indicates the car's age, which impacts the car's depreciation and market value. This numerical attribute can be directly used, or it can be transformed into the car's age by subtracting year of manufacture from the current year. These normalization techniques are often used to scale the appropriate values. Another key factor in determining car prices is mileage. Higher mileage is an indicator of higher wear and tear and hence lower price. Mileage is typically normalized to ensure it is in a comparable scale with other numerical features (Burnham et al., 2021). The condition of a car e.g. excellent, good, fair, poor can significantly impact car price. The categorical variables can be encoded using ordinal encoding. The geographical location of the car, where it is being sold, can also influence its price because of regional demand, economic conditions and market saturation.

3.3 Evaluation Metrics

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |y_i - \hat{y}_i| \tag{1}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \tag{2}$$

The performance of the predictive model was evaluated using two key metrics: Mean Absolute Error and R-squared score. These metrics provide similar perspectives on the model's accuracy and ability to capture the variability in car prices. MAE measures the average magnitude of errors between the predicted and actual car prices, offering a simple evaluation of prediction accuracy (Willmott & Matsuura, 2006). This metric is used for its simplicity and interpretability. It provides a direct measure of the typical size of prediction errors in the same units as the target variable. A lower MAE shows that the model's predictions align with observed values, reflecting a higher level of precision (Chai & Draxler, 2014). MAE only focuses on the magnitude, avoiding the cancellation of positive and negative errors. This ensures a clear representation of prediction accuracy, making MAE a reliable measure for comparing models or assessing performance across different datasets. The R^2 score evaluates the proportion of variance in the target variable that is explained by the model (Nagelkerke, 1991). An R^2 score approaching one suggests that the model successfully explains the variability in the data, indicating strong performance in identifying and utilizing predictive features. Conversely, a lower R^2 score implies that a significant portion of the variability remains unexplained, which may highlight limitations in the model's design, the adequacy of the selected features, or the presence of additional factors influencing car prices that were not included in the analysis (Draper & Smith, 1998).

3.4 SHAP Analysis

SHAP (SHapley Additive exPlanations) is a widely used technique for interpreting complex model predictions by allocating the overall prediction among features according to their marginal contributions, grounded in the cooperative game theory concept of Shapley values (Shapley, 1953). Specifically, it evaluates how adding or removing each feature affects model outputs across all possible subsets of features, thereby providing a rigorous, additive explanation of feature importance (Lundberg & Lee, 2017). By summing the individual SHAP values for all features along with a baseline, SHAP ensures transparency of a model's predictions at both local (instance level) and global (dataset-level) scales, ultimately enhancing model interpretability and trustworthiness in high-stakes applications; in this work, we leverage SHAP analysis to elucidate how each feature in the dataset individually contributes to the predicted outcomes.

3.5 Datasets

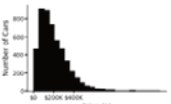
Our research utilizes an internal dataset originally scraped from the web in 2020, consisting of 826,117 car records. The high initial record count was reduced to 8,137 unique records after removing a 98 percent duplication rate. This high rate was primarily attributed to repeated listings, mirrored postings across platforms, and relisted vehicles. The dataset encompasses 11 critical attributes that inform vehicle valuation. Primary identifiers include the make and model of the car, alongside the listed price, the odometer mileage, and the overall condition, categorized as new, used, or certified pre-owned. Mechanical and aesthetic specifications are captured through the vehicle's transmission type, drivetrain configuration (e.g., AWD, FWD, or RWD), exterior color, and interior color. Finally, the dataset accounts for logistical and qualitative market factors by including the specific dealership selling the car, the distance of the vehicle from a specified location, and associated customer reviews and ratings. As the dataset was scraped in 2020, the findings reflect a pre-COVID and pre-semiconductor chip shortage market. Consequently, the generalizability of these results may be affected by subsequent shifts in market dynamics and the significant price volatility observed in the post-2020 used car ecosystem.

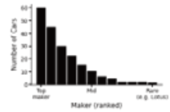
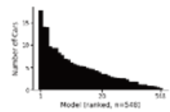
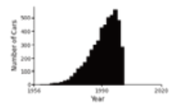
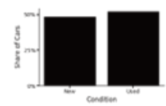
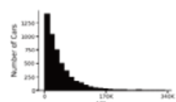
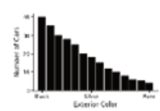
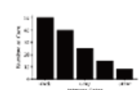
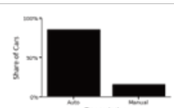
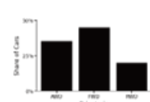
To prepare the dataset for analysis, we conducted an initial round of data preprocessing and feature engineering. These steps were crucial to make the dataset more structured, consistent, and suitable for downstream analysis. Preprocessing included tasks like removing duplicate entries, handling missing values, and standardizing categorical data such as colors and transmission types. Feature engineering focused on enhancing the dataset by deriving meaningful variables from the existing attributes, which helped improve the representativeness of the data for our analysis and modeling efforts. Table1 shows the Data Dictionary for the Car Dataset.

3.6 Exploratory Data Analysis (EDA)

Exploratory data analysis was conducted to uncover the fundamental characteristics and distributions of the dataset's attributes. The target variable, price, exhibited a heavily right-skewed distribution due to the presence of rare luxury vehicles, which necessitated a log-transformation to approximate a normal distribution for modeling. The categorical distribution of the 548 unique vehicle models and their respective manufacturers was highly uneven; consequently, manufacturers with negligible representation were aggregated into an "Other" category to ensure statistical significance. While the manufacturing years span a 45-year period adding historical diversity, the dataset is predominantly populated by newer vehicles. The inventory is evenly split between new and used conditions, with mileage varying significantly to act as a primary metric for vehicle wear and value depreciation. Additionally, exterior and interior colors required standardization to correct inconsistent naming conventions across the dataset.

Table 1: Data Dictionary for Car Dataset

Attribute	Description	Feature Processing	Distribution
Price	Price is the target variable and exhibits a right-skewed distribution.	Remove the “Not Priced” values from this column.	

Maker	Represents the manufacturer of the car.	The car date, maker and model with additional features are all combined in this column.	
Model	Specifies the car model, with a total of 548 unique models.	We extract the “Model”	
Year	Indicates the manufacturing year of the car, spanning 45 years.		
Condition	Describes whether the car is new or used. The data is evenly distributed between new and used cars	We converted all the values to either, “New”, “Used” and “Certified”.	
Miles	Records the distance covered by the car.	For those cars where “Condition” was “New” we just replaced “Miles” with “0”.	
ExtColor	The exterior color of the car, requiring standardization due to inconsistent naming	We just replaced the prefixes to only the value like, “Ext. Color: Silver” -> “Silver”,	
IntColor	The interior color of the car, with fewer categories than ExtColor	We just replaced the prefixes to only the value like, “Int. Color: Black” -> “Black”,	
Transmission	Indicates whether the car is automatic or manual, suitable for categorical encoding	We just replaced the prefixes to only the value	
Drivetrain	Specifies drivetrain configuration (e.g., AWD, FWD, RWD), which correlates with price and performance	We just replaced the prefixes to only the value like, “Drivetrain: RWD” -> “RWD”,	

4 Baseline Model Development

To establish a simple yet effective baseline for our work, we experimented with a variety of machine learning models, focusing on regression tasks to predict continuous price values. This approach differs from many previous studies, such as those by Srivastava et al. (2019), which predominantly framed the problem as a classification task by dividing price ranges into discrete classes or bins. These studies aimed to simplify the predictive modeling process by categorizing prices into predefined brackets, such as "low", "medium", or "high", but often sacrificed the granularity necessary for precise applications like dynamic pricing strategies. Models Used for Baseline Models were trained using an 80:20 train-test split and evaluated via 10-fold cross-validation. Hyperparameters were optimized using grid search to ensure robust performance across all algorithm classes. We employed the following machine learning models, each chosen for their unique strengths and ability to capture different aspects of the data:

4.1 Linear Regression

Linear regression models the relationship between a dependent variable and one or more independent variables by fitting a linear equation to observed data. The concept was introduced by Sir Francis Galton. The model is represented as:

$$y = X\beta + \epsilon \tag{3}$$

4.2 Lasso Regression

Lasso (Least Absolute Shrinkage and Selection Operator) regression was introduced by Tibshirani (1996). It enhances linear regression by adding an L1 regularization term to the loss function. This penalizes the absolute values of the coefficients, performing feature selection by shrinking some coefficients to zero. The objective function is:

$$\min \left\{ \frac{1}{N} \|y - \beta_0 - X\beta\|_2^2 \right\} \tag{4}$$

4.3 Ridge Regression

Ridge regression, also known as Tikhonov regularization (McDonald, 2009), was independently developed by Andrey Tikhonov and later popularized in the context of statistics by Hoerl and Kennard (1970). It addresses multicollinearity by adding an L2 regularization term to the linear regression loss function, penalizing the sum of the squared coefficients. The objective function is:

$$\sum_{i=1}^{n} (Y_i - \hat{y}_i)^2 + \lambda \sum_{j=1}^{p} \beta_j^2 \tag{5}$$

4.4 Elastic Net

Elastic Net is a regularization technique that combines both L1 and L2 penalties of the Lasso and Ridge methods. It was proposed by Hui Zou and Trevor Hastie in 2005 (Zou & Hastie, 2005). This combination is particularly useful when dealing with highly correlated predictors or when the number of predictors exceeds the number of observations.

$$\text{Min}\left(\frac{1}{2N}\sum_{i=1}^{N} (y_i - \beta_0 - x_i^T\beta)^2 + \lambda \sum_{j=1}^{p} |\beta_j|\right) \tag{6}$$

4.5 Random Forest Regression

`Random Forest is an ensemble learning method developed by Breiman (2001). It constructs multiple decision trees during training and outputs the average prediction of the individual trees to improve predictive accuracy and control overfitting.

$$\hat{y} = \frac{1}{N}\sum_{i=1}^{N} f_i(\mathbf{x}) \tag{7}$$

where $f_i(\mathbf{x})$ is the prediction from the i-th tree.

4.6 Gradient Boosting Regression

Gradient Boosting is a machine learning technique developed by Friedman (2002). It builds models sequentially, each new model attempting to correct the errors of the previous ones. In regression tasks, it minimizes a specified loss function by adding weak learners, typically decision trees, in a stage-wise manner.

$$F_m(\mathbf{x}) = F_{m-1}(\mathbf{x}) + \gamma h_m(\mathbf{x}) \tag{8}$$

4.7 XGBoost

XGBoost (eXtreme Gradient Boosting) is an optimized implementation of gradient boosting introduced by Chen and Guestrin (2016). It focuses on speed and performance, introducing regularization terms in the loss function to prevent overfitting and efficiently handling missing values.

$$obj(\theta) = \sum_{i=1}^{n} \ell(y_i, \hat{y}_i) + \sum_{k=1}^{K} \Omega(f_k) \quad (9)$$

4.8 LightGBM (Light Gradient Boosted Machine)

LightGBM is a gradient boosting framework developed by Ke et al. (2017). It is designed for efficiency and scalability, using a histogram-based approach to find optimal split points, which speeds up training and reduces memory usage.

4.9 CatBoost Regression

CatBoost is a gradient boosting algorithm developed by Prokhorenkova et al. (2018). It is well-suited for categorical data and efficiently handles categorical features by performing optimal splits and avoiding overfitting through ordered boosting.

$$F_m(x) = F_{m-1}(x) + \gamma_m \sum_{i=1}^{n} g_i h_m(x_i) \quad (10)$$

4.10 Multi-Layer Perceptron (MLP)

The Multi-Layer Perceptron is a class of feedforward artificial neural networks. The concept was introduced by Rosenblatt (1958) with the perception and later expanded to multiple layers. MLPs can learn complex patterns and nonlinear relationships in data. $\mathrm{z(l)} = \mathrm{W(l)a(l-1)} + \mathrm{b(l)a(l)} = \mathrm{(z(l))}$ Approach and Rationale Each model was trained and evaluated to understand its strengths and weaknesses in predicting car prices based on the features available in our dataset. The diversity of models allowed us to compare the performance of simpler linear models, regularization techniques, ensemble-based methods, and more sophisticated neural networks. Our choice to use regression models instead of classification aligns with the objective of predicting precise price values rather than placing them into predefined categories, which provides finer granularity and better real-world applicability. This baseline model analysis serves as a benchmark for future enhancements and provides valuable insights into the relative performance of different approaches.

4.11 — Stacked Regression and Meta-Learner

In the stacked regression model, we employed a two-level architecture. The six base learners in the first level are - Random

Forest, Gradient Boosting, SVR, ElasticNet, XGBoost, LightGBM, and MLP. Each of these learners are trained using a 10-fold cross-validation. We collected their out-of-fold predictions to form a new feature matrix. This procedure is done to ensure that the meta-learner is never trained in predictions that were derived from data it had seen. This prevented data leakage. In the second level of this architecture a Ridge Regression model served as the meta-learner. We had selected the Ridge Regression because of its ability to handle correlated inputs, and also because of its tendency to shrink and not to eliminate, the contribution of weaker learners. This provided a stable and interpretable blending weight.

5 Results and Analysis

The experimental evaluation was conducted across three distinct categories of models: traditional regression types, decision tree/ensemble methods, and neural network–based architectures. Table 2 presents the performance metrics for traditional regression models, where Linear Regression served as the primary baseline. Table 3 details the impact of varying hidden layer architectures on MLP performance, highlighting the susceptibility to overfitting. Finally, Table 4 compares ensemble methods, showing that Gradient Boosting and Stacked Regression achieved the highest R-squared values.

Table 2: Performance comparison of different regression models

Model	Mean	Variance	MAE
Linear Regression	0.7462	0.0247	0.1935
Lasso Regression	0.7441	0.0152	0.1936
Ridge Regression	0.7442	0.0184	0.1934
SVR Regression	0.4210	0.0405	0.3029
KNN Regression	0.6498	0.0282	0.2163

Table 3: Performance comparison of MLP regression models

Model	Mean	Variance	MAE
Vanilla MLP Regression (default 100)	0.5820	0.1433	0.1931
Vanilla MLP Regression (32 × 8)	0.7524	0.0254	0.1914
Vanilla MLP Regression (32 × 16)	0.7555	0.0242	0.1903
Vanilla MLP Regression (32 × 64)	0.7616	0.0310	0.1897
Vanilla MLP Regression (64 × 16)	0.7721	0.0266	0.1884

Figure 4: SHAP Summary Plots for Different Regression Models

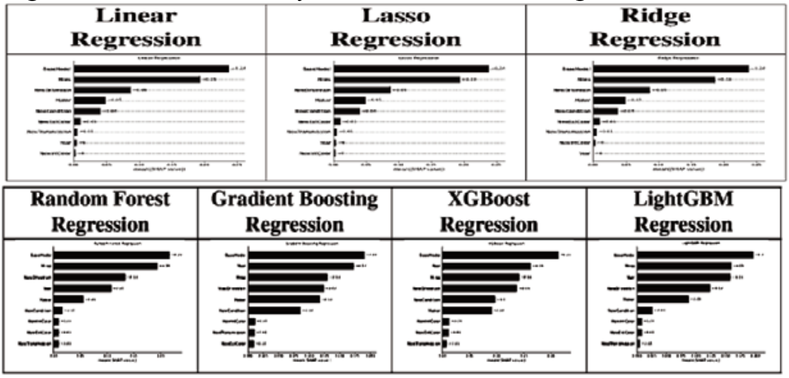


Table 4: Performance comparison of different ensemble models

Model	Mean	Variance	MAE
Random Forest Regression	0.8512	0.0150	0.1446
Gradient Boosting Regression	0.8573	0.0117	0.1431
XGBoost Regression	0.8568	0.0203	0.1449
LightGBM Regression	0.8529	0.0238	0.1478
Stacked Regression, Random Forest, Gradient Boosting, SVR ElasticNet, XGBoost, LightGBM MLP	0.8661	0.0134	0.1417

5.1 Analysis

The evaluation of the machine learning algorithms revealed a distinct performance gradient across regression, ensemble, and neural network models. Traditional linear regression, along with its regularized Lasso and Ridge variants, demonstrated consistent baseline performance, achieving an R-squared score of approximately 0.74. While Ridge regression showed stability in handling multicollinearity, the linear models were ultimately constrained by their inability to map complex, non-linear interactions between vehicle variables. In contrast, ensemble-based approaches -including Random Forest, Gradient Boosting, XGBoost, and LightGBM—significantly outperformed the traditional methods, yielding R-squared values between 0.85 and 0.86. These models effectively captured intricate, non-linear feature interdependencies, with Gradient Boosting Regression emerging as the superior standalone performer due to its robust generalization capabilities. A stacked regression model further improved predictive accuracy to 0.8661 by leveraging the complementary strengths of these algorithms. Conversely, the Multi-Layer Perceptron (MLP) neural network models achieved a lower R-squared score of roughly 0.77. Although neural networks possess the architecture to learn high-dimensional interactions, their effectiveness was severely limited by the small dataset size, resulting in high variance and an observed tendency toward overfitting.

5.2 Feature Contributions

The study employed SHAP (SHapley Additive exPlanations) to interpret the contributions of individual features, revealing that mileage, make, and year were the most significant predictors of car valuation. SHAP analysis illuminated intricate interactions, demonstrating how the impact of mileage is frequently modulated by the vehicle's make and year, which highlights the complex dependencies successfully captured by the models.

Mileage emerged as the primary predictor of price, exhibiting a distinct non-linear relationship. Specifically, steeper depreciation was observed within the first 50,000 miles, after which the rate of value loss tended to stabilize. In terms of model accuracy, ensemble approaches proved much more effective at capturing this mileage-based depreciation compared to traditional regression models.

A vehicle's make and model also exerted a substantial influence on pricing. Premium brands, such as BMW and Lexus, achieved higher R-squared contributions across all models, while ensemble methods successfully identified distinct pricing advantages for specific categories like hybrid vehicles. Random Forest and XGBoost algorithms particularly excelled at capturing these make-specific nonlinearities. Similarly, the year of manufacture played a crucial role, with newer vehicles commanding higher predicted prices driven by technological advancements. Depreciation noticeably accelerated for vehicles older than five years—a trend consistent across all evaluated models, though Gradient Boosting and XGBoost proved most adept at handling these specific non-linear patterns.

Finally, mechanical specifications and aesthetic attributes contributed to nuanced valuation shifts. All-wheel drive (AWD) configurations exerted a strong positive influence on predicted prices, particularly in snow-prone regions. Conversely, manual transmissions produced mixed effects, generally reducing prices for luxury vehicles while increasing them for sports cars. Tree-based models captured these trends significantly better than linear regression approaches. While exterior and interior colors had a comparatively smaller effect on pricing, neutral tones like black and white yielded marginally higher SHAP values than niche colors. Linear models frequently struggled to detect the subtle pricing variations introduced by these aesthetic attributes.

5.3 Limitations

While this study provides a robust framework for used car valuation, it is subject to certain constraints. The analysis relies on an internal dataset scraped from the web in 2020, which, after preprocessing and the removal of duplicates, yielded 8,137 unique vehicle records. This restricted dataset size inherently constrained the predictive effectiveness of the Multi-Layer Perceptron (MLP) neural network models. Consequently, the MLPs exhibited high variance and a susceptibility to overfitting due to insufficient data required for adequate regularization. Furthermore, while the models analyze vehicle-specific attributes, they do not dynamically account for broader, real-time macroeconomic shifts that influence pricing.

5.4 Future Research Directions

To address existing limitations, future research should prioritize the integration of larger, more contemporary datasets to fully harness the high-dimensional pattern recognition capabilities of deep learning models. Transitioning from static historical data to the application of online learning techniques with real-time data streams would significantly enhance model adaptability, allowing predictions to adjust dynamically to sudden shifts in market dynamics and consumer behavior. Additionally, future models should be expanded to incorporate broader macroeconomic indicators, such as regional economic health, fluctuating fuel prices, and supply chain disruptions, to create a more holistic and comprehensive pricing framework.

5.5 Practical Implications

The predictive framework developed in this study offers substantial operational value to stakeholders across the secondary automotive market. For dealerships, the deployment of highly accurate ensemble-based models facilitates the optimization of inventory management and the execution of competitive pricing strategies. Data-driven valuations enable more precise decision-making regarding trade-in appraisals and inventory turnover, ultimately maximizing profitability. For consumers, these models democratize access to reliable price estimates, enhancing market transparency and empowering buyers to negotiate fair value for their investments. Furthermore, manufacturers can leverage these predictive insights to track depreciation trends and feature valuations, allowing them to align long-term strategic planning, product development, and market positioning with evolving secondary market demands.

6 Conclusion

This study provides a comprehensive benchmarking of machine learning techniques for predicting used car prices within the complex landscape of the U.S. automotive market. We evaluated a range of models—from traditional regression approaches to advanced ensemble learning algorithms and neural networks—based on their predictive performance, interpretability, and robustness. The results reveal a clear performance gradient across model categories. Linear models, including linear, Lasso, and Ridge regression, offer baseline accuracy and strong interpretability; however, they are limited in their ability to capture nonlinear relationships and complex feature interactions, making them less suitable for granular, real-time pricing applications.

In contrast, ensemble-based methods such as Random Forest, Gradient Boosting, XGBoost, and LightGBM demonstrate significantly higher predictive accuracy and lower variance. These models effectively capture interdependencies among features, including the combined influence of mileage, year of manufacturing, drivetrain, and make on resale value. Among the evaluated approaches, Gradient Boosting Regression emerges as the most effective standalone model, while ensemble strategies further enhance predictive performance, achieving an R^2 score of 0.8661. Neural network–based models, specifically multilayer perceptron (MLPs), exhibit strong potential but are constrained by dataset size.

Although these models can learn high-dimensional nonlinear patterns, they are susceptible to overfitting and are limited by insufficient regularization when trained on smaller datasets. A key contribution of this research is the application of SHAP (SHapley Additive exPlanations) values to enhance model interpretability. This technique provides transparent insights into feature importance and identifies key determinants of vehicle pricing, including mileage, make, year, model, and overall vehicle condition. The study also underscores the critical role of data preprocessing in improving model performance. Data quality issues—such as duplicate records, inconsistent labeling, and improper scaling—can substantially degrade predictive accuracy. In conclusion, this study not only benchmarks the effectiveness of various machine learning models for used car price prediction but also proposes a scalable, interpretable, and data-driven framework for secondary market price estimation.

Declarations

All authors declare that they have no conflicts of interest.

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Aligning Accounting Education with CPA Evolution and Market Demand: The Rise of Technology-Intensive STEM Accounting Programs in the Era of AI And Big Data

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Abstract

Accounting education is transforming as big data and AI reshape the profession. In response to the CPA Evolution model and market demand for tech-proficient graduates, many U.S. graduate programs have pursued STEM designation. This study profiles 82 STEM-designated accounting programs to identify the structural factors driving this adoption. Findings indicate that these programs are predominantly concentrated in large, research-intensive (R1) universities with high national rankings and AACSB accreditation. The sample captures 50 percent of both the U.S. News top accounting programs and the Big Four firms' target schools. Notably, no Historically Black Colleges and Universities (HBCUs) currently offer STEM-designated accounting programs, revealing a significant equity gap. The study concludes that while STEM designation is a strategic response to technological transformation, its adoption is led by resource-rich institutions, highlighting a need for support for underrepresented colleges to modernize their curricula.

1. Introduction

Accounting education faces significant challenges in the era of artificial intelligence because the accounting industry is now driven by the growing demands of big data. Technology has dramatically transformed the daily responsibilities of accountants so that professionals are no longer just learning and applying advanced tools but also developing and innovating new technologies to help clients make informed decisions and enhance the quality of services (Vera, 2023).

Based on the American Institute of Certified Public Accountants (AICPA) survey of accounting firms in 2023, 99 percent of respondents identified data analysis skills and related tools (such as Microsoft Excel and Power BI) as valuable for new hires. Furthermore, 87 percent of firms rated advanced analytics capabilities (including data mining, data visualization, and predictive analytics) as important competencies for recent graduates entering the profession (American Institute of Certified Public Accountants [AICPA], 2023c).

In response to the data-driven accounting environment and technology-dependent accounting practices, the American Institute of Certified Public Accountants and Chartered Institute of Management Accountants (AICPA & CIMA) propose "Accounting is STEM", advocating for accounting to be officially designated as a STEM discipline, given accountants' increasing reliance on scientific, technological, engineering, and mathematical competencies. They use STEM skills like data analytics and machine learning to enhance audits, assess fraud risks, automate business processes, and more (AICPA, n.d.).

Furthermore, the AICPA and the National Association of State Boards of Accountancy (NASBA) initiated the CPA Evolution project in 2017 to examine CPA licensure and determine whether there were opportunities to improve the certification process and better address the challenges facing the profession. They voted to support the licensure change proposed by CPA Evolution in 2020 (Yeaton, 2021). The AICPA and NASBA implemented a new core-plus-discipline CPA licensure model and launched a redesigned Uniform CPA Exam in January 2024, with enhanced integration of technology throughout the exam (AICPA & NASBA, n.d.).

The initiative has led to the development of new resources, such as the CPA Evolution Model Curriculum, to help educators adapt their programs. Most accounting faculty indicated that their accounting programs will be making curriculum changes based on CPA Evolution (Mayes, 2022). The goal is to better prepare future CPAs for the technological and analytical demands of the profession. While the Department of Homeland Security (DHS) has not yet officially designated accounting as a STEM field, many individual academic programs have already taken steps in this direction. In fact, by early 2025, more than 80 accounting programs have received their own STEM designation from the federal government. This allows them to strengthen their curricula and attract a broader pool of students (AICPA, n.d.).

Despite growing attention to technology-driven curriculum reform, important gaps remain in existing research. First, there is limited empirical evidence describing the structural characteristics of STEM-designated accounting programs. Second, no study has systematically examined how institutional resources - such as research activity, accreditation status, and faculty capacity - shape the adoption of STEM designation. As a result, little is known about which universities are leading this shift and what organizational factors enable or constrain participation.

This study directly addresses these gaps by providing the first comprehensive descriptive profile of 82 STEM-designated accounting programs in the United States. Specifically, the analysis examines institutional, business-school, and program-level characteristics; identifies adoption patterns associated with research intensity, accreditation, faculty resources, and rankings; and highlights disparities in STEM diffusion across different segments of higher education.

The results reveal clear and consistent patterns that help explain how and why STEM designation has diffused across graduate accounting education. The findings indicate that STEM-designated accounting programs are most commonly found in institutional environments characterized by strong academic reputation, high research activity, robust faculty resources, and established professional recognition. The alignment between these structural characteristics and STEM adoption suggests that universities with greater organizational capacity, accreditation depth, and national visibility may be better positioned to implement the curricular changes required by STEM designation. At the same time, the diffusion of STEM programs across a breadth of institutional types - public and private, high-ranked and unranked - demonstrates a sector-wide response to technological transformation within the accounting profession.

In summary, the emergence and rapid growth of STEM-designated accounting programs reflect both market-driven forces and institution-driven strategic responses. On one hand, employer demand for technologically proficient graduates - reinforced by the expanding importance of data analytics, automation, and AI in professional practice - has pushed universities to modernize their curricula. On the other hand, institutions with stronger resources, accreditation structures, and research capacity appear better positioned to undertake the substantial curricular innovation required for STEM designation. These dynamics underscore the importance of institutional readiness and capacity in shaping the future of accounting education, particularly as the profession evolves toward a more data-intensive and technology-integrated environment.

The rising adoption of STEM-designated programs carries important implications for educators, policymakers, and industry stakeholders. For universities considering STEM designation, the experiences of early adopters highlight the critical role of investment in faculty expertise, technological infrastructure, and alignment with the competency expectations embedded in the new CPA licensure model. Notably, no underrepresented institutions - such as Historically Black Colleges and Universities (HBCUs) - currently offer STEM-designated accounting programs. Understanding the patterns identified in early adopting institutions may provide useful insight and guidance for such universities as they prepare future applications and seek to enhance program competitiveness.

This study offers valuable insights for educators, policymakers, and industry stakeholders seeking to understand the evolving landscape of accounting education. The results have important implications for other universities seeking STEM designation for their accounting programs. The nature and variety of STEM courses incorporated into the curricula of existing STEM-designated accounting programs can serve as valuable reference material. Notably, no underrepresented institutions, such as Historically Black Colleges and Universities (HBCUs), currently have STEM-designated accounting programs. These findings may provide useful insights and guidance for such institutions as they prepare future applications.

The remainder of this study is organized as follows. The next section presents a comprehensive literature review that provides detailed information on STEM-designated accounting programs and their course designs. This is followed by the research methodology section, which describes the data collection procedures and analytical methods employed in the study. The subsequent section reports the empirical results. Finally, the concluding section discusses the key findings and highlights the study's contributions.

2. Literature Review

2.1. The Integration of STEM Competencies in Modern Accounting

This evolving alignment between accounting education and the federal STEM definition provides the foundation for the growing adoption of STEM-designated accounting programs in the United States. The U.S. Department of Homeland Security (DHS) - through the Department of Education's Classification of Instructional Programs (CIP) system - defines STEM programs as academic disciplines grounded in science, technology, engineering, or mathematics, with a focus on analytical reasoning, quantitative methods, computational skills, and technological application. Under this framework, programs are considered STEM when their curricular content emphasizes mathematical modeling, data analysis, statistical reasoning, computing, programming, and other technical competencies that support innovation and evidence-based decision-making (Homeland Security Investigations [HSI], 2024, National Center for Education Statistics [NCES], 2023).

Big data is reshaping the accounting profession. Accounting goes beyond traditional financial record-keeping and reporting. Although accounting has historically been categorized as a business discipline, recent transformations in the profession increasingly align it with the federal STEM criteria. Andiola, Masters, and Norman (2020) demonstrate through interviews with accounting department leaders at AACSB-accredited institutions that contemporary accounting curricula now routinely include data analytics, visualization tools, statistical methods, robotic process automation, and introductory machine-learning techniques, reflecting a deliberate shift toward technology-driven competencies across audit, tax, and financial reporting education. Complementing this educational perspective, Fedyk, Hodson, Khimich, and Fedyk (2022) provide large-scale archival evidence, drawn from over 310,000 audit-hours, that artificial intelligence is fundamentally improving the professional audit process, with greater AI investment linked to a 5.0 percentage-point lower probability of financial restatements, declining audit fees, real-time risk assessment, and automated anomaly detection via machine-learning algorithms and Big 4 proprietary platforms.

Collectively, these findings indicate that modern accounting practice relies heavily on data analytics, automation, information systems, machine-learning applications, and quantitative modeling. CPAs and accountants draw on these STEM-related competencies to serve individuals, businesses, and governments - using statistical analysis to detect fraud, predictive modeling to guide strategic decisions, AI to assess financial risk in real time, and robotic process automation to identify anomalies - while leveraging firm-specific technological platforms to enhance data analysis and reporting (AICPA, n.d.). These capabilities align closely with the competency domains emphasized in the federal DHS STEM designation framework.

2.2. AICPA's Legislative Advocacy for STEM Designation in Accounting (2021–2025)

These educational reforms and empirical developments demonstrate that contemporary accounting has become a technology-intensive, STEM-aligned profession, reinforcing AICPA's long-standing advocacy for its formal recognition under the DHS STEM framework. Since 2021, AICPA-together with state societies and other key stakeholders-has consistently advanced this objective (AICPA, 2025a). On June 10, 2021, AICPA voiced strong support for the Accounting STEM Pursuit Act, which sought to integrate accounting into K-12 STEM education. On December 16, 2021, it endorsed the bipartisan STEM Education in Accounting Act, introduced by Senators Susan Collins (R-ME) and Jacky Rosen (D-NV). In September 2023, AICPA renewed its support for reintroducing bipartisan legislation aimed at establishing accounting as a STEM pathway while promoting workforce diversity. Advocacy intensified on July 30, 2024, when the AICPA - joined by every state CPA society and numerous stakeholders - submitted a letter to the Department of Homeland Security urging the inclusion of accounting on the DHS STEM Designated Degree Program List. The accompanying white paper, informed by a 2024 AICPA curriculum survey, showed that over 90 percent of U.S. accounting programs require at least 11 STEM-related topics, exceeding the requirements of several programs already classified as STEM by DHS. On April 15, 2025, the AICPA expressed strong support for legislation recognizing accounting as a STEM discipline.

Building on this momentum, on July 30, 2025, the AICPA - together with all state CPA societies and more than 300 universities - formally resubmitted its nomination to add the Accounting CIP Code to the DHS STEM list (AICPA, 2025b). The submission underscores that accounting is inherently a STEM discipline, integrating information technology, data analytics, and technological innovation into financial measurement, reporting, and decision optimization. Modern accountants are expected to demonstrate proficiency in both foundational skills (database management, statistics, mathematics, and risk assessment) and emerging technologies (artificial intelligence, machine learning, blockchain, and cryptocurrency). Taking together, these sustained, multi-year efforts highlight the profession's definitive shift toward technology-driven, STEM-aligned competencies and its pursuit of formal recognition within the federal DHS STEM framework.

2.3. STEM and the CPA Evolution Initiative

Another STEM-aligned strategy is the CPA Evolution initiative, jointly launched by the AICPA and NASBA beginning in 2017 and formally implemented with the new CPA licensure model in 2024. CPA Evolution is designed to modernize the CPA licensure framework by aligning it with the rapidly changing technological and analytical competencies required in contemporary and future accounting practice. Under the new model, all CPA candidates must complete three Core Exam sections - Auditing and Attestation (AUD), Financial Accounting and Reporting (FAR), and Taxation and Regulation (REG) - which assess the foundational knowledge and skills needed by all newly licensed CPAs. Candidates must then select one Discipline Exam section - Business Analysis and Reporting (BAR), Information Systems and Controls (ISC), or Tax Compliance and Planning (TCP) - to demonstrate deeper expertise in a specialized domain (AICPA, 2023b).

Importantly, the redesigned CPA Exam explicitly incorporates STEM-related competencies. Data and technology concepts, along with higher-order analytical skills, are tested across all Core and Discipline sections (AICPA, 2023a). In detail, The AUD section incorporates data and technology concepts by assessing candidates' understanding of how data is structured and flows through underlying information systems, as well as their ability to verify the completeness and accuracy of source data. Candidates are also evaluated on their use of data-analytic outputs to support risk assessment and execute planned audit procedures. The FAR section similarly tests candidates' ability to verify the completeness and accuracy of source data used in financial reporting and to utilize multiple data sources to prepare supporting schedules for account balances. The REG section evaluates candidates' use of data and technology tools to verify the integrity of source data used in tax return preparation and to interpret outputs from automated validation and diagnostic tools that identify potential errors or anomalies.

Within the Discipline examinations, the BAR section assesses advanced applications of data and technology, including verifying data integrity when comparing historical results to budgets and forecasts, transforming data for decision-making, determining appropriate data attributes and sources for financial statement analysis, and interpreting outputs from data-analytic techniques to explain performance or detect discrepancies. The ISC section evaluates newly licensed CPAs' competencies in information systems, including processing integrity, availability, security, confidentiality, and privacy. It also tests knowledge of data management across the data life cycle - collection, storage, governance, and usage - and emphasizes IT audit and advisory topics such as System and Organization Controls (SOC) engagements. Finally, the TCP section incorporates data and technology concepts through assessments that require verifying the completeness and accuracy of source data used in preparing tax returns and supporting schedules. Collectively, these elements illustrate the profession's ongoing shift toward a STEM-integrated licensure framework.

2.4. STEM-Designated Accounting Programs

Although the U.S. Department of Homeland Security (DHS) has not formally classified accounting as a STEM discipline, many individual accounting graduate programs have successfully obtained STEM designation through the CIP-code application process. Because the redesigned CPA Exam integrates data, technology, and analytics competencies across all Core and Discipline sections, these programs have updated their curricula to align with the new licensure requirements. Based on information disclosed on the websites of most STEM-designated accounting programs, institutions commonly cite three primary motivations for pursuing STEM certification. First, the programs align with the 2024 CPA Exam under the CPA Evolution model. The restructured Uniform CPA Examination requires all candidates to demonstrate proficiency in data analytics, technology applications, and higher-order digital competencies across AUD, FAR, and REG, as well as within the new Discipline sections. STEM-designated accounting programs have redesigned their curriculum around data analytics, automation, programming languages (e.g., Python, R, SQL), data visualization tools (e.g., Tableau, Power BI), and emerging technologies such as AI, blockchain, and robotic process automation. These curricular enhancements help students prepare more effectively for the modern CPA Exam while meeting the 150-hour education requirement.

The second advantage of these programs is to enhance post-graduation work authorization for international students. STEM designation allows F-1 international graduates to obtain an additional 24-month Optional Practical Training (OPT) extension beyond the standard 12-month period (DHS, 2025). This provides up to 36 months of full-time U.S. work authorization, giving graduates more time to secure long-term employment, obtain sponsorship, and build professional experience without the constraints of the traditional one-year limit. Finally, these programs provide stronger labor-market competitiveness for domestic and international students. Accounting employers - including Big Four firms, large national practices, and corporate finance departments - are increasingly seeking candidates who combine traditional accounting expertise with advanced analytical and technological skills. A STEM designation signals rigorous quantitative training and career-relevant technological capabilities, improving graduates' competitiveness in areas such as audit analytics, tax technology, forensic analysis, advisory services, and financial data science. The designation benefits both domestic students seeking cutting-edge training and international students who value the extended OPT period.

The benefits outlined above have motivated a growing number of accounting graduate programs to actively pursue STEM designation. This raises an important question: What types of programs are most likely to successfully obtain STEM status? To address this issue, the present study conducts a profiling analysis to better understand the characteristics of STEM-designated Master of Accounting or similar programs. Specifically, the study is guided by the following research questions:

RQ1: What institutional characteristics are associated with programs that receive STEM designation?
RQ2: What business school characteristics differentiate STEM-designated programs?
RQ3: What program-level attributes define STEM-designated accounting graduate programs?

3. Methodology

3.1. Data Collection of STEM-Designated Accounting Programs
To investigate the characteristics of STEM-designated accounting programs, we employed a comprehensive and systematic data-collection strategy. Four primary data sources were used, and a multi-step verification procedure was applied to determine whether a Master of Accounting (MAcc) or equivalent graduate accounting program is officially STEM-designated.

First, we consulted the list compiled by the American Institute of Certified Public Accountants (AICPA) and distributed through various state CPA societies. These professional organizations maintain summaries of universities whose accounting programs have obtained STEM designation. However, the most complete version available provides information only through January 2023 (AICPA & CIMA, 2023). This dataset served as a foundational resource for identifying an initial pool of STEM-designated programs. As a supplementary source, we also reviewed the U.S. News Accounting Program Ranking (U.S. News & World Report, 2025) and the accounting-program ranking published by the Big Four accounting firms (Deloitte, PwC, EY, and KPMG) (The Big 4 Accounting Firms, 2025). Although these rankings do not directly identify STEM-designed programs, they provide broader coverage of prominent accounting programs that may hold STEM status. To ensure comprehensive program identification, we compared the AICPA university list with the U.S. News and Big Four rankings to identify any additional universities appearing in these rankings but absent from the AICPA list.

Second, we reviewed the official websites of all universities on the AICPA list, as well as the additional universities identified in the previous step. This review focused on business school and graduate accounting program webpages, with attention to program descriptions, curriculum structures, and detailed course offerings. Programs generally indicate STEM status explicitly through labels such as “STEM-designated.” This step allowed us to directly verify STEM designation status and to collect detailed information on both traditional accounting coursework and technology-oriented content, including courses in data analytics, programming, probability, and related areas. Moreover, for all universities whose STEM designation was validated, we collected additional institutional and program-level characteristics from external sources. Using data from U.S. News & World Report, we obtained each institution’s overall U.S. News ranking, university enrollment, business school enrollment, and undergraduate accounting program ranking. We also incorporated the Big Four accounting firms’ ranking of accounting programs, drawn from publicly available ranking data. Together, these measures provide indicators of institutional reputation, program size, and employer perceptions of program quality, thereby enriching the dataset and supporting a more comprehensive analysis of factors associated with the adoption of STEM-designated accounting programs.

In addition, we classified each university using the Carnegie Classifications research-activity designations. Under this framework, institutions fall into three categories: R1 (very high research activity), R2 (high research activity), and RCU (research colleges and universities with more modest research activity) (American Council on Education [ACE], 2025). Incorporating these classifications allowed us to contextualize the accounting programs within the broader research profiles of their institutions. This facilitated an examination of whether STEM-designated accounting programs tend to cluster within higher-research institutions (e.g., R1 or R2) or whether they are also prevalent among RCU institutions. The research-activity classifications thus add a systematic, institution-level dimension to our analysis and enhance the rigor and interpretability of our findings.

Finally, we supplemented the institutional information by incorporating accreditation and structural characteristics from the AACSB membership database (Association to Advance Collegiate Schools of Business [AACSB], 2025). Using the AACSB’s official directory, we recorded whether each institution held AACSB Business accreditation and/or AACSB Accounting accreditation. We also collected data on the number of full-time faculty members in the business school and the institution's control type (public or private). These variables provide important organizational context for understanding the adoption of STEM-designated accounting programs and enable analysis of whether accreditation status, faculty capacity, and institutional type are associated with the likelihood of offering a STEM-designated accounting curriculum.

3.2. Research Method: Descriptive Analysis of STEM-Designated Accounting Programs

To characterize STEM-designated Master of Accounting (MAcc) or equivalent graduate accounting programs, this study employs a descriptive research design. The objective is to develop a comprehensive profile of these programs by examining their institutional, business-school-level, program-level, and curricular characteristics. This approach allows the identification of patterns and distinctive features, thereby providing a detailed portrait of STEM-designated accounting programs and their alignment with technology-driven educational trends.

The descriptive method utilizes a structured dataset of 82 universities offering STEM-designated accounting programs, as compiled in the data collection phase (see previous section). The analysis focuses on four dimensions: (1) institutional characteristics, (2) business school characteristics, (3) program-level attributes, and (4) curriculum composition, with particular attention to technology-oriented coursework.

3.2.1. Institutional Characteristics

This dimension evaluates the institutional context in which STEM-designated accounting programs operate. Key variables include institutional control type (public or private), Carnegie Classification (R1, R2, RCU, or none), U.S. News university ranking categories (Top 100; 101 - 200; >200; or unranked), and institutional enrollment size (>10,000; 5,000 - 10,000; <5,000).

3.2.2. Business School Characteristics

This dimension examines attributes of the business schools housing accounting programs. Variables include AACSB business accreditation (accredited or not), business school faculty size following AACSB classification (large: >75 faculty; medium: 36 - 75 faculty; small: <36 faculty), and business school student enrollment (>3,000; 1,000 - 3,000; <1,000).

3.2.3. Program-Level Attributes

This dimension focuses on the characteristics of the accounting programs themselves. Variables include U.S. News undergraduate accounting rankings (listed or unlisted) and Big Four firm rankings for target schools (listed or unlisted) as indicators of program reputation. Additional variables include AACSB supplemental accounting program accreditation (business school and accounting program accredited, business school accredited but accounting program unaccredited, and not accredited) as an additional measure of program quality.

4. Results

This analysis characterizes 82 universities offering STEM-designated Master of Accounting (MAcc) or equivalent graduate accounting programs, based on the provided dataset. The study employs a descriptive research design to profile these programs across three dimensions: (1) institutional characteristics, (2) business school characteristics, and (3) program-level attributes. Below is a detailed analysis of each dimension, identifying patterns and distinctive features.

4.1. Institutional Characteristics

Table 1: Institutional Characteristics

Variable	Category	Frequency	Percentage
Institutional Control Type	Public	43	52.44%
	Private	39	47.56%
Carnegie Classification	R1 (Very High Research Activity)	55	67.07%
	R2 (High Research Activity)	16	19.51%
	RCU (Research Colleges and Universities)	6	7.32%
	None/Unclassified	5	6.10%
U.S. News University Ranking	Top 100	43	52.44%
	101 - 200	19	23.17%
	>200	13	15.85%
	Unranked	7	8.54%
Institutional Enrollment Size	>10,000	45	54.88%
	5,000 - 10,000	29	35.37%
	<5,000	8	9.76%

Figure 1: Institutional Characteristics

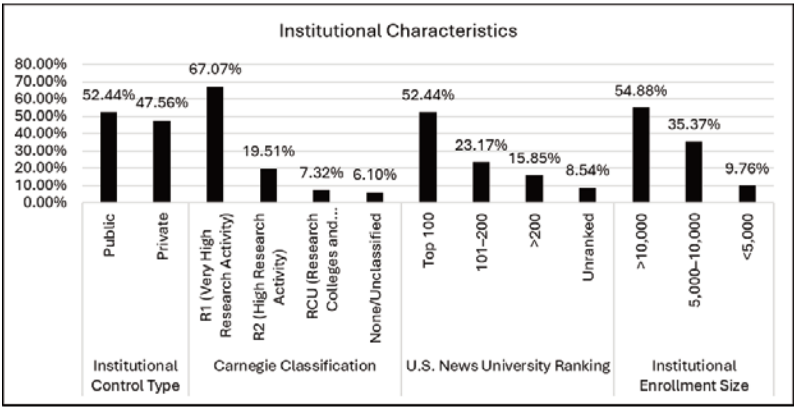

Table 1 and Figure 1 summarize the institutional context of STEM-designated accounting programs, including institutional control type, Carnegie Classification, U.S. News university ranking, and institutional enrollment size. The institutional characteristics of STEM-designated accounting programs reveal several clear patterns. Public universities make up a slight majority (52.44 percent), while private institutions account for 47.56 percent, indicating that both sectors actively offer STEM-designated accounting programs, though public institutions may benefit from larger resource bases and state support. In terms of research intensity, most programs (67.07 percent) are housed in R1 universities, followed by R2 institutions (19.51 percent), RCU institutions (7.32 percent), and a smaller group of unclassified institutions (6.10 percent). This distribution underscores the strong connection between STEM designation and high-research environments.

Regarding institutional reputation, 52.44 percent of the universities are ranked in the U.S. News Top 100, with additional representation in the 101 - 200 range (23.17 percent), above 200 (15.85 percent), and among unranked institutions (8.54 percent), suggesting that while many programs are located in highly ranked universities, adoption also extends to lower-ranked and unranked institutions. Finally, institutional size shows a similar pattern: 54.88 percent of programs are offered at large universities with enrollments exceeding 10,000, 35.37 percent at medium-sized institutions with 5,000 - 10,000 students, and only 9.76 percent at smaller institutions.

Overall, the findings show that STEM-designated accounting programs are largely concentrated in large, resource-rich, and research-intensive universities - particularly public R1 institutions that often appear in the U.S. News Top 100. This pattern suggests that the adoption of STEM designation is closely tied to environments with substantial financial resources, strong research capacity, and established academic reputation, all of which support the development of technology-driven accounting curricula. At the same time, the presence of programs across a range of institutional types indicates that interest in STEM-oriented accounting education extends beyond elite, highly ranked universities, reflecting a broader sector-wide shift toward data- and technology-enhanced accounting training.

4.2. Business School Characteristics

Table 2: Business School Characteristics

Variable	Category	Frequency	Percentage (%)
AACSB Business School Accreditation	Accredited	80	97.56%
	Not Accredited	2	2.44%
Business School Faculty Size	Large (>75 faculty)	50	60.98%
	Medium (36 - 75 faculty)	25	30.49%
	Small (<36 faculty)	7	8.54%
Business School Enrollment	>3,000	38	46.34%
	1,000 - 3,000	37	45.12%
	<1,000	7	8.54%

Figure 2: Business School Characteristics

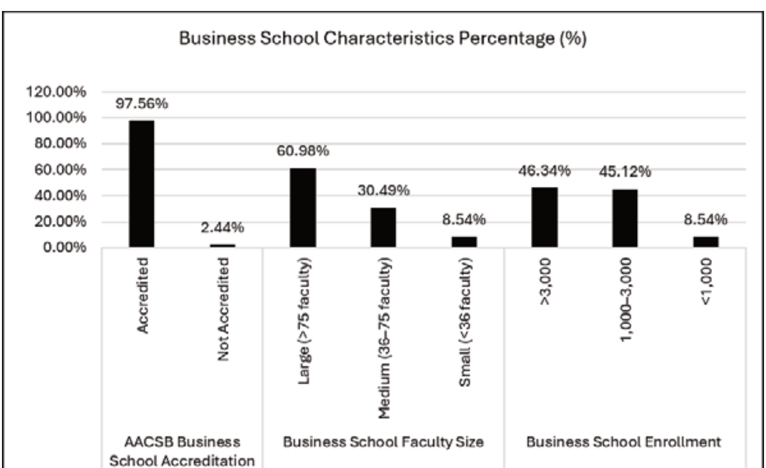

Table 2 and Figure 2 summarize the characteristics of business schools housing STEM-designated accounting programs, including AACSB business accreditation, faculty size, and business school enrollment. The characteristics of business schools offering STEM-designated accounting programs reveal a strong concentration of accredited and well-resourced institutions. Nearly all schools (97.56 percent) hold AACSB business accreditation, underscoring the high level of academic quality associated with these programs; the two non-accredited institutions - Augustana University and Golden Gate University - are both private and unranked, indicating that non-accredited programs may operate within more niche or regionally focused markets.

Faculty size patterns further reflect substantial institutional capacity: a majority of business schools (60.98 percent) employ a large number of faculty (more than 75 faculty members), while another 30.49 percent maintain a medium number (36 - 75). Only 8.54 percent operate with a small number of faculty (fewer than 36), typically found in smaller or less research-intensive institutions such as Augustana University and Michigan Tech. Business school enrollment follows a similar structure, with almost half of the schools (46.34 percent) enrolling more than 3,000 students and another 45.12 percent enrolling 1,000 - 3,000 students. Smaller business schools with fewer than 1,000 students represent just 8.54 percent of the sample and are more common among private or specialized institutions, including Rice University and the University of Vermont.

Collectively, these findings show that STEM-designated accounting programs are predominantly offered by AACSB-accredited, large-scale, and well-staffed business schools. Business schools with substantial faculty resources and enrollments - often exceeding 3,000 students - are especially common, reflecting the robust infrastructure and capacity needed to support technology-integrated and STEM-oriented accounting curricula. This concentration within resource-rich business schools underscores the importance of accreditation, faculty depth, and organizational scale in enabling the development and delivery of advanced, technology-driven accounting education.

4.3. Program-Level Attributes

Table 3: Program-Level Attributes

Variable	Category	Frequency	Percentage within Sample	Percentage of National Ranking
U.S. News Best Undergraduate Accounting Ranking (Top 58)	Listed	29	35.37%	50.0% (29/58)
	Unlisted	53	64.63%	–
Big Four Firms Target Schools Ranking (Top 50)	Listed	25	30.49%	50.0% (25/50)
	Unlisted	57	69.51%	–
AACSB Accounting Accreditation	Both business school and accounting program are AACSB-accredited	39	47.56%	–
	Business school is AACSB-accredited, but accounting program is not separately accredited	41	50.00%	–
	Neither accredited	2	2.44%	–

Figure 3: Program-Level Attributes

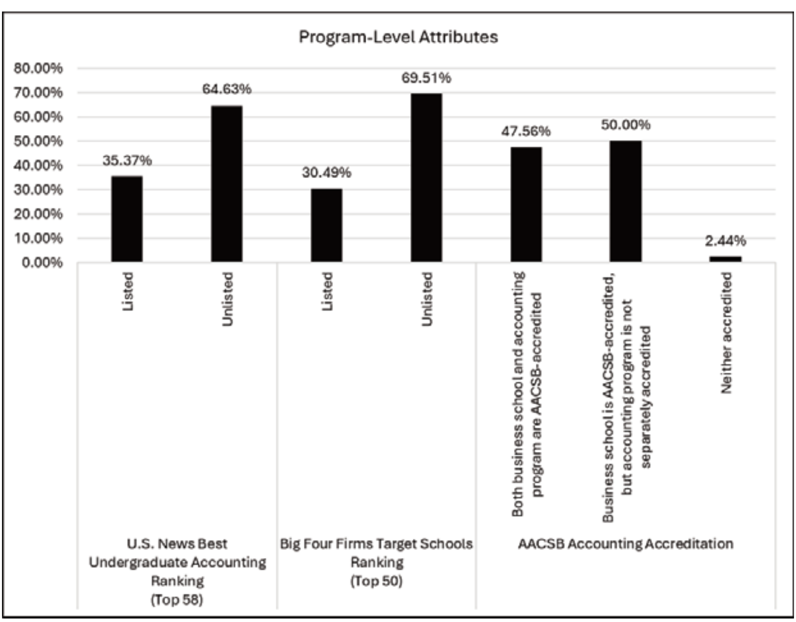

Table 3 and Figure 3 summarize the characteristics of the accounting programs, including U.S. News undergraduate accounting ranking, Big Four firm target schools' ranking, and AACSB supplemental accounting accreditation. As shown in Table 3, the 82 programs included in this study also display a strong presence among nationally recognized and professionally targeted accounting programs. Although only 35.37 percent of the sample appears in the U.S. News Best Undergraduate Accounting top 58, these 29 programs collectively capture 50.0 percent of the national ranking (29/58), indicating substantial representation among the most highly ranked undergraduate accounting programs. A similar pattern emerges for the Big Four Firms Target Schools ranking: while 30.49 percent of the sample is listed in the top 50, these 25 programs again account for half of the nationally identified target schools (25/50 = 50.0 percent). Accreditation patterns reinforce this quality profile. Nearly all programs (97.56 percent) are affiliated with AACSB-accredited business schools, and 47.56 percent hold the additional AACSB supplemental accounting accreditation, while only 2.44 percent lack any AACSB accreditation.

Taken together, these results indicate that the sample represents an exceptionally strong concentration of nationally elite, professionally recognized, and rigorously accredited undergraduate accounting programs. This remarkable clustering underscores the high quality of the sample and reflects its strong alignment with national academic reputation, professional relevance, and top-tier standards in U.S. undergraduate accounting education.

5. Discussion and Conclusion

5.1. Discussion

This study provides a comprehensive descriptive analysis of 82 universities offering STEM-designated Master of Accounting (MAcc) or equivalent graduate accounting programs in the United States. By profiling institutional characteristics, business school attributes, and program-level indicators, this analysis offers important insights into how U.S. universities have begun reshaping graduate accounting education in response to profound technological and market shifts. The emergence of STEM-designated Master of Accounting programs reflects not only institutional characteristics but also broader transformations within the accounting profession - including accelerating demand for data analytics skills, pressures from AI-driven business environments, and major changes to CPA licensure requirements.

Across institutions, the findings highlight that STEM-designated accounting programs are disproportionately concentrated in large, research-intensive, and academically reputable universities. Public R1 institutions - many of which appear in the U.S. News Top 100 - represent the core of STEM program adoption. These universities generally possess strong research infrastructures, larger financial and faculty resources, and established reputations for technological and analytical scholarships. Their structural advantages likely reduce barriers to implementing STEM-oriented curricula, particularly those requiring advanced quantitative, data, and technology components. Nevertheless, the presence of programs in R2, RCU, and even unranked institutions indicates that STEM adoption is not limited to elite universities. Instead, it reflects a broader shift within higher education toward integrating analytics and technology across accounting curricula, driven by evolving employer expectations and the growing role of data science and information systems in professional practice.

Business school characteristics reinforce this pattern. Nearly all programs are located in AACSB-accredited schools, and most reside in large, well-staffed, and well-resourced business units. The high prevalence of AACSB accreditation underscores the alignment between STEM designation and academic quality standards. Large faculty bodies and substantial student enrollments further suggest organizational capacity to support the specialized coursework, technology integration, and curricular redesign required for STEM designation. Business schools operating with smaller faculty bodies or enrollments represent a small minority and tend to be private, specialized, or less research-intensive institutions, indicating that resource constraints may shape the feasibility of adopting STEM-intensive graduate accounting curricula.

At the program level, the results show a pronounced clustering among nationally recognized and professionally prominent accounting programs. Half of all U.S. News Top 58 undergraduate accounting programs and half of the Big Four Firms' top 50 target schools appear in the sample, despite the sample representing only 82 universities nationwide. This overrepresentation suggests that leading accounting programs have been early adopters of STEM designation, likely leveraging the credential to enhance competitiveness in attracting high-ability domestic and international students. Additionally, nearly half of the programs hold AACSB supplemental accounting accreditation, reinforcing the high quality and rigorous standards associated with STEM-designated offerings.

These institutional patterns directly align with current job-market demands. Surveys from the accounting profession indicate overwhelming employer emphasis on data analysis, advanced analytics, visualization tools, and technology competencies for new hires. As accounting roles increasingly require proficiency with AI-driven tools, automation systems, and predictive analytics, graduate programs face pressure to prepare students for technologically intensive practice environments. The strong presence of STEM designation among highly ranked and professionally recognized programs suggests that universities are using STEM frameworks to signal their commitment to producing graduates equipped with these competencies.

The evolution of CPA licensure further accelerates this shift. The CPA Evolution initiative and the 2024 launch of the new core-plus-discipline CPA Exam explicitly integrate technology, data analytics, and systems competencies across all exam sections. This regulatory change creates direct incentives for accounting programs to redesign curricula around analytics, information systems, and other STEM-related skills. Many faculties have already reported plans to revise their programs accordingly, and the growing number of accounting programs receiving STEM designation - more than 80 by early 2025 - illustrates how institutions are proactively adjusting to the new licensure landscape. The overlap between programs adopting STEM designation and those with high national rankings suggests that leading programs view STEM alignment not only as beneficial for students but also as essential for maintaining leadership in the profession.

5.2. Conclusion

In conclusion, this study demonstrates how U.S. universities have adopted STEM-designated Master of Accounting programs in response to rapid technological change, evolving employer expectations, and major shifts in CPA licensure. The findings show that STEM-designated programs are concentrated in large, research-intensive, AACSB-accredited, and professionally prominent institutions - those with the capacity to integrate analytics, information systems, and technology-rich coursework into accounting curricula. The strong alignment between program characteristics and the technological competencies now required in the profession suggests that STEM designation has become an important strategic response to advances in AI, big data, automation, and the redesigned CPA Exams. At the same time, the presence of STEM programs across a broader set of institutional types indicates that the shift toward technology-enhanced accounting education is not limited to elite universities but reflects a field-wide transformation.

5.3. Contributions

This study makes several important contributions to the emerging literature on STEM-designated accounting education. First, it offers the first comprehensive descriptive analysis of 82 STEM-designated accounting programs in the United States, documenting their institutional, business-school, and program-level characteristics. Second, the findings reveal clear patterns linking STEM adoption to universities' research intensity, accreditation structures, faculty resources, and national rankings, providing empirical evidence on the organizational conditions that facilitate curricular innovation. Third, the study highlights uneven diffusion across institution types, thereby identifying structural disparities that warrant attention from educators and policymakers. Collectively, these contributions enhance understanding of how STEM designation is emerging within accounting education and provide a foundation for future research and policy development.

5.4. Limitations and Future Directions

While this study provides a comprehensive portrait of STEM-designated accounting programs, it is subject to several limitations. First, the analysis relies on a census of programs identified from publicly available sources, including the AICPA list through early 2023 and subsequent institutional announcements. Because the number of STEM-designated programs is expanding rapidly, the descriptive patterns reported here may shift over time. Periodic updates will be necessary to capture future growth and institutional changes.

Second, this study focuses on program characteristics and does not examine the outcomes associated with STEM designation. Future research should investigate whether graduates of STEM-designated programs experience different career trajectories compared to those from traditional MAcc programs. Potential avenues include differences in salaries, initial job placements, CPA exam performance under the new licensure model, employer perceptions, and long-term promotion prospects. Such analyses would provide deeper insight into whether STEM designation delivers measurable benefits to students and employers or functions primarily as a curricular modernization strategy.

As AI, automation, and analytics continue reshaping practice, and as CPA licensure continues to evolve, the role of STEM competencies in accounting education is likely to grow. Continued research on program effectiveness, student outcomes, and the long-term impact of CPA Evolution on accounting education will be essential for understanding how STEM designation shapes the future of accounting education.

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National Surgical Solutions: Stabilizing Growth In the Ambulatory Surgery Center Market

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Abstract

National Surgical Solutions, one of the largest ambulatory surgery center operators in the United States, is experiencing declining same-facility case volumes, surgeon aging, and margin pressure despite strong revenue growth. Historically fueled by acquisitions, the company now faces rising capital costs, lifecycle-related volume erosion, and increasing competition. Leadership must determine how to stabilize performance and position the company for sustainable growth. Three options emerge: continue acquisition-led expansion, invest in Physician Relationship Managers (PRMs) to rebuild organic volume, or expand into higher-acuity service lines. The case asks students to evaluate these alternatives and recommend a path forward.

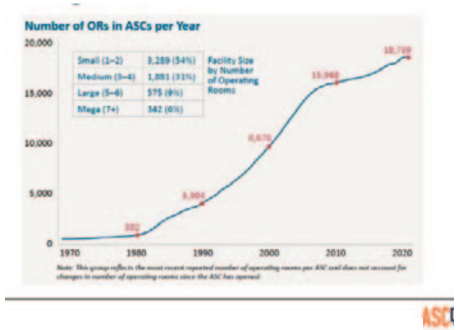
Keywords: National Surgical Solutions, ambulatory surgery centers, business model, corporate healthcare, growth, acquisitions, physician partnerships, relationship marketing

Industry Background

Most surgeries use to take place in hospitals, resulting in long waits and extended recovery times for patients. Now more procedures are performed in specialized outpatient centers. Ambulatory Surgical Centers (ASCs), established in 1981, focus on procedures that do not need overnight stays or hospital admittance. These centers allow people to receive high-quality care and return home within hours, thereby significantly improving convenience and reducing disruption to daily activities.

The industry outlook is optimistic. In 2025, over 80% of U.S. surgeries were outpatient (including hospitals and ASCs), up from just 16% in 1981. ASCs now handle roughly 72% of all surgical procedures (ASC Data, 2025). Their volume is projected to increase by 21% between 2024 and 2034 (Mukerji, 2024). This surge in outpatient procedures underscores the growing preference for ASCs for two reasons: (1) cost-effectiveness for the centers, and (2) an efficient alternative to traditional hospital-based surgery for the patient. Moving a surgery from a hospital to an ASC can save $684 per procedure (Hao et al., 2024).

Figure 1: Size of ASC Market



Source: ascassociation.org

Collectively, ASCs are operating over 18,000 surgical suites, according to the Ambulatory Surgery Center Association (ASCA, n.d.), performing more than 23 million procedures each year (See Figure 1). Over the total active facilities, approximately 6,500 are Medicare-certified. ASCs cover a broad spectrum of specialties; however, 62% of facilities are single specialty, with orthopedics accounting for 36.7% of cases, pain management for 35.5%, ophthalmology for 34.7%, and endoscopy for 32.2%. In dollars, industry revenues continue to increase, yet profits have faced challenges due to higher labor and equipment costs. The U.S. market size, measured in value, is estimated at $62.03B in 2032, with a Compound Annual Growth Rate (CAGR) of 4.1% over the forecast period (U.S. Ambulatory Surgical Centers Market Report, 2026).

Competition in the ASC market is intensifying, and National Surgical Solutions is not in a leadership position. Large, well-capitalized competitors, including Surgery Partners, United Surgical Partners International (Tenet), Surgical Care Affiliates (Optum), AmSurg, and HCA Healthcare, dominate fast-growing markets and have more experience (Newitt, 2025). Surgery Partners, for example, leads in physician-centric growth, data analytics, and high-acuity migration, placing National Surgical Solutions at a competitive disadvantage. As more of their competitors accelerate investment in technology, recruitment infrastructure, and payer contracting. National Surgical Solutions must find ways to stand out and catch up.

Approximately 90% of ASCs are partially or wholly owned by physicians, fostering an emphasis on personalized care and operational flexibility, rather than running 24/7/365 like hospitals. By comparison, hospitals participate in the ASC market through ownership or partnerships in roughly 25% of cases. The physician-led model contributes to substantial healthcare savings. As noted earlier, studies estimate that ASCs reduce costs for outpatient surgeries by 45–60% compared to hospitals (ASCA, n.d.). Additionally, ASCs consistently meet or exceed rigorous safety and quality standards set by regulatory agencies such as the Centers for Medicare & Medicaid Services (CMS), further reinforcing their reputation for delivering reliable, high-value care.

ASCs are pursuing growth through mergers and acquisitions (M&A) to scale their operations, increase their negotiating power with payers, and achieve economies of scale. The healthcare industry is experiencing consolidation, and it is just a matter of time before ASC consolidations accelerate (Mendez, et al., 2026). Results of the survey indicate that 6% of respondents say they anticipate engaging in independent ASC sale activity in 2025, with 84% saying they do not; however, over 50% of independent ASC respondents say they would consider a strategic partnership: 57% with a health system, 30% work with PE, and 28% with a management company. These industry shifts create both growth opportunities and structural risks for national ASC operators such as National Surgical Solutions, particularly as surgeon demographics and competitive pressures reshape case volumes.

Company Information and Model

Founded in 2004, National Surgical Solutions (NASDAQ: NSS) is one of the nation's premier publicly traded healthcare services companies, specializing in outpatient surgical procedures and ancillary care. As the sixth largest provider of ambulatory surgery centers (ASCs) in the United States, National Surgical Solutions manages a diverse portfolio of ASCs, surgical hospitals, and multi-specialty physician practices. With more than 190 facilities spanning 33 states, National Surgical Solutions commands substantial negotiating power with leading insurers, including Cigna, Aetna, and UnitedHealthcare.

National Surgical Solutions improves patient care by working with local surgeons, who decide where patients have surgery. The company grows in two different ways: first, it acquires established ambulatory surgery centers to rapidly build infrastructure and market presence; second, it deploys Physician Relationship Managers (PRMs) to organically rebuild and expand surgeon case volumes, which are vital to local success. The mix of buying centers and building relationships helps steady growth and reduces risk after acquisitions.

The Physician Relationship Manager (PRM) growth model utilizes advanced data analytics to identify and recruit the most promising physician champions. Before initiating recruitment, National Surgical Solutions conducts comprehensive analyses of physicians' case volumes, Current Procedural Terminology (CPT) codes, and case mixes to ensure optimal alignment. National Surgical Solutions further differentiates itself by offering physicians equity partnerships, highly competitive payer contracts, and significantly greater autonomy than traditional hospital settings. These advantages—combined with operational efficiency and faster turnover—make National Surgical Solutions the destination of choice for leading surgeons. In 2023 alone, the PRM strategy resulted in 369 newly affiliated surgeons, 14,352 incremental cases, and $41 million in new revenue.

Another determinant of success in surgeon recruitment is fostering positive attitudes and behaviors toward both the ASC and its new ownership. Ensuring high levels of surgeon satisfaction is vital, as dissatisfaction can lead to significant declines in case volume following an acquisition. Typical payouts for surgeons range from $1 to $5 million. However, ASCs face unique challenges due to the aging physician workforce; notably, one in four surgeons is 65 or older, and the average surgeon is 53 years old (+/- 8 years) (Cortez et al., 2022). Centers cannot allow physicians to maintain ownership/equity when they quit or retire. The sale of high-volume practices can impact ASC revenue and pose headwinds to the effectiveness of the PRM growth strategy.

Backed by private equity and robust access to capital as a publicly traded company, National Surgical Solutions delivers state-of-the-art facilities and cutting-edge equipment—features highly sought after by leading surgeons and those serving patients with specialized needs—because both affect throughput. Nevertheless, acquisitions in the ASC sector require careful diligence; caveat emptor remains highly relevant. When National Surgical Solutions acquires a facility, it typically obtains a combination of the following assets:

- Existing license(s)
- Operating rooms
- Facility infrastructure
- Existing staff
- Local brand or reputation
- Current surgeon partners and utilizers

Although buying new centers boosts the company's assets and reputation, it does not guarantee profitability. From 2021 to 2023, National Surgical Solutions had operating losses because it spent a lot on upgrades and sometime overpaid for centers with inflated case volumes. Often, these centers see fewer cases within the first 12 to 24 months post-acquisition. This drop is common across the industry nationwide (see Exhibit 1), unless the company invests more or recruits new surgeons.

Company Financials

Between 2021 and 2023, National Surgical Solutions achieved revenue growth exceeding $500 million, underscoring the company's leadership in expanding outpatient surgical services and facilitating the shift of procedures from hospital-based to ambulatory care settings. In fiscal year 2023, National Surgical Solutions generated $2.74 billion in revenue, reflecting a strong 8% year-over-year growth and a 14.1% increase over the prior year. This impressive performance was fueled by strategic acquisitions, greenfield developments, and optimized utilization across the company's established network of centers (see Exhibit 2).

However, operating expenses increased over the 2021–2023 period, primarily due to rising labor costs, higher medical supply prices, and the expansion of administrative infrastructure required to support national operations. Interest expense remained a major component of overall costs. In result, even with positive operating income each year, the company reported net losses of $54.6 million in 2022 and $11.9 million in 2023 attributable primarily to interest

Exhibit 1: Lifecycle of an Ambulatory Surgery Center (ASC)

Lifecycle Stage	Typical Timeframe	Operational Characteristics	Financial Performance Pattern
Stage 1: Acquisition / Launch	Year 0–1	• Facility newly acquired or opened • Existing surgeon partners highly engaged • Case volumes temporarily elevated • Significant investments & management attention	• Strong revenue and EBITDA • Performance often exceeds sustainable baseline
Stage 2: Growth	Years 1–2	• Initial integration completed • Strong relationships with Surgeons • Some physicians might exit, but others still buying in	• Profitable but not at max cap • Margins stabilize but begin to soften
Stage 3: Max Capacity	Years 2–4	• Maximize capacity • Surgeons reduce case volumes ("cashing out") • Aging surgeons scale back schedules or retire • Competition increases (new ASCs, hospitals)	• Declining case volumes • EBITDA compression • Fixed costs become more visible
Stage 4: Decline	Years 4–6	• One or more high-volume surgeons exit • Facility becomes less attractive to new surgeons • Equipment and layout begin to age	• Revenue decline accelerates • Margins deteriorate • Center may be underperforming asset
Stage 5: Reinvestment or Exit	Year 5+	• Facility requires reinvestment, repositioning, or sale • New recruitment or specialty expansion needed	• Either recovery through organic growth • Or divestiture at discounted valuation

Source: Industry reports on ASC performance; American College of Surgeons; American Association of Medical Colleges; case writer analysis and synthesis.

Exhibit 2: National Surgical Solutions, Inc. – Selected Financial Performance, 2021–2023 (Dollars in millions)

Financial Item	2021	2022	2023
Total Revenues	$2,225.1	$2,539.3	$2,743.3
Operating Expenses	1,922.9	2,194.1	2,415.3
Operating Income	302.2	345.2	328.0
Interest Expense	(221.0)	(234.9)	(193.0)
Income Before Taxes	81.2	110.3	135.0
Net Income (Loss) Attributable to National Surgical Solutions	$(70.9)	$(54.6)	$(11.9)

Source: Annual Report 2023; case writer analysis.

expenses, non-controlling interests, and other non-operating factors. These results reflect the company's ambitious, acquisition-driven growth strategy and the substantial investments required to maintain its national leadership position.

In alignment with best practices in the healthcare services industry, National Surgical Solutions' leadership team employs EBITDA-based budgeting as a cornerstone for evaluating the cash-generating potential of its facilities—prior to considering financing and accounting factors. EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) serves as the principal metric for operating performance at both the corporate and facility levels. Annual budgets for individual surgery centers are established based on projected EBITDA, with actual performance tracked against these targets throughout the year. In acquisitions, National Surgical Solutions utilizes EBITDA multiples to value prospective centers, reflecting anticipated post-acquisition performance. Physician ownership stakes are similarly priced using EBITDA-based valuations, reinforcing a performance-driven culture.

In 2023, National Surgical Solutions strategically expanded its physician recruitment efforts by deploying Physician Relationship

Exhibit 3: Adjusted EBITDA (Dollars in millions)

Year	Adjusted EBITDA
2021	$339.6
2022	380.2
2023	438.1

Source: Annual Report 2023

Managers (PRMs) to proactively identify and attract new surgeons to existing facilities. This targeted initiative was designed to maximize utilization at current centers, delivering incremental growth without the significant capital outlays associated with acquisitions or new construction. As a result, the program generated $41 million in additional revenue, demonstrating the effectiveness of a disciplined, relationship-driven growth strategy.

Despite its scale and diversified growth model, National Surgical Solutions faces increasing pressure to stabilize case volumes and restore profitability as many centers move into later stages of the ASC lifecycle. One area where hospitals may hold an advantage over ASCs is case mix. Hospitals normally have ‘loss leaders’ (i.e., they make little to no profit on OB deliveries) but do well on GYN surgical cases.

To contextualize the financial pressures facing National Surgical Solutions, Exhibit 4 shows a few selected operating metrics from the past three years. These indicators highlight emerging trends in volume and margin performance that inform the company’s strategic dilemma.

Exhibit 4: Selected Operating Metrics

Metric	2021	2022	2023
Total Surgical Cases	600,000	625,000	640,000
Same-Facility Case Volume Growth	+ 1.0%	+ 0.5%	- 1.0%
Revenue per Case	$3,710	$3,760	$3,850
ASC EBITDA Margin	18%	19%	17%
Surgeon Attrition Rate	6%	7%	8%

Source: Annual Report 2023

Problem Statement

As National Surgical Solutions’ leadership evaluates its next phase of growth, what strategic initiatives should the firm prioritize to reverse declining case volumes, address margin erosion due to rising nursing wage pressures, and restore overall profitability?

Situational Analysis

ASCs, including National Surgical Solutions, face a bright yet challenging future. Top trends identified in the industry include:

1. An increasing number of surgeries are being performed in the outpatient setting. Historically, cardiology, joint replacement, spine, and vascular surgeries were the only approved procedures for reimbursement. The industry is experiencing rapid expansion in the portfolio of surgeries approved for ASC reimbursement. Portfolio expansion is expected to grow in the future.
2. An expansion in the number of higher-acuity cases and specialized care is occurring due to several factors: longer life expectancies among Americans, an increasing number of aging seniors requiring higher levels of ongoing care, and strong patient preference for in-home care.
3. An increasing number of poorly managed or underfunded independent ASCs.
4. The conversion of single-specialty ASCs into multi-specialty centers is increasing, especially in states with evolving Certificate of Need (CON) laws.

Despite the growth opportunities, problems remain. For example, the industry remains intensely competitive with National Surgical Solutions' top two competitors, HCA and Tenet, aggressively expanding their ASC holdings. Also, private equity-backed ASCs are creating additional competitive pressure. Higher interest rates and the rising cost of capital are making it very costly to build or renovate facilities. Supply chain volatility and inflation are eroding profit margins as the cost of medical supplies, equipment, and wages continue to rise. Furthermore, cost control in ASCs depends on standardizing instruments and supplies, however achieving physician alignment can be challenging. Ownership stakes help drive the consistency needed to manage expenses effectively.

The national nursing shortage is another complicating factor increasing cost for ASCs. Hospitals have aggressively increased wages to retain perioperative nurses, creating a widening pay gap between hospital systems and physician-owned ASCs. Many independent ASCs pay lower wages, making it difficult to compete for experienced operating room and surgical recovery nurses. As a result, staffing shortages and turnover have intensified, driving some centers to sell to corporate operators who can offer more competitive compensation packages. For National Surgical Solutions, rising labor costs directly compress margins and further obstruct efforts to stabilize performance at maturing facilities. Lastly, regulatory changes in Medicare reimbursement rates or covered procedures impact profitability. (See Exhibit 5 for NSS SWOT analysis). Exhibit

Exhibit 5: SWOT Analysis for National Surgical Solutions

	Valence of Factors	
Location of Factors	Positive	Negative
Internal	Strengths: 1. Growth in in numbers 2. Industry knowledge & expertise 3. Cost Savings 4. Strategic Planning 5. Database access 6. Managed care contracting 7. Capitalization 8. Incentives for doctors 9. Local recruiting efforts 10. Modern facilities 11. Convenience	Weaknesses: 1. Excessive costs of construction and renovations 2. Staff turnover 3. Margin erosion 4. Scheduling 5. Ownership pricing 6. Partnership issues 7. Technology enhancement costs
External	Opportunities: 1. Patient preferences 2. Modernizing the patient experience 3. Increase number of ASC facilities for sale 4. Increase number of hospital joint ventures 5. Increased number of newly constructed facilities 6. Less restrictive CON Laws 7. Increase in number of approved procedures for ASCs 8. Technology enhancements 9. Reimbursement rates increasing	Threats: 1. Increased competition 2. Supply chain chaos 3. Economy uncertainty 4. Tighter margins 5. Hostile takeovers 6. Declining operating incomes 7. Stock price reductions 8. Aging of surgeons 9. Shortage of nurses and professional staff

6 provides a consolidated view of the operating and financial metrics that will be useful in evaluating the three strategic alternatives.

Alternatives

As National Surgical Solutions evaluates its next phase of growth, leadership is considering three strategic pathways. Each option addresses declining case volumes from a different angle, but all require targeted technological investment to improve efficiency, strengthen surgeon engagement, and enhance financial performance.

Exhibit 6: Comprehensive Operating & Financial Metrics

Metric	2021	2022	2023
Total Surgical Cases	600,000	625,000	640,000
Same-Facility Case Volume Growth	+1.0%	+0.5%	–1.0%
Revenue per Case	$3,710	$3,760	$3,850
Same-Facility Revenue	$2.05B	$2.07B	$2.05B
ASC EBITDA Margin	18%	19%	17%
Surgical Hospital EBITDA Margin	12%	13%	12%
Capital Expenditures	$140M	$165M	$180M
Total Debt	$2.6B	$2.7B	$2.75B
Average Interest Rate	6.5%	7.0%	7.2%
PRM Program Cost	$18M	$20M	$22M
PRM ROI (Revenue/Cost)	2.0x	2.1x	1.9x
Acquisition Spend	$220M	$260M	$300M
Average Acquisition Multiple	7.5×	8.0×	8.2×
Surgeon Attrition Rate	6%	7%	8%
Average Surgeon Age	52	53	54
Block Utilization	68%	70%	67%
OR Utilization	62%	64%	61%
High-Acuity Case Mix	12%	14%	16%
TJR Cases Performed	7,200	8,000	9,200
% of Total Surgical Cases	1.2%	1.3%	1.4%
Revenue per TJR Case	$14,500	$15,200	$16,000
TJR Revenue	$104M	$122M	$147M
TJR EBITDA Margin	28%	29%	30%
TJR EBITDA Dollars	$29M	$35M	$44M
CapEx for TJR Equipment	$18M	$22M	$25M
Average CapEx per Site	$1.5M	$1.7M	$1.8M
Payback Period (Years)	3.2	3.0	2.8
Average OR Time per TJR (Minutes)	90	85	80
Post-Op Stay (Hours)	6.5	6.0	5.8
Complication Rate	1.2%	1.1%	1.0%
% of Total EBITDA	10%	11%	15%
Incremental EBITDA from TJR Growth	—	+$6M	+$9M

Acquisition Growth: This strategy focuses on expanding National Surgical Solutions’ national footprint by acquiring new ambulatory surgery centers. The goal is to offset volume declines at mature centers by adding newly acquired facilities that contribute immediate revenue and expand market presence. Acquisitions also increase negotiating leverage with payers and suppliers, enabling economies of scale. However, this approach requires substantial capital outlays, exposes the company to integration risk, and often results in post-acquisition volume erosion as surgeons reduce case volumes or retire. Many acquired centers also require significant wage boosts to retain nursing staff, further increasing integration costs and reducing early-stage EBITDA.

In addition, several technological investments are required to make this a viable strategy. First, advanced analytics are needed to evaluate acquisition targets, validate case volumes, and model post-acquisition performance. Second, integrated Electronic Health Records (HER) systems, cloud-based scheduling platforms, and standardized operational dashboards are needed to help accelerate integration and reduce the volatility typically seen in the first 12–24 months after purchase. These tools are imperative to effectively pursue acquisition-led growth.

Physician Relationship Manager Growth

This alternative shifts the strategic emphasis to organic, in-market growth, using the Physician Relationship Manager (PRM) model to recruit, retain, and reactivate surgeons within existing facilities. National Surgical Solutions would focus on maximizing the utilization and profitability of current centers by systematically replacing retiring surgeons with younger, mid-career physicians. Because surgeon satisfaction depends heavily on reliable staffing, stabilizing nursing wages and retention is essential to the success of PRM-driven growth. This approach recognizes that surgeon relationships drive long-term case stability. Normal ASC lifecycle declines would be offset through replacement pipelines.

A PRM-driven growth strategy requires lower capital investment and mitigates volume erosion due to surgeon aging. In addition, EBITDA would improve by increasing lucrative case volumes within existing fixed-cost structures. As a result, it enhances return on invested capital (ROIC). This would also allow the firm to improve the profitability of each facility's case mix. A technological investment would be necessary to optimize predictive analytics capabilities, customer relationship management, and integrated scheduling.

Service Line Expansion into High-Acuity Procedures

This strategy focuses on expanding the company's clinical capabilities to include higher-acuity, higher-reimbursement procedures such as total joint replacements, spine surgeries, cardiovascular interventions approved for ASC settings. However, expanding into higher-acuity procedures also intensifies the company's exposure to nursing wage inflation, as these cases require highly skilled perioperative nurses and increase the cost of scaling advanced service lines. By diversifying its case mix and increasing revenue per case, National Surgical Solutions can offset volume declines driven by an aging surgeon population and strengthen its competitive position. High-acuity service lines also attract top surgeons seeking modern facilities equipped for advanced procedures.

Successful execution depends heavily on targeted technological investment. High-acuity cases require advanced imaging, robotics, navigation systems, and integrated perioperative platforms to ensure safety, efficiency, and regulatory compliance. Data analytics support payer negotiations and reimbursement modeling, while digital care-coordination tools streamline pre- and post-operative workflows. Technology, therefore, enables both the clinical feasibility and the financial viability of expanding into more complex procedures. However, NSS faces a competitive disadvantage in this space, as competitors have already built strong high-acuity platforms with advanced robotics, imaging, and perioperative technology, raising the bar for clinical capability and capital requirements.

Conclusion

NSS faces an important strategic decision. Case volumes continue to decline, nursing wage inflation squeezes margins, and national competitors are accelerating investments in high-acuity capabilities and physician recruitment. The company's long-standing reliance on acquisition-driven growth is no longer delivering the stability needed.

Three strategic alternatives exist: continuing to pursue acquisitions, shifting toward PRM-driven organic growth, or expanding into higher-acuity procedures. Each option offers meaningful upside and significant risks. Capital is limited and expensive, competitive pressures are rising, and the wrong choice could further weaken the company's position in an increasingly consolidated industry.

The future direction of the organization hinge on selecting the right strategy. Which strategy should the company pursue, and what assumptions support your recommendation.

Teaching Note
National Surgical Solutions: Stabilizing Growth In the Ambulatory Surgery Center Market

Case Type: Decision-focused teaching case
Discipline: Marketing Management / Healthcare Strategy

Keywords: Ambulatory surgery centers; ASC lifecycle; human capital; surgeon aging; nursing wages; acquisition strategy; PRM model; high-acuity expansion; healthcare strategy; relationship marketing

1. Case Overview (Instructor Use Only)

This case examines National Surgical Solutions (NSS), one of the largest ASC operators in the United States, as it confronts declining same-facility case volumes, surgeon aging, and margin pressure despite strong top-line growth. The company has traditionally relied on acquisitions to expand its footprint, but rising capital costs, integration challenges, and lifecycle-related volume erosion have weakened the effectiveness of this strategy. The case also highlights the growing impact of nursing wage inflation, which has become a central driver of margin compression and a key constraint shaping NSS's strategic options.

2. Target Audience and Course Placement

This case is appropriate for:

- Healthcare Administration / Healthcare Strategy
- MBA or Executive MBA Strategy courses
- Advanced undergraduate capstone courses

3. Learning Objectives

After completing the case discussion, students should be able to:

- Critically assess the tradeoffs among acquisition-led growth, PRM-driven organic expansion, and high-acuity service line development.
- Apply the ASC lifecycle model to identify drivers of volume erosion and evaluate their impact on profitability.

- Diagnose post-acquisition performance declines by examining human capital misalignment, incentive structures, and lifecycle dynamics.
- Analyze the economics of organic growth, acquisition-driven expansion, and service line diversification within a regulated healthcare environment.
- Compare the capital intensity, risk exposure, and long-term sustainability of the three strategic alternatives.
- Evaluate how nursing wage inflation affects margins, staffing stability, and the feasibility of each strategic option.
- Use ROI, NPV, and sensitivity analysis to test assumptions and strengthen strategic recommendations (optional).

4. Pedagogical Rationale (Instructor Guidance)

This case works well in the classroom because it naturally guides students from descriptive analysis into strategic decision-making. The financial exhibits, lifecycle model, and competing growth pathways create a structured flow: students begin by diagnosing the root causes of declining performance, then evaluate the tradeoffs among the alternatives. The discussion builds toward a data-driven recommendation that requires integrating strategy, finance, and relationship marketing making the case both analytically rigorous and highly engaging.

Nursing wage inflation should be emphasized as a strategic not operational variable. It affects acquisition integration, PRM success, and high-acuity feasibility. Instructors should encourage students to treat labor costs as a core economic driver.

The discussion builds toward a data-driven recommendation that integrates strategy, finance, and relationship marketing.

5. Strategic Insight: Nursing Wage Inflation as a Strategic Variable

Nursing wage inflation is one of the most important and often overlooked drivers in the case. Instructors should highlight:

- Wage inflation directly compresses EBITDA margins.
- Hospitals have raised wages aggressively, widening the pay gap with ASCs.
- Acquired centers often require immediate wage adjustments to retain staff.

- High-acuity procedures require more skilled perioperative nurses, increasing labor intensity.
- PRM success depends on reliable staffing; surgeon satisfaction collapses when turnover is high.

Teaching Tip:
Ask students: “Which strategy is most sensitive to nursing wage inflation?” This insight often shifts student recommendations.

This typically reveals:
- Acquisitions → highly sensitive
- PRM growth → moderately sensitive
- High-acuity expansion → extremely sensitive

6. Suggested Student Preparation

Students should read the case and prepare brief responses to the following:
1. What is driving declining case volumes at NSS?
2. Why has acquisition-driven growth become riskier?
3. How does the PRM model change the economics of growth?
4. How do nursing wages affect each strategic option?
5. How does high-acuity expansion change the company’s risk profile?
6. What strategy should NSS pursue over the next 24–36 months?

7. Teaching Plan (75-minute course)

*Opening (*10 minutes)
Guide students to notice:
- Declining same-facility volume
- Margin compression
- Rising labor costs
- Underutilized capacity

ASC Lifecycle (10 minutes)
Use Exhibit 1 to explain why mature ASCs decline without reinvestment or recruitment.
Key insight: acquisitions often inherit lifecycle decline.

Strategic Alternatives (25 minutes)
Discuss each option shown in Exhibit 7.

Exhibit 7: Strategic Alternatives

Acquisition-Led Growth	**PRM-Driven Organic Growth**	**High-Acuity Expansion**
High capital intensity	Lower capital intensity	Higher reimbursement potential
Integration risk	Stronger ROI	Requires advanced technology and skilled nurses
Wage adjustments required to retain nurses	Dependent on nursing stability	Competitors already ahead
Lifecycle decline in acquired centers	Improves case mix and fixed-cost leverage	High capital and labor intensity

8. Quantitative Extensions (Optional)

For instructors seeking more analytical rigor, the case supports:

ROI Analysis
Compare capital efficiency:
- PRM growth → low capital, high incremental EBITDA
- Acquisitions → high capital, uncertain early returns
- High-acuity → high capital, long payback

NPV Analysis
Useful for evaluating:
- High-acuity buildouts
- Large acquisitions
- Facility reinvestment decisions

Sensitivity Analysis
Stress-test assumptions:
- Nursing wage inflation
- Surgeon attrition
- Case volume growth
- Reimbursement changes

Teaching Tip:
Have students identify which variable the strategy is most sensitive to. This often changes their recommendation.

9. Likely Student Recommendations

Students typically choose one of three paths:

- PRM-driven growth (most common): strong ROI, low capital, stabilizes volume.
- High-acuity expansion (ambitious students): higher revenue per case but high risk.
- Acquisition-led growth (less common): students often reject due to capital intensity and lifecycle decline.

10. Instructor Wrap-Up

Emphasize that NSS's challenge is not simply volume decline it is the intersection of:

- lifecycle erosion
- nursing wage inflation
- capital constraints
- competitive pressure

The winning strategy depends on which constraint students believe is most binding.

11. Discussion Questions with Teaching Guidance

The questions in Exhibit 8 are designed to help students move from diagnosing the root causes of performance decline to developing defensible strategic recommendation.

12. Analysis and Suggested Solution (Instructor Use Only)
Financial Trade-Offs and Strategic Implications

This section provides the instructor with the underlying strategic logic and recommended solution that should emerge from the class.

The firm faces a classic multi-horizon growth dilemma: acquisitions provide immediate scale but erode quickly due to lifecycle decline; PRM-driven organic growth stabilizes the base but ramps more slowly; and high-acuity expansion offers long-term

Exhibit 8: Discussion Questions with Teaching Guidance

Question	Teaching Points	Pedagogical Insight	Discussion Starters
1. Why does the performance of ASC's begin to decline within 2 years?	Pre-sale volume inflation; Surgeon liquidity reducing work incentives; Accelerated retirement following asset sales: Absence of enforceable volume commitments; Facility lifecycle mismatch.	Human capital risk dominates asset risk. This question teaches students that ASC performance is driven far more by human capital dynamics than by physical assets. It reframes the case from a facilities problem to a behavioral economics problem: surgeons change their effort, case mix, and retirement timing after liquidity events. Students often assume volume decline is operational; this question helps them see it is incentive-driven and predictable.	1. What potential problems are evident in Exhibit 6? 2. Which factor would you worry about most if you were COO?
2. What strategic problem does the PRM model solve that acquisitions do not?	Lower capital intensity; Relationship-driven growth: Greater control over volume generation; Alignment with marketing management theory (personal selling, LTV); Address surgeon aging and succession issues.	This question highlights the distinction between buying volume and building volume. Students learn that acquisitions provide capacity but not commitment, whereas PRMs create relationship-based, recurring case flow. It reinforces core marketing concepts like personal selling, customer lifetime value, and relationship management in a healthcare context where "customers" are surgeons, not patients.	1. Which PRM outcome in the case surprised you most? 2. Is this a marketing solution or an operational one?
3. Should NSS eliminate acquisitions entirely?	Acquisitions still provide scale and geographic entry; Organic growth stabilizes baseline volumes; A hybrid strategy reduces volatility; Cost of capital influences the mix.	This question pushes students beyond binary thinking. Many initially argue for "all PRM" or "all acquisition," but the deeper lesson is portfolio strategy: different growth levers serve different purposes depending on capital costs, lifecycle stage, and market entry needs. It teaches students to balance short-term stabilization with long-term positioning.	1. If interest rates dropped tomorrow, would your answer change? 2. Which alternative best addresses the ASC lifecycle?

4. What are the dangers of aggressive budgeting in a public company?	*Key Risks:* Internal misalignment Market credibility erosion Ethical concerns in guidance Pressure-induced poor decision-making	This question exposes students to the organizational consequences of unrealistic financial targets a common but under-taught issue in strategy courses. It helps them see how overly optimistic guidance cascades through the organization, distorting incentives, eroding credibility, and encouraging risky decisions. It also connects financial forecasting to ethical leadership.	1. What happens when budgets assume volume that never materializes? 2. Who inside the company feels the pressure first?
5. What performance metrics should leadership prioritize going forward?	*Suggested Metrics:* Case volume per surgeon (by tenure), Surgeon retention rates, Succession risk, PRM ROI (cases, revenue, margin), Case volume per surgeon (by tenure), Block utilization, Case volume per surgeon (by tenure), Specialty mix profitability	This question shifts students from diagnosis to forward-looking management control. It teaches them to distinguish between leading indicators (surgeon retention, PRM ROI, block utilization) and lagging indicators (revenue, EBITDA). Students learn that in human-capital-driven service businesses, early warning metrics matter more than financial outcomes.	
6. Which metric predicts trouble earliest?		This question helps students recognize that early warning signs in ASC performance rarely appear in revenue. Instead, the earliest indicators of trouble are same-facility case volume, surgeon attrition, and EBITDA margin compression. Guiding students to identify these metrics reinforces the case's central lesson: ASC performance is driven by human capital and lifecycle dynamics, not by facility count or top-line growth. This sets up the strategic alternatives discussion by highlighting why acquisitions alone cannot stabilize performance.	1. Which metric should the COO monitor first? 2. Why do financial outcomes lag operational warning signs? 3. How early can leadership realistically detect lifecycle decline?

7. How does nursing wage inflation change attractiveness of each strategic alternative?		This question teaches students that labor economics. Nursing wage inflation reshapes the strategic landscape: acquisitions become more expensive because newly acquired centers often require immediate wage resets; PRM-driven growth depends on staffing stability to maintain surgeon satisfaction; and high-acuity expansion requires higher-skilled, higher-cost perioperative nurses. Students learn that wage inflation compresses margins faster than revenue can offset, making labor cost sensitivity a central strategic constraint.	1. Which strategy is most vulnerable to wage inflation? 2. How does wage pressure affect surgeon satisfaction and PRM success?
8. Which strategy delivers the strongest return on invested capital (ROIC), and why?		This question shifts students from qualitative reasoning to financial logic. It teaches them that PRM-driven growth typically generates high incremental EBITDA with minimal capital, acquisitions require substantial capital with uncertain early returns, and high-acuity expansion offers higher revenue per case but demands significant upfront investment and longer payback periods. Students learn to evaluate strategy through the lens of capital efficiency an essential skill in a high-interest-rate environment.	1. Which strategy creates the most value per dollar invested? 2. How does the cost of capital influence your recommendations?
9. What assumptions do recommendation depend on, and which one is most vulnerable?		This question introduces sensitivity analysis without requiring calculations teaching students that every strategic recommendation rests on assumptions about surgeon recruitment, nursing wage stabilization, volume growth, reimbursement rates, and capital availability. By identifying the most fragile assumption, students learn to stress-test their own reasoning and recognize that strategy is only as strong as the conditions that support it.	1. What happens if your key assumption fails? 2. Which assumption is most outside NSS's control?

*Note: This question ties directly to NSS's history of optimistic guidance and acquisition-driven expectations.

margin lift but requires meaningful capital and technology investment. The core financial trade-off is between capital intensity and volume sustainability. In a high-interest-rate environment, the economics of acquisition-led growth weaken, while the relative ROI of PRM-driven volume and selective high-acuity expansion improves.

The instructor should guide students toward recognizing that no single alternative solves the problem. Instead, the company must balance short-term stabilization, medium-term volume rebuilding, and long-term margin expansion.

The recommended hybrid strategy emphasizes organic growth while selectively pursuing acquisitions. This reflects an effort to stabilize cash flows, improve ROIC, and restore credibility in financial guidance.

13. Quantitative Anchor (Exhibits Located in Appendix B)

- 369 new surgeons recruited
- 14,352 new cases (~39 cases per surgeon in Year 1)
- $41 million in incremental revenue
- Approx. $2,850 revenue per case (blended)
- High-acuity cases (e.g., total joints) generate 4–5× revenue per case and 30% EBITDA margins

These numbers illustrate why PRMs stabilize the base and why high-acuity expansion materially improves profitability.

Recommended Strategy
A hybrid growth strategy emphasizing:
PRM-Driven Organic Growth (Primary Near-Term Lever)

Rationale:
- Highest ROI in a high-cost-capital environment
- Directly addresses surgeon aging and lifecycle decline
- Improves utilization within existing fixed-cost structures
- Strengthens long-term surgeon loyalty and case stability

Target Mix: ~ 60% of growth effort
Selective, Lifecycle-Screened Acquisitions (Secondary Lever)

Rationale:

- Maintains payer leverage and geographic scale
- Allows entry into attractive markets
- Works only when lifecycle risk is screened and ROIC thresholds are enforced

Target Mix: ~25–30% of growth effort
(Lower than historical levels due to higher interest rates and integration risk.)
High-Acuity Service Line Expansion (Long-Term Margin Lever)

Rationale:
- High-acuity cases (joints, spine, cardiovascular) deliver significantly higher revenue per case and EBITDA margins
- Creates competitive differentiation and attracts top surgeons
- Offsets aging surgeon volume with higher-value procedures
- Requires technology investment (robotics, imaging, navigation), but payback periods are favorable

Target Mix: ~10–15% of growth effort
(Focused on centers with the right demographics, payer mix, and facility layout.)

Strategic Guardrails:
Human Capital Guardrails
- Surgeon age and succession analysis
- PRM staffing aligned with facility capacity
- Monitoring of surgeon retention and case mix shifts

Financial Guardrails
- Conservative budgeting tied to trailing performance
- ROIC thresholds adjusted for higher interest rates
- Lifecycle screening for all acquisitions

Operational Guardrails
- Facility readiness for high-acuity cases
- Technology investment tied to projected case mix
- Block and OR utilization targets

Together, these insights help students see why NSS must balance short-term stabilization with long-term margin expansion.

Instructor Takeaway
The optimal solution is not choosing one alternative but sequencing all three. PRMs stabilize the base and rebuild volume; selective

acquisitions maintain scale; and high-acuity expansion drives long-term margin improvement. Together, these levers allow NSS to balance short-term performance stabilization with long-term strategic positioning in a capital-constrained environment.

14.Instructor Prompts (Optional Teaching Cues)

Prompts are intentional questions the instructor asks to deepen analysis, redirect discussion, or surface a specific insight.
Instructor Prompt:
"Which strategy creates the most value per dollar invested?"
ROI: PRM growth is the clear leader.

Guide students to see that PRM growth produces the strongest ROI because it requires the least capital and delivers the fastest EBITDA lift.

Instructor Prompt:
"Which strategy creates the most value per dollar?"

Direct students to the ROI section.

- PRM growth shows the highest ROI because it requires minimal capital and leverages fixed costs.
- Acquisitions show low ROI due to high purchase multiples and lifecycle decline.
- High-acuity expansion shows variable ROI, which opens a discussion about risk.

Teaching move:
Ask students to calculate ROI themselves using the numbers provided. This forces them to confront the capital intensity differences.

Instructor Prompt:
"Does growth automatically create value?"

Push students to recognize that acquisitions may grow revenue but still destroy value once capital costs and lifecycle decline are considered.

Instructor Prompt:
"Does growth equal value creation?"

Use the NPV section to challenge assumptions.

- PRM → positive NPV
- Acquisition → neutral or negative NPV
- High-acuity → positive only if assumptions hold

Teaching move:
Ask "Why might a strategy with strong revenue growth still destroy value?" This leads students to discuss cost of capital, integration risk, and surgeon attrition.

NPV: Acquisitions struggle under high capital costs; PRM is strongest.

Instructor Prompt: "Which strategy is most sensitive to risk?"

- Acquisitions are highly sensitive to surgeon attrition and volume decline.
- High-acuity expansion is highly sensitive to nursing wage inflation and payer mix.
- PRM growth is the most resilient because it leverages fixed costs and can replace retiring surgeons.

Instructor Prompt:
"Which strategy would you recommend and under what assumptions?"

Sensitivity: High-acuity expansion is the most volatile; PRM is the most stable.

Encourage students to integrate financial, operational, and competitive considerations into a defensible recommendation.

Instructor Prompt:
"Which strategy is most sensitive to risk?"

Guide students to the sensitivity table.

- Acquisitions are highly sensitive to volume decline.
- High-acuity expansion is highly sensitive to nursing wage inflation and payer mix.
- PRM growth is least sensitive, making it the most resilient.

Teaching move:

Ask "If nursing wages rise 10%, which strategy suffers most? Why?"

Instructor Prompt:
"What assumptions would you challenge?"

Encourage students to question:
- Volume projections
- Surgeon recruitment assumptions
- Wage inflation
- Reimbursement stability
- Competitive pressure from competition

Teaching move:
Have students adjust one variable (e.g., volume –10%) and recalculate EBITDA. This turns the case into a hands-on decision exercise.

Instructor Prompt:
"Which strategy would you recommend and why?"

Students must integrate:
- ROI
- NPV
- Sensitivity
- Competitive positioning
- Nursing wage pressure
- Surgeon aging
- Capital constraints

This leads to a richer, more defensible recommendation.

Instructor Cues (How to Use the Exhibits Without Overwhelming Students)

These cues help you integrate the financial and operational exhibits into the flow of class discussion. They are designed to surface the core strategic tensions in the case without requiring students to parse every line of the tables. Each cue directs attention to a specific insight that anchors the discussion and naturally transitions into the strategic alternatives. These cues help you integrate the table into the flow of class without overwhelming students.

Cue 1: Start With the Contradiction
"Look at the first four lines of Exhibit 6. How can total cases and revenue be rising while same-store revenue is flat and margins are falling?" This immediately surfaces the core problem: acquisitions mask underlying decline.

Cue 2: Direct Students to Lifecycle Indicators
"Which metrics tell you this company is entering the erosion stage of the ASC lifecycle?" Students should identify:

- Same-facility case volume decline
- Rising surgeon attrition
- Rising average surgeon age
- Declining utilization
- Margin compression

This anchors the discussion in Exhibit 6 (ASC lifecycle).

Cue 3: Highlight Capital Intensity and Risk
"What story do the CapEx, debt, and interest rate lines talk about the sustainability of acquisition-led growth?" This pushes students to connect financial structure to strategy.

Cue 4: Pivot to PRM Economics
"What do the PRM cost and ROI lines tell us about the economics of organic growth?" This helps students see PRMs as a marketing investment, not an operational expense.

Cue 5: Spotlight High-Acuity Economics
"Why do TJR cases matter even though they're only 1–1.4% of total volume?" This sets up the high-acuity expansion alternative.

Students should notice:

- High revenue per case
- High EBITDA margin
- Short payback period
- Growing share of total EBITDA

Cue 6: Close With Strategic Implications
"Based on Exhibit 6, which growth strategy best addresses the root cause of decline?" This naturally leads into the recommendation debate. This exhibit should be used as the analytical anchor for the entire class discussion.

15. How to Distribute the Optional Financial Appendix (Teaching Note Guidance)

If instructors choose to incorporate the optional ROI, NPV, and sensitivity analysis, the Student Financial Appendix which includes blank templates should be distributed as part of the student-facing case or provided as a one-page handout at the start of class. The appendix is intentionally designed to offer inputs without outputs—students receive the capital requirements, EBITDA ranges, and blank templates, but no completed calculations. This structure allows faculty to “turn on” the quantitative layer without overwhelming students or shifting the case into a finance exercise. Instructors may assign the appendix as pre-class preparation, use it for an in-class breakout, or reserve it for advanced sections that want to compare the financial attractiveness of the strategic alternatives. The appendix is optional and does not affect the core learning objectives; it simply provides an additional analytical pathway for courses that want deeper financial rigor.

16. Teaching Note Conclusion

This case demonstrates that ASC performance is driven less by physical assets and more by human capital, surgeon behavior, and predictable lifecycle dynamics. Relationship-driven growth through PRMs directly addresses surgeon aging and volume erosion, while high-acuity expansion offers a pathway to long-term margin improvement. Acquisition-led growth alone cannot overcome these structural forces; sustainable performance requires a relational strategy grounded in marketing management and physician engagement.

17. Author Disclosure and Ethical Considerations

One of the case authors is an employee of the organization described in this case. All data have been drawn from public sources, appropriately disguised, or developed for instructional use. No confidential or proprietary information is included. This disclosure is provided for transparency and does not compromise the academic or pedagogical integrity of the case.

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