Assessing Disparities in Shelter Performance within North Carolina: The Influence of Economic and Demographic Factors on Adoption and Euthanasia Rates

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Abstract

This study investigates the relationship between economic and demographic factors and the operational efficiency of animal shelters across North Carolina. Specifically, we have analyzed whether counties with higher median incomes and greater resource availability exhibit lower euthanasia rates and higher adoption rates compared to less affluent areas. Grounded in Resource Dependence Theory (RDT), this research examines how shelters rely on external funding, donations, and community resources to maintain operations and improve outcomes. Using publicly available data from the North Carolina Department of Agriculture's annual shelter reports and the U.S. Census Bureau's 2020 Decennial Census we have employed statistical methods, including regression modeling, correlation analysis, and geospatial analysis, to identify trends in shelter performance. Key variables include shelter operating expenses, euthanasia rates, adoption rates, intake rates, county-level income, population density, and demographic composition.

Beyond identifying disparities, this research explores potential strategies to enhance shelter efficiency and improve animal welfare outcomes. Proposed solutions include targeted funding allocation for underperforming shelters, the expansion of community outreach and adoption initiatives, and the implementation of data-driven resource distribution models to optimize shelter operations. Additionally, we assess the impact of policy interventions such as spay/neuter programs and foster networks in mitigating shelter overcrowding and euthanasia rates. By synthesizing quantitative analysis with policy recommendations, this study aims to provide actionable insights for shelter administrators, policymakers, and advocacy groups striving to improve adoption rates and reduce euthanasia across the state.

CCS Concepts

• **Information systems** → *Data analytics*; • **Applied computing** → *Animal welfare*; • **Computing methodologies** → Machine learning.

Keywords

Animal Shelters, Euthanasia Rates, Adoption Rates, North Carolina, Socioeconomic Factors, Resource Dependence Theory, Data Analytics

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1 Introduction

North Carolina had the second-highest animal euthanasia rate in the U.S. in 2021, with about 14,400 dogs and cats euthanized in 2022 [12]. These statistics underscore the importance of understanding the interplay between regional socioeconomic conditions and shelter operations. While differences in adoption and euthanasia rates are evident, this study seeks to investigate how specific community-level factors—such as income, poverty, and housing stability—contribute to these disparities in outcomes. Many of these counties have shelters that struggle with overcrowding and limited resources, often resulting in higher euthanasia rates. Economic conditions, such as income levels and community engagement, play a crucial role in determining a shelter's ability to provide care and re-home animals. Shelters in lower-income areas often face challenges due to limited financial support, impacting their ability to provide optimal care and resources.

Data-driven solutions are essential in understanding and addressing these disparities. By analyzing large-scale data, such as shelter records, demographic data, and economic indicators, insights can be gained about the factors most influencing shelter performance. These insights can guide interventions and strategies to improve animal welfare. Understanding the root causes of high euthanasia rates and low adoption rates is crucial to informing targeted funding, policy changes, and expanded adoption initiatives.

This study explores how economic and demographic factors impact shelter outcomes, using data from the North Carolina Department of Agriculture's annual shelter reports. Regression modeling, correlation analysis, and GIS mapping were applied to identify the social and economic factors that most influence shelter performance. We hypothesized that shelters in counties with higher median incomes had lower euthanasia rates and higher adoption rates due to limited resources. Our findings could inform strategies such as targeted funding, expanded adoption initiatives, and policy recommendations to improve shelter efficiency. An analysis was performed on shelter records, demographic data, and economic indicators through statistical modeling and geographic mapping. By combining quantitative analysis with policy evaluation, this research aimed to provide practical solutions for enhancing shelter operations and improving animal outcomes in North Carolina.

2 Background

Animal shelters are integral to community animal welfare, managing the intake, adoption, and sometimes euthanasia of unwanted or stray cats and dogs. These shelters' operational efficiencies are deeply influenced by economic conditions, demographic variables, community support, and housing

policies, which vary widely across different regions. Prior research has explored these dynamics from different angles. Heyde [5] demonstrated how strategic resource allocation through Data Envelopment Analysis (DEA) enhances shelter outcomes. Meanwhile, studies have shown that social vulnerability does not necessarily correlate with higher euthanasia rates, as targeted adoption services can mitigate these challenges [8]. This finding highlights a broader gap in understanding how social and economic contexts shape shelter performance, reinforcing the need for localized policy interventions. These foundational studies illustrate the variety of contextual factors shaping shelter outcomes, prompting deeper investigation into which of these matter most at the county level in North Carolina.

A meta-analysis by Lambert et al. [6] identified owner health issues as a major driver of pet surrenders, underscoring the need for supportive services to maintain pet-owner bonds during crises. Similarly, research has found that shelter adoption rates improve when barriers such as breed labels are removed, with one study reporting an 11.3-day reduction in median stay length for dogs following breed label removal [3]. Further, restrictive housing policies contribute to 14% of shelter intakes, emphasizing the need for policy reforms to expand pet-friendly housing options [1]. These findings collectively suggest that shelter intakes and outcomes are shaped not just by internal management but by broader systemic factors, including housing stability and public perceptions of shelter animals. Together, these findings highlight how policies related to housing and animal labeling may inadvertently influence shelter populations and should be considered alongside demographic data.

Access to veterinary care significantly shapes adoption and euthanasia rates, particularly in under served communities. Studies indicate that shelters in low-income areas experience higher intakes and euthanasia rates due to limited access to affordable veterinary care [7]]. Additionally, subsidized spay/neuter programs have been found to produce varying effects depending on local conditions, emphasizing the need for targeted intervention strategies [11]. Neal [8] further argues that policy solutions must be tailored to areas lacking sufficient veterinary services, suggesting that region-specific approaches can more effectively improve shelter outcomes. These patterns prompt important questions about how accessibility to veterinary services may disproportionately affect certain communities, shaping our hypotheses and research direction.

Funding strategies and innovative adoption models play a crucial role in shelter sustainability. Resource Dependence Theory (RDT) has been applied to explain how nonprofit shelters secure and manage critical resources, highlighting the importance of diversified funding and donor engagement [10]. This is also supported by Mohan-Gibbons et al. [13], who found that foster-based adoption programs reduce shelter stays while expanding community involvement. These findings illustrate how financial and operational strategies directly influence shelter success, reinforcing the need for strategic planning in both resource allocation and adoption models. By understanding the resource constraints many shelters face, we can better examine how funding strategies correlate with success indicators like adoption and euthanasia rates.

Technological advancements are increasingly shaping shelter operations. Machine learning models have been used to predict animal length of stay, helping shelters optimize their resources [2]. Tools like the ShelterViz web app aggregate data from thousands of shelters, providing actionable insights for operational improvements [4]. However, these innovations remain underutilized in resource-limited environments, where constraints on funding and technological infrastructure hinder implementation. This disparity suggests that while data-driven approaches hold promise, equitable access to these tools is necessary for meaningful impact. As such, technology's potential must be weighed against access barriers, particularly for resource-limited shelters—a point that connects to broader equity concerns in our analysis.

By leveraging statistical methods and geospatial analysis, our study aims to provide a comprehensive assessment of shelter performance disparities across North Carolina. This research extends prior work by integrating socioeconomic, demographic, and policy variables to identify actionable pathways for improving animal welfare. By addressing existing gaps and challenging conventional assumptions, this study has the potential to inform future policies that create more equitable outcomes for shelter animals, ensuring that structural barriers do not disproportionately impact their well-being.

3 Methodology

3.1 Dataset Description

The framework of this research relies on two key datasets that will help explore and analyze the correlations between socioeconomic factors and animal shelter outcomes among counties in North Carolina. Data was retrieved from the North Carolina Department of Agriculture [9], which provides comprehensive breakdowns of animal shelters within the state. Additionally, the dataset contains county-level statistics on shelter intakes, adoptions, euthanasia, financial operating expenses, and the average cost spent on each animal. To incorporate economic data and analyze whether it has underlying influences on shelter outcomes, a subsection of the 2020 U.S. American Community Survey maintained by the U.S. Census Bureau [12] was obtained containing key features. These features focus on household income, home ownership rates, poverty rates, and more economic indicators. The economic variables chosen aim to provide insights into the possible correlations between financial stability and housing conditions contributing to differing rates of adoption and euthanasia across various counties in the state of North Carolina. Furthermore, a geospatial map with rental properties across the United States with inclusive pet policies will assess whether access to pet-friendly housing influences shelter rates.

3.2 Data Cleaning

The animal shelter dataset was cleaned to ensure consistency and analytical integrity. All entries not related to dogs or cats were removed, and animal type labels were standardized to "CAT" or "DOG." Column names were reformatted for uniformity, and the `calendar_year` column was dropped due to redundancy. Records missing values in key fields such as intake, adoptions, or euthanasia were excluded from the dataset.

To improve the accuracy of adoption rate calculations, an `adjusted_intake` variable was created by subtracting animals returned to owners from the total intake. Adoption and euthanasia rates were then calculated using this adjusted figure. Initial visualizations revealed skewed distributions for some outcome variables, which influenced the decision to apply quantile-based binning and informed the identification of outliers. Shelter records were aggregated at the county level, resulting in usable data for 65 of North Carolina's 100 counties.

Demographic and housing data from the 2022 American Community Survey was also cleaned and prepared for integration. County names were standardized across both datasets to support accurate merging, enabling correlation and regression analysis with variables such as poverty rate, median income, rental housing prevalence, and insurance coverage.

3.3 Analysis Design

To analyze disparities in animal shelter outcomes across North Carolina counties, we employed a multi-step data modeling strategy. We began by creating bins for both adoption and euthanasia rates using quantile-based discretizations. This grouped counties into Low, Medium, and High tiers for each outcome, enabling us to explore patterns across stratified levels of shelter performance.

We then used K-Means clustering to identify natural groupings among counties based on socioeconomic and shelter-related features. Prior to clustering, all numerical variables were standardized, and principal component analysis (PCA) was used to reduce the dimensionality of the feature space. The resulting clusters were visualized and interpreted to highlight differences in community resources, shelter intake, and outcomes. A silhouette score of 0.59 suggested strong separation between the clusters.

To predict outcome tiers, we trained two separate Random Forest classifiers: one for adoption rate bins and another for euthanasia rate bins. Input features included poverty rate, rental rate, median income, homeownership, insurance coverage, SNAP participation, and shelter intake. Both models were evaluated using accuracy, precision, recall, F1-score, and confusion matrices. Feature importance scores were extracted to identify the strongest predictors.

Data visualizations, including bar charts and choropleth maps, were used to compare average socioeconomic conditions across both adoption and euthanasia bins. This dual analysis allowed us to identify overlap and divergence in the conditions influencing shelter success and failure.

4 Results

4.1 Distribution Patterns

Descriptive visualizations revealed that adoption rates across counties were approximately normally distributed, while euthanasia rates were heavily right-skewed. The average adoption rate was 51.88% (SD = 22.00), while the mean euthanasia rate was 27.83% (SD = 20.08). Three counties exhibited euthanasia rates above 81%, indicating outlier regions facing significant resource constraints. These distributions supported the decision to apply quantile-based binning to better interpret stratified patterns in shelter performance.

4.2 Binning Analysis

Binning results showed clear contrasts between county groups. Counties in the High Adoption Rate tier were generally characterized by higher median incomes, lower poverty, greater homeownership, and moderate shelter intake volumes. In contrast, counties in the Low Adoption Rate tier showed significantly higher poverty and rental housing rates, along with lower incomes. The same socioeconomic patterns appeared in the Euthanasia Rate bins, where counties in the High Euthanasia Rate group experienced elevated poverty, higher intake, and lower income levels. A cross-tabulation revealed that 15 counties were both Low Adoption / High Euthanasia, while 14 counties were High Adoption / Low Euthanasia, illustrating stark disparities in shelter outcomes.

4.3 Clustering Analysis

K-means clustering grouped counties based on shelter-related and socioeconomic variables, such as intake, income, poverty, and housing characteristics. Clustering revealed two primary groups: one cluster composed of better-resourced counties with stronger adoption performance, and another with counties facing high euthanasia rates and more limited economic support. These clusters aligned with the binning results, reinforcing the presence of structural divisions in shelter performance across the state.

4.4 Classification Modeling

Random Forest models were developed to predict adoption and euthanasia tiers using county-level features. Each model achieved approximately 60% accuracy, with the adoption model performing best for predicting the Low Adoption class. Feature importance rankings consistently identified poverty rate, shelter intake, and rental housing percentage as the top predictors. These results highlight how community-level factors most strongly influence negative outcomes, supporting the theoretical framework of Resource Dependence Theory.

4.5 Geospatial Visualization

Choropleth maps were used to visually compare adoption and euthanasia outcomes across counties. Adoption rate bins were represented using a CB-safe color palette, while euthanasia rates were encoded with diagonal hatch lines to distinguish high-rate counties. The resulting map highlighted geographic clusters of disadvantage, reinforcing how economic and housing disparities shape shelter outcomes in specific regions of North Carolina.

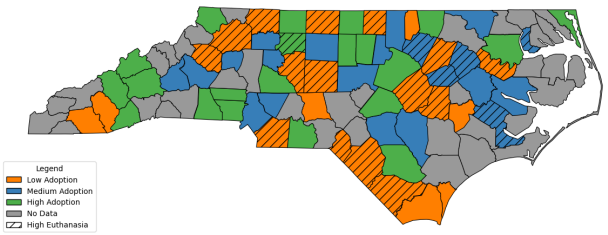

Figure 1: Adoption and Euthanasia Rate Levels in North Carolina Counties

5 Discussion

5.1 Socioeconomic Factors and Shelter Outcomes

This study investigated two main questions: (1) How do socioeconomic conditions influence adoption and euthanasia rates in North Carolina animal shelters? and (2) Which factors most strongly predict disparities in shelter performance? The results provide clear evidence that counties with lower poverty rates, higher median incomes, and stable housing (homeownership for example) consistently achieve higher adoption and lower euthanasia rates. Conversely, counties with limited resources, that have high poverty, high rental rates, and elevated intake, face systemic challenges that perpetuate poor shelter outcomes. These findings align with Resource Dependence Theory (RDT), which suggests that shelters in resource-poor environments struggle to secure external funding, community support, and infrastructure that is necessary to operate effectively.

5.2 Key Implications

The geospatial clustering of low-adoption/high-euthanasia counties emphasizes regional inequities tied to structural disadvantages. For example, rental-dominated housing correlates with these populations being less likely to adopt, while poverty limits access to veterinary care, which increases surrender rates. These patterns validate RDT's emphasis on external resource dependency. To address these disparities, policymakers should take steps such as: Prioritize targeted funding to under-resourced shelters in high-poverty counties, expanded veterinary services and staffing, advocate for pet-friendly housing policies to reduce intake linked to restrictive rental markets, a driver of 14 percent of surrenders. Also, implement data-driven resource allocation, using predictive models to identify at-risk counties and optimize practices like spay/neuter programs.

5.3 Limitations

Although this study offers valuable information on the influence of community-level conditions on shelter outcomes, several limitations must be acknowledged. First, the analysis was limited to 65 of the 100 counties in North

Carolina due to missing or incomplete data, excluding 35 counties - many of which represent rural shelters facing unique challenges. This partial coverage may affect the generalizability of the results and risks omitting critical trends in underserved regions. Additionally, the reliance on self-reported animal shelter data from annual reports submitted to the North Carolina Department of Agriculture introduces potential inconsistencies, particularly in metrics such as intake, adoption, and euthanasia figures. Such discrepancies could introduce noise into the analysis and under-report euthanasia rates, undermining the reliability of outcome predictions.

The scope of the analysis was also limited to a single year, limiting insights into longitudinal trends. Shelter performance and community conditions are dynamic, and future studies using multi-year data could provide a more comprehensive understanding of fluctuations. Methodologically, while principal component analysis and clustering techniques were applied to reduce data dimensionality and identify patterns, choices in feature selection and binning may have influenced the results. These decisions, though data-driven, warrant careful interpretation.

The Random Forest models identified poverty, intake and rental rates as the top predictors (60 percent accuracy), but their moderate performance suggests that unmeasured variables significantly influence outcomes. For example, the study did not account for shelter-specific factors such as management practices, foster network capacity, community education campaigns, or regional differences in the availability of spay / neuter programs. Cultural attitudes toward adoption and variations in access to veterinary care - critical drivers of surrender and euthanasia rates - were also omitted. Furthermore, reliance on census data risks oversimplifying complex socioeconomic dynamics, as localized policies, staffing levels, and community support programs may explain residual variance in shelter performance.

5.4 Future Works

To build on this work, researchers should expand data collection to all 100 counties, which will highlight rural-urban differences. They should include qualitative metrics such as volunteer engagement, and they should test advanced machine learning techniques to improve the generalizability of the model.

This study shows that structural inequities, not just shelter management, dictates animal welfare outcomes. By grounding the findings in RDT, we emphasize the need for systemic interventions, such as equitable funding and reforms to housing policy. Addressing these root causes will require collaboration with shelters, policymakers, and communities. This will make sure that resources align with the needs of both animals and the populations that care for them.

6 Conclusion

This study underscores how socioeconomic and demographic factors, such as poverty, income inequality, and unstable housing, shape animal shelter outcomes across North Carolina. Through binning analysis, clustering, classification modeling, and geospatial visualization, we demonstrate that counties with stronger economic indicators (e.g., higher median income, homeownership) achieve better adoption rates and lower euthanasia rates. Conversely, resource-limited counties face systemic challenges, reinforcing Resource Dependence Theory's premise that shelters depend critically on community resources and structural conditions.

The analysis identified poverty rate, shelter intake volume, and rental housing prevalence as consistent predictors of outcomes. While the models' moderate accuracy (60 percent) highlights the complexity of these dynamics, the findings emphasize the need for multifaceted interventions: targeted funding, pet-friendly housing policies, expanded veterinary care access, and community engagement. By integrating demographic and operational data, this study provides a foundation for policymakers and shelters to address root causes of disparities, ensuring resource allocation aligns with community needs.

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