Modeling Supply & Demand in the Self-Storage Market Using Data Envelopment Analysis (DEA)

Devin Echavarria
School of Business
New Jersey City University, Jersey City, NJ 07311, USA
Email: devinech3@gmail.com

Kyle Grund
School of Business
New Jersey City University, Jersey City, NJ 07311, USA
Email: kylegrund@outlook.com

EunSu Lee, Ph.D. (Corresponding author)
Professor of Management
School of Business
New Jersey City University, Jersey City, NJ 07311, USA
Email: elee3@njcu.edu

Received Sep. 20, 2024, Revised Nov. 1, 2024, Accepted Dec. 28, 2024
Published Dec. 31, 2024.

Management Review: An International Journal, 19(2): 78-114.
ISSN: 1975-8480 eISSN: 2714-1047
https://doi.org/10.55819/mrij.2024.19.2.78

ABSTRACT

This study investigates the drivers of structural demand for self-storage facilities and market attractiveness across New Jersey's diverse counties, using a refined dataset of 821 facilities from 2020 to 2023. By focusing exclusively on structural demand, this analysis intentionally excludes cyclical demand fluctuations *caused by economic cycles, providing a clearer picture of long-term market dynamics. Key variables influencing Net Rentable Square Feet (NRSF) per capita and facilities per capita were identified through regression analysis and subsequently analyzed via Data Envelopment Analysis (DEA) to assess the overall efficiency of the self-storage industry in New Jersey's 21 counties. This study innovatively fills a significant industry gap by utilizing NRSF per capita and facilities per capita as proxies in the DEA, where direct unit data availability is often scarce. Findings indicate a marked reliance on self-storage correlated with urban densification and demographic changes. Efficiency scores revealed varying levels of industry success in meeting these demands, offering urban planners and the self-storage industry valuable data-driven insights for strategic development in the evolving urban landscape.*

Keywords: Self-storage economics, structural demand, demographic trends, land use planning, regression, data envelopment analysis.

INTRODUCTION

In recent years, the self-storage industry has witnessed a remarkable boom in New Jersey, mirroring a broader national trend. This surge is not merely a business phenomenon; it reflects deeper shifts in societal habits, urban development, and economic conditions. New Jersey, with its unique blend of urban, suburban, and rural landscapes, presents a particularly intriguing case for the study of this expansion. The state's diverse demographic and economic profile, coupled with its proximity to major metropolitan areas, has fostered a fertile ground for the growth of self-storage facilities. This trend is not only indicative of changing consumer behaviors and lifestyle needs but also has significant implications for urban planning and real estate development.

The burgeoning of the self-storage market in New Jersey raises compelling questions about the underlying drivers of customer demand. Understanding who uses these facilities, why, and under what circumstances, is crucial for several reasons. Firstly, it offers insights into broader trends in housing and urban development, especially in the context of New Jersey's varied urban settings. The demand for additional storage space is often a byproduct of urban densification, housing affordability issues, and the evolving nature of modern lifestyles, which tend to favor mobility and flexibility over permanence.

Secondly, analyzing customer demand in the self-storage industry is essential for identifying emerging socio-economic patterns. The utilization of these facilities can serve as an indicator of consumer behavior, reflecting aspects such as accumulation tendencies, transitional phases in life like relocation or downsizing, and the impacts of economic fluctuations on households and businesses. In a state as economically diverse as New Jersey, these patterns can provide valuable insights into the health and direction of the broader economy.

Furthermore, understanding the dynamics of self-storage demand is pivotal for stakeholders in both the private and public sectors. For developers and investors, it guides informed decision-making regarding facility locations, sizes, and services. For urban planners and policymakers, it offers cues for integrating storage solutions into residential and commercial planning, thereby contributing to more efficient and sustainable urban landscapes. In essence, the self-storage boom in New Jersey is not just a matter of real estate; it is a window into the evolving needs and behaviors of its residents and businesses. This study aims to delve into the intricacies of this trend, exploring the multifaceted drivers of self-storage demand and their implications for the state's urban fabric and socio-economic landscape.

In summary, the integration of regression techniques, and DEA formed a comprehensive methodological framework. This two-fold approach not only enhanced the granularity of the research but also enriched the interpretative power of the data, paving the way for actionable insights into the alignment of supply and demand within the self-storage industry of New Jersey.

LITERATURE REVIEW

The self-storage industry, marked by its robust growth and evolving dynamics, has emerged as a significant sector in the urban landscape. Wall Street Journal article entitled "Need to Store That? Booming Self-Storage Industry Says No Problem," highlights the burgeoning nature of this industry (Pleven, 2015). The article insights set the stage for understanding the self-storage industry's rapid expansion and its growing relevance in today's urban settings. This growth trajectory provides a compelling backdrop for examining the industry's interaction with urban development, a key focus of our study (Pleven, 2015).

In the self-storage industry, understanding demand dynamics is crucial for strategic planning and market analysis. The industry typically employs two primary frameworks for measuring demand: the 4Ds and the Lifestyle Commercial Transitional (LCT) model. The 4Ds (i.e, death, divorce, dislocation, and downsizing) highlight life events that traditionally drive the need for self-storage, reflecting situations where individuals or businesses must temporarily or permanently relocate or store items (Harris, 2017). On the other hand, the LCT model broadens this scope by incorporating socio-economic factors such as changes in lifestyle, economic transitions, and commercial needs. This model recognizes that alongside personal life changes, broader economic and lifestyle trends also significantly influence storage demand, such as increased mobility, smaller living spaces in urban areas, and fluctuating business needs (Burnam, 2024).

Net Rentable Square Feet (NRSF) per capita has been the traditional metric for evaluating self-storage supply. This metric measures the total rentable square footage available per capita within a given market area, serving as a standard gauge for market saturation and identifying potential undersupply or oversupply conditions (Jozsa, 2022). It assesses how much storage space is available compared to the population size, which can help investors and operators understand the balance between supply and demand in various regions. While NRSF per capita has been a standard measure, its suitability as the optimal metric for evaluating self-storage supply has come under scrutiny. Critics argue that NRSF per capita may not capture the nuanced dynamics of self-storage demand effectively, particularly in diverse urban landscapes where factors such as population density and urban design vary widely. For instance, in densely populated urban areas like Manhattan in New York City, NY, where smaller living spaces are common, the demand for smaller unit sizes increases. This scenario suggests a shift toward measuring units per capita, which could provide a more accurate reflection of actual consumer needs and market conditions. This critique emphasizes the need for more flexible and context-sensitive metrics that consider both the size and number of units in conjunction with demographic and urban characteristics (Burnam, 2024).

The intersection of the self-storage industry with urban planning and zoning is critically examined by Modou Nyang (2019). Nyang's study delves into the complexities of urban land use, particularly in dense metropolitan areas like New York City. The research suggests that despite the high demand for self-storage in urban regions, the allocation of valuable urban land to this industry might not always represent the best use of space, especially when considering the potential for job creation or other more community-oriented developments. This perspective is crucial in understanding the challenges faced in zoning and land use planning in urban settings (Nyang, 2019).

Harun *et al.* (2011) provides a pertinent example of applying DEA in real estate research. Their work demonstrates the utility of DEA in assessing the efficiency of Real Estate Investment Trusts (REITs), highlighting the relevance of choosing appropriate inputs and outputs in the analysis. This approach aligns with our study's use of DEA to evaluate the operational efficiency of self-storage facilities. The parallels drawn here underscore the versatility of DEA in different real estate contexts and reinforce its suitability for analyzing the self-storage industry, particularly in assessing how effectively these facilities operate within the evolving urban landscape (Harun *et al.*, 2011).

This literature review has synthesized key aspects of the self-storage industry, illustrating its rapid growth and evolving role in urban environments. We examined traditional and emerging methods for measuring demand and supply, highlighting the shift from Net Rentable Square Feet (NRSF) per capita to more nuanced metrics like units per capita, which better reflect the specific needs of densely populated areas. The review also touched on the intersection of self-storage with urban planning and zoning challenges, underscoring potential conflicts and optimization opportunities in land use. Furthermore, the use of Data Envelopment Analysis (DEA) and regression analysis within this sector demonstrates the application of robust analytical tools to assess operational efficiency and understand market dynamics. These insights lay a solid foundation for our study, which aims to further elucidate the operational efficiencies of self-storage facilities, contributing to strategic development and planning in the industry.

DATA AND ANALYSIS

In preparation for analysis, the raw data underwent a meticulous transformation process. Initially, data cleaning was performed to eliminate any inconsistencies and correct errors, thus ensuring the accuracy and relevance of the information. Subsequent normalization harmonized the values measured on disparate scales into a standardized common scale, facilitating direct comparisons across various metrics. Finally, disaggregation was applied where necessary to enhance the resolution of the analysis. This step involved breaking down comprehensive data into more specific categories or segments, yielding a granular perspective conducive to the nuances of regression and DEA analysis. The analytical procedures were carried out using RStudio, leveraging specialized packages such as 'Benchmarking' for DEA, 'psych' for psychometric analyses and exploratory statistics, and 'ggplot2' for advanced data visualization.

Data Description

The data for this study is primarily derived from two distinct sources: records from a local real estate developer based in New Jersey and publicly available datasets from the United States Census Bureau (United States Census Bureau, 2023). The storage facility data was graciously provided by a reputable New Jersey-based real estate developer. While the specifics of this dataset are proprietary and confidential, it encompasses comprehensive records of approximately 820 storage facilities across New Jersey. The dataset includes a wealth of information on each facility, including but not limited to the owner, address, city, zip code, county, net rentable square feet (NRSF), and the facility's status, categorized by different development stages and years ranging from 2020 to 2023 and facilities in the development pipeline (see Table 1). It represents a valuable and unique compilation of data, reflecting the current landscape of storage facilities in the region. The records cover a period crucial for understanding current trends and developments in the storage facility industry, especially in the context of post-2020 urban and demographic shifts. The storage facilities have been categorized by the year developed.

Although not directly part of the storage facility dataset, *Demographic Data Integration* is augmented with external demographic data such as population sizes and socio-economic indicators from the US Census Bureau. This integration will enable a multidimensional analysis of how storage facility characteristics correlate with demographic trends. *Owner Information* explains details about the ownership of each facility, which could range from local businesses to national chains, and offers a perspective on the market composition. *Address Details* give specific addresses of each facility, which are essential for precise geospatial mapping and analysis. *Location Information* is the dataset and contains categorical location data like the city and county of each facility, allowing for geospatial analysis and regional comparisons. The storage facility dataset encapsulates a diverse range of urban, suburban, and rural areas, reflecting the varied landscape of New Jersey. It includes facilities spread across 21 counties and multiple cities, providing a comprehensive view that is vital for understanding regional variations and trends within the storage facility sector. *Net Rentable Square Feet (NRSF)* is a key metric providing the size of each facility and offering insights into the scale and capacity of storage spaces across different regions. *Facility Status* includes categories such as

'Planned/Permitted' and 'Under Construction', which are both known as ‘Pipeline Facilities’, as well as specific years (2020, 2021, 2022, 2023), and 'Pre-2020 Supply'. This variable is crucial for understanding the development stages and growth trends of the facilities.

Table 1. Self-Storage Dataset Snapshot

Owner	Address	City	Zip Code	County	NRSF	Status
Storage Post Self Storage	1189 Magnolia Ave, Elizabeth, NJ 07201	Elizabeth	07201	Union	76,308	2020
Public Storage	475 Walnut St, Norwood, NJ 07648	Norwood	07648	Bergen	65,762	2021
Extra Space Storage	224 Ridgedale Ave, Cedar Knolls, NJ 07927	Cedar Knolls	07927	Morris	74,126	2023
Cape May Storage	1024 Shun Pike Rd, Cape May, NJ 08204	Cape May	08204	Cape May	20,000	Planning/ Permitted

Exploratory Data Analysis

Figure 1 visualizes the distribution of storage facilities across different owners in New Jersey. It indicates that a total of 241 operators are present within the dataset, out of which 57 operators have more than one storage facility. A smaller subset of 23 operators has a larger presence, each owning four or more facilities. Figure 1 highlights that Extra Space Storage is the most prevalent owner, with 132 facilities under its name. This is followed by Public

Storage and CubeSmart Self Storage, which own 66 and 59 facilities, respectively. The ownership then tapers down, with the least represented owners in the chart having four facilities each.

This distribution suggests a market with a variety of players, ranging from individuals or entities with single facilities to large, possibly national, chains with a significant number of properties. The presence of a few owners with a high number of facilities could indicate consolidation in the market, with certain companies having a dominant presence. Meanwhile, the majority of owners possess a relatively small number of facilities, pointing towards a fragmented segment of the market with numerous smaller players.

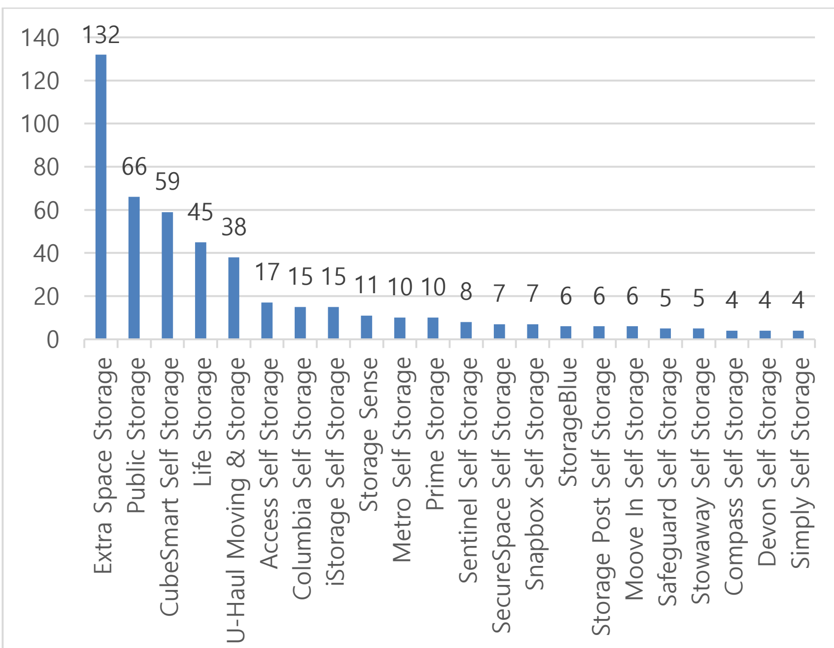

Figure 1. Count of Storage Facilities by Operator.

The sum of NRSF across all facilities is 50,118,398 feet^2, which underscores the total market size in terms of rentable space within the dataset. The top 5 operators collectively hold a 46% share of the market based on NRSF, while all other facilities constitute the remaining 54%. This indicates a concentration of the market in the hands of the top owners. Table 2 suggests that a typical storage facility in this dataset has just over 61,000 feet^2 of rentable space. The median NRSF is 60,879 feet^2, which is very close to the mean, pointing to a relatively symmetric distribution of facility sizes. However, the skewness value of 1.56 indicates a moderate right skew, meaning that there is a longer tail on the right side of the distribution with more facilities having a higher NRSF than the mean.

However, the presence of facilities with varying sizes is indicated by the standard deviation, which is quite substantial at 1,162.19 feet^2. This large standard deviation reflects a wide distribution of facility sizes. The range of the dataset is quite large at 350,231 feet^2, with the smallest facility having an NRSF of 1,591 feet^2 and the largest having an NRSF of 351,822 feet^2. This vast range highlights the significant variability in the size of storage facilities.

Table 2. Descriptive Statistics of NRSF (in feet^2)

Items	Values	Items	Values
Mean	61,045.55	Kurtosis	9.11
Standard Error	1,162.69	Skewness	1.56
Median	60,879.00	Minimum	1,591.00
Mode	25,000.00	Maximum	351,822.00

The combined analysis of the descriptive statistics and the NRSF market share indicates that the self-storage market in New

Jersey is both diverse and concentrated. While there are numerous small to medium-sized players, the market is dominated by a few large entities that control over half of the rentable storage space. This market dynamic could have implications for competition, pricing, and availability of storage options for consumers in New Jersey.

Demographic Data

In addition, demographic data was sourced from the United States Census Bureau. The Census Bureau's datasets provide detailed insights into population trends, housing, income, and other socio-economic factors pertinent to each county and city in New Jersey (United States Census Bureau, 2023). This information is critical for understanding the demographic context in which these storage facilities operate. The integration of this demographic data with the storage facility records allows for a multi-dimensional analysis, offering a nuanced understanding of the interplay between storage facility characteristics and the surrounding demographic landscape.

This includes absolute figures like the total population and median household income, percentages such as those representing ethnic composition, and economic indicators like total annual payroll. The census data includes race, types of housing units, and levels of education attained. The dataset incorporates geographic identifiers that allow for detailed spatial analysis, which is critical for correlating demographic trends with the distribution of storage facilities. Population data for the years 2020 and 2022 provides a temporal dimension, enabling the study to examine changes over time. By tracking such a wide array of attributes across multiple years, the study aims to correlate demographic shifts with the demand for storage facilities, thereby providing insights into how population dynamics influence the storage industry. This dataset serves as the basis for a nuanced analysis that can inform urban planning, real estate development, and economic policy within New Jersey.

The population data presented in Table 3 offers a snapshot of New Jersey and its constituent counties, highlighting the resident population changes from the 2020 Census to the 2022 estimates, along with the population density per square mile. New Jersey, with a land area of 7,354.8 square miles, saw its population decrease marginally from 9,289,031 in the 2020 Census to an estimated 9,261,699 in 2022.

At the county level, Atlantic County, encompassing 555.5 mi^2, exhibited a modest increase in population from 274,536 in 2020 to 275,638 in 2022. Conversely, Bergen County, one of the most densely populated counties with 4,093.8 people per mi^2 in 2022, saw a slight decrease in its resident numbers from 955,746 in 2020 to 952,997 in 2022. Burlington County, with a considerable land area of 799.3 mi^2, maintains a lower population density and recorded a small increase to 466,594 residents in 2022. Camden County, while smaller in land area at 221.4 mi^2, supports a higher density of 2,371.3 people per mi^2, and its population remained relatively stable with a slight increase to 524,907 in 2022. Notably, Essex County stands out with the highest population density among the listed counties, with 6,737.4 people per mi^2 in 2022, despite a slight decrease in population from 862,782 in 2020 to 849,477 in 2022. Hudson County, although the smallest in land area at 46.2 mi^2, has a dense urban population with a considerable increase to 703,531 residents in 2022. The demographic trends across these counties reflect varied patterns of urbanization and population distribution. Counties like Cape May and Cumberland show lower density living with 380.2 and 313.1 people per mi^2 respectively in 2022, which could correlate with different lifestyle patterns and hence varying demands for storage facilities.

Table 3. Population Data by County (American Community Survey of 2022)

Census	*Land*	*Resident Population*		*Population per mi²*	
County	*Area in miles²*	Census Y2020	Estimates Y2022	Census Y2020	Estimates Y2022
Atlantic County	555.5	274,536	275,638	494.2	496.2
Bergen County	232.8	955,746	952,997	4,105.6	4,093.8
Burlington County	799.3	461,863	466,103	577.8	583.1
Camden County	221.4	523,486	524,907	2,364.9	2,371.3
Cape May County	251.5	95,266	95,634	378.8	380.2
Cumberland County	483.4	154,148	151,356	318.9	313.1
Essex County	126.1	862,782	849,477	6,842.9	6,737.4
Gloucester County	322.0	302,285	306,601	938.8	952.2
Hudson County	46.2	724,857	703,366	15,691.7	15,226.5
Hunterdon County	427.8	128,962	129,777	301.4	303.3
Mercer County	224.4	387,340	380,688	1,725.8	1,696.2
Middlesex County	309.2	863,183	861,418	2,791.5	2,785.8
Monmouth County	468.2	643,608	644,098	1,374.7	1,375.7
Morris County	461.0	509,277	511,151	1,104.8	1,108.9
Ocean County	628.3	637,229	655,735	1,014.2	1,043.7
Passaic County	186.0	525,052	513,936	2,822.7	2,762.9
Salem County	331.9	64,834	65,117	195.4	196.2
Somerset County	301.9	345,356	346,875	1,144.1	1,149.1
Sussex County	518.7	144,231	146,084	278.1	281.7
Union County	102.8	575,352	569,815	5,598.6	5,544.8
Warren County	356.5	109,638	110,926	307.5	311.1
Total: New Jersey	7,354.8	9,289,031	9,261,699	1,263.0	1,259.3

Overall, the population data at the county level in New Jersey suggests nuanced demographic shifts, with some areas experiencing growth and others seeing slight declines. This demographic ebb and flow are crucial for understanding the demand dynamics in the self-storage market as it may indicate where the need for storage facilities is increasing or decreasing, aligning with the overarching goal of this research to analyze the intersection of demographic changes and the storage facility industry.

Integration of Storage and Census

The integration of demographic and storage facility data is a pivotal component of this study, providing a visual correlation between population density and storage facility distribution across New Jersey. Heat maps serve as an instrumental tool in this integration, offering a color-coded representation of both existing and potential storage spaces relative to population metrics.

To facilitate a comprehensive analysis, the Net Rentable Square Feet (NRSF) data has been categorized into two main segments: 'Existing NRSF', which includes facilities available prior to 2020 and those developed between 2020 and 2023, and 'Pipeline NRSF', comprising facilities that are currently in the stages of planning, permitted, or under construction. This distinction allows for a nuanced examination of the storage facility market, delineating between the current supply and anticipated growth.

The study employs population density as a key demographic indicator, juxtaposed with NRSF per capita, to assess the spatial distribution of storage resources in relation to the population. Heat maps illuminate areas with dense populations that may necessitate more storage space, as well as regions where the storage facility market may be oversaturated or underserved. The purpose of these heat maps is to visually articulate the balance—

or imbalance—between the availability of storage space and the population's potential need for it. By doing so, the heat maps underscore regions of interest that warrant further investigation and provide a preliminary understanding of market dynamics.

In the following section, we present a series of heat maps that illustrate the density of the population against the backdrop of existing and pipeline NRSF. These visuals are designed to provide a clear and immediate perception of geographic patterns, guiding the reader through a spatial analysis that highlights concentrations of storage facilities and identifies potential areas of growth or saturation. The integration of data through these heat maps directly aligns with the study's overarching goal: to explore the impact of urbanization and demographic transitions on the demand for self-storage. By correlating storage facility data with population density, we gain insights into how urban development patterns and demographic characteristics drive the need for additional storage space—insights that are vital for informed urban planning and real estate development decisions.

Figure 2(a) illustrates the population density across New Jersey, measured as the number of residents per square mile. Shades intensify from rural to urban centers, highlighting regions where population concentrations are highest. This visualization underscores areas that may exhibit a greater demand for storage facilities, aligning population clusters with the potential need for space optimization solutions.

To dissect the availability of storage space relative to the population, Figure 2(b) depicts the total Net Rentable Square Feet (NRSF) per capita. This map reveals the balance between storage supply and the population, with warmer colors indicating a higher amount of storage space available per person. Such insights are pivotal for identifying markets that may be underserved or oversupplied.

Lastly, Figure 2(c) portrays the total number of storage facilities, irrespective of their size or capacity. This visualization shows the spatial distribution of facilities across the state, with the concentration of points indicating areas of high facility density. It offers a direct visual cue to the spread of storage options available to consumers and serves as a marker for market saturation and competition levels.

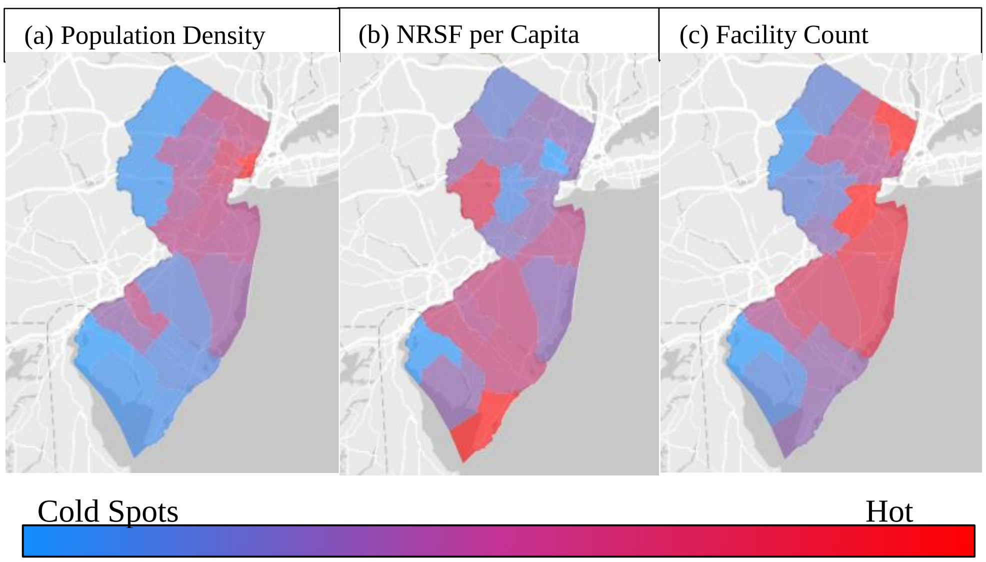

Figure 2. Heat maps of Population Densisty (a), NRSF per Capita (b), and Facility Count (c)

As New Jersey forges ahead amid the currents of urbanization and demographic shifts, our granular examination of population density coupled with storage facility data yields profound insights. From 2020 to 2022, the state observed a modest dip in overall population density from 1,263.0 to 1,259.3 persons per square mile, suggesting relative stability. Yet, beneath this veneer of steadiness, the local tapestries of New Jersey's counties tell a more intricate story.

Statewide, the self-storage market reveals a steady march towards equilibrium, evidenced by a median NRSF per capita of 5.3 and a mean of 5.7. This equilibrium, however, is not uniformly distributed. Cape May County's figure of 11.0 per capita—towering over the state's median—raises questions about potential oversupply, while Essex County's lower figure of 3.5 per capita signals a burgeoning market with headroom for growth.

The total number of facilities adds a complementary perspective, elucidating market structure. Middlesex County's saturation point, with 72 facilities, contrasts starkly with the modest number in Sussex County, indicating a highly competitive environment that may challenge new market entrants. The synthesis of these metrics underscores the critical need for strategic planning within the self-storage industry. Location intelligence, informed by an understanding of demographic movements and economic trends, becomes paramount for decision-making. The challenge for urban areas will be to optimize space utilization, while suburban and rural regions may explore diversification of storage services.

The visual analysis affirms that New Jersey's self-storage market is as complex and varied as its demographic fabric. Navigating this landscape demands a multifaceted approach—one that appreciates the subtleties of regional demand, anticipates future demographic shifts, and embraces economic forecasting. As we continue to unravel the socio-economic dynamics shaping the self-storage industry, it is clear that an informed, data-driven strategy is vital for the sector's sustainable development and for meeting the evolving needs of New Jersey's communities.

METHODOLOGY

This study's main objective is to dissect and understand the dynamics influencing the self-storage industry in New Jersey, with a focus on identifying the key components of structural demand. This entails a comprehensive analysis of how demographic and economic factors in New Jersey's diverse counties correlate with the availability and growth of self-storage space on a per capita basis. To achieve this objective, the study employs two main methodological approaches: regression analysis and Data Envelopment Analysis (DEA).

Regression Analysis

Identifying critical factors is the most important step in improving performance (Gaukler et al., 2023; Billal et al., 2019). The study assessed the relationship between various demographic and economic variables and supply variables NRSF per capita and Facilities per capita using regression analysis for an in-depth exploration of how specific factors are statistically associated with the availability of self-storage space. A total of 28 independent variables were initially considered, encompassing a wide range of demographic, economic, and urban development factors. These variables were selected based on their potential relevance to self-storage demand, as suggested by existing literature and market hypotheses. Several multivariate regression models were tested, incorporating different combinations of the initial 28 variables. This iterative process was guided by statistical significance, model fit, and the elimination of multicollinearity, ensuring robust and reliable results.

While the regression analysis was instrumental in quantifying the relationship between specific variables and NRSF per capita and facilities per capita, the DEA will delve into a more operational perspective. The DEA serves as a natural progression from the regression analysis, moving from identifying key determinants to evaluating the operational efficiency of the self-storage industry in New Jersey's diverse markets.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is utilized as a tool to evaluate the efficiency of the self-storage industry across different markets within New Jersey. This technique is particularly suited for assessing the relative efficiency of multiple decision-making units (in this case, counties) in converting inputs (demographic and economic factors) into several outputs (NRSF per capita and facilities per capita). DEA provides a framework for benchmarking the counties against each other and identifying the best practices in the industry. In this context, the DEA can be seen as a measure of the interplay between supply (NRSF and Facilities) and demand (as indicated by demographic factors), evaluating how efficiently different counties balance these elements (Ragsdale, 2017).

The rationale for employing DEA at this stage is twofold: comparative efficiency and strategic implaciton. DEA allows for a comparative analysis of the efficiency of various counties, offering a macro-level view of the industry's performance in different demographic contexts. The results from the DEA are expected to provide strategic insights for the self-storage industry, highlighting efficient market servicing and potential areas for growth or realignment, especially in counties where demographic factors suggest unmet demand or over-servicing.

In transitioning to DEA, the study builds on the understanding gained from the regression analysis, using it to inform a broader evaluation of market efficiency within the self-storage sector in New Jersey. This multi-faceted approach ensures a comprehensive analysis of the industry, from understanding key market drivers to assessing operational effectiveness across the state.

Data Envelopment Analysis (DEA), introduced by Charnes, Cooper, and Rhodes (CCR), is a mathematical programming technique used to evaluate the relative efficiency of Decision-Making Units (DMUs). Each DMU consumes certain amounts of inputs to produce certain amounts of outputs, and efficiency is evaluated by comparing the ratio of weighted outputs to weighted inputs across DMUs (Panwar, Olfati, Pant, & Snasel, 2022). The mathematical representation of a basic CCR, output-oriented DEA model for a single DMU (DMU_i) is as follows:

The efficiency of i-th DMU E_i is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs, which can be written as (1):

$$E_i = \frac{\sum_{j=1}^{n_O} O_{ij} w_j}{\sum_{j=1}^{n_I} I_{ij} v_j} \quad (1)$$

Here, O_{ij} is the amount of output j produced by DMU_i, w_j is the weight for output j, and n_O is the number of output variables (i.e., $n_O=2$). I_{ij} is the amount of input j consumed by DMU_i, v_j is the weight for input j and n_I is the number of output variables (i.e., $n_I=3$).

The weights are determined to maximize the efficiency of DMU_i, which leads to the following objective function (2):

$$MAX: \sum_{j=1}^{n_O} O_{ij} w_j \quad (2)$$

This objective function aims to maximize the weighted sum of outputs for DMU_i. There are, however, three constraints that must be considered in this linear programming problem. The first constraint ensures that no DMU can have an efficiency score greater than 1, which is written as (3):

$$\sum_{j=1}^{n_O} O_{kj} w_j \leq \sum_{j=1}^{n_I} I_{kj} v_j \text{ , } \forall \ DMU \ k = \{1,2 \dots, K\} \qquad (3)$$

This means that the weighted sum of outputs for any DMU (DMU_k) cannot exceed its weighted sum of inputs. The second constraint ensures that the weighted sum of inputs for DMU_i is equal to 1, which can be written as (4):

$$\sum_{j=1}^{n_1} I_{ij} v_j = 1 \qquad (4)$$

This constraint is crucial for making the efficiency scores of different DMUs comparable to each other. The final constraint ensures that all weights are non-negative (5):

$$w_j, v_j \geq 0, \forall \ j = \{1,2, \dots, J\} \qquad (5)$$

This is a standard constraint in DEA models, ensuring that neither inputs nor outputs are given negative importance in the efficiency calculations. These equations collectively represent a fractional linear programming problem, and they form the basis of the CCR DEA model for measuring the relative efficiency of DMUs (Ragsdale, 2017).

In our study, we utilize Net Rentable Square Feet (NRSF) per Capita and Facilities per Capita as primary metrics to assess self-storage supply, providing a detailed view of market penetration in relation to population density. NRSF per Capita offers insights into the amount of storage space available per individual, which is crucial for analyzing how different communities across New Jersey—ranging from dense urban to sprawling suburban areas—are served. Facilities per Capita, used in lieu of Units per Capita due to data limitations, serves as a broader gauge of how many storage facilities are accessible per capita, helping to understand market saturation and the accessibility of these facilities. This metric is particularly informative in urban areas, where denser populations typically correlate with a higher demand for smaller storage units. By integrating these metrics, our approach provides a comprehensive analysis of how demographic factors and urban density impact self-storage utilization, highlighting the unique needs and behaviors of communities within varied urban environments.

In summary, the methodology is designed to provide a holistic and detailed understanding of the factors driving the self-storage market in New Jersey, offering valuable insights for industry stakeholders, urban planners, and policymakers.

Results and Implications

In our endeavor to measure the overall efficiency of the self-storage industry in New Jersey, we carefully considered the demographic and economic characteristics of each county. The choice of these variables was informed significantly by the findings from our preceding regression analysis. This analysis identified specific variables that demonstrated a strong correlation with the Net Rentable Square Feet (NRSF) per capita and Facilities per capita, indicating their potential impact on the self-storage market's dynamics. Consequently, these variables were selected as inputs in our DEA to provide a robust and empirically grounded framework for assessing operational efficiency across the counties (Harun *et al.*, 2011). Xs are the inputs, while Ys are the outputs.

Households (X1): This metric offers a direct baseline for demand, as it directly correlates with the number of potential users of self-storage facilities. The more households in a county, the higher the potential demand for self-storage. This variable is fundamental in assessing the scale of residential demand within a specific geographical area.

Total Employer Establishments per Capita (X2): This measures the density of businesses within a county, serving as a proxy for commercial demand for self-storage. Businesses often require storage for documents, equipment, or excess inventory. A higher number of establishments per capita suggests a stronger potential demand from the commercial sector, which can be particularly relevant in areas with a high concentration of small businesses or seasonal industries.

Persons per Household (X3): This variable reflects the household composition and is crucial for understanding residential storage needs. Areas with larger average household sizes might indicate a greater need for storage space due to limited living quarters, particularly in urban settings where homes are smaller. Conversely, regions with smaller household sizes might indicate different types of storage needs, possibly less volume but more frequency in usage.

Total Retail Sales per Capita (X4): This metric not only suggests the level of consumer spending and economic activity within a county but also helps identify areas with high consumer foot traffic. Higher retail sales per capita typically correlate with increased economic activity and consumerism, leading to greater accumulation of goods and a higher demand for storage solutions.

Additionally, areas with robust retail activity are often destinations consumers visit frequently, making them ideal locations for self-storage facilities. Placing storage facilities near major shopping areas, such as grocery stores or retail centers, can increase convenience for consumers, integrating self-storage into their regular travel routes and shopping habits. This strategic placement enhances the visibility and accessibility of self-storage facilities, potentially increasing utilization rates.

NRSF per Capita (Y1): This metric quantifies the total net rentable square feet of storage space available per capita in a given area. It provides a vital indicator of the capacity of storage space relative to the population, serving as a direct measure of how well the supply meets the demand in terms of volume. By evaluating NRSF per Capita, stakeholders can assess whether there is sufficient storage space to accommodate the needs of the local population, or if there are potential opportunities for market growth or need for adjustment in storage offerings.

Facilities per Capita (Y2): This measure indicates the number of self-storage facilities relative to the population size, providing insights into the density and distribution of storage options across different regions. It helps gauge market saturation and accessibility, informing whether a particular area is oversupplied or underserved. A higher number of facilities per capita might suggest a competitive market with abundant access for consumers, while a lower number could indicate a market with room for new entrants or expansion of existing facilities.

The descriptive statistics for the dataset reveal a wide range of values for the population (X1) with a substantial average of about 441,033, indicating varied potential customer bases for self-storage facilities across counties. Median gross rent (X2) and travel time to work (X3) show less variability and are slightly skewed, suggesting that most counties have values below the average for these variables. The percentage of foreign-born persons (X4) is moderately skewed to the right, with a few counties having a high percentage. The net rentable square feet per capita (Y1) as the output measure has a positive skewness and a notable difference between the mean and median, indicating a few counties with particularly high or low self-storage space per person. Overall, the data shows significant diversity in the factors influencing self-storage needs and supply.

Table 5: Variable Mix Descriptive Statistics

Items	X1	X2	X3	X4	Y1	Y2
Mean	163,722	0.02472	2.60	16,557	5.74	0.00010
Median	174,454	0.02257	2.62	16,535	5.29	0.00009
SD	100,427	0.00541	0.15	3,621	1.69	0.00005
Range	326,099	0.02186	0.73	12,150	7.47	0.00027
Min	24,744	0.01749	2.16	9,134	3.49	0.00004
Max	350,843	0.03935	2.89	21,284	10.96	0.00324

The selection of input and output variables is essential for the validity and relevance of a Data Envelopment Analysis (DEA) study. This combination of demographic and economic inputs, along with our industry-specific output, allows us to analyze the efficiency with which the self-storage industry in New Jersey utilizes these factors in providing its services. The selected variables align with our goal of measuring the efficiency of the self-storage industry in meeting demand in relation to the unique characteristics of each New Jersey county. In the following stage, we apply these factors in a DEA model to evaluate and compare the efficiency across counties.

The analysis resulted in a range of efficiency scores for the 21 DMUs, or New Jersey counties. The efficiency scores reflect the effectiveness of each county in utilizing its demographic and economic factors to meet the self-storage demand, as quantified by the NRSF per capita.

Table 4. Data Envelopment Analysis Data

Counties	X1	X2	X3	X4	Y1	Y2
Atlantic	106640	0.022294	2.52	17447	7.029756	0.00012
Bergen	350843	0.033079	2.69	21284	5.197223	0.00008
Burlington	174454	0.022394	2.59	18428	6.940106	0.00012
Camden	198757	0.021831	2.6	13447	6.111671	0.00010
Cape May	43277	0.039358	2.16	20749	10.96724	0.00032
Cumberland	52584	0.018314	2.72	13305	5.316334	0.00011
Essex	312942	0.022577	2.66	11378	3.496943	0.00005
Gloucester	109996	0.020297	2.7	16535	7.077837	0.00013
Hudson	290054	0.019745	2.43	11837	5.290638	0.00006
Hunterdon	49676	0.028541	2.54	19818	8.546145	0.00015
Mercer	139549	0.025496	2.62	20554	5.025693	0.00008
Middlesex	301967	0.02542	2.76	17964	5.316558	0.00008
Monmouth	248117	0.030005	2.57	19730	6.17901	0.00010
Morris	189607	0.031885	2.64	21120	5.128091	0.00008
Ocean	239466	0.021725	2.64	14642	5.234023	0.00009
Passaic	177209	0.023349	2.89	16032	5.27309	0.00009
Salem	24744	0.017492	2.56	9134	3.57303	0.00012
Somerset	127566	0.028042	2.67	20417	4.15157	0.00007
Sussex	56348	0.021447	2.54	12974	4.50714	0.00014
Union	199996	0.024562	2.83	15624	4.923344	0.00007
Warren	44370	0.021293	2.43	15281	5.297216	0.00010

In the context of the DEA analysis applied to the self-storage industry in New Jersey, interpreting the efficiency scores requires an understanding of different aspects of efficiency: technical, scale, and overall efficiency. Technical efficiency, as reflected by the BCC (Banker, Charnes, and Cooper) model, measures how well a Decision-Making Unit (DMU), in this case, counties, converts inputs (X variables) into outputs (Y variables) under variable returns to scale. This accounts for the fact that output does not necessarily increase proportionally with inputs due to varying operational scales and efficiencies among counties.

Table 6. DEA Efficiency Scores

County	BCC	CCR
Somerset	2.085516	2.126423
Bergen	1.863675	1.924419
Morris	1.841294	1.888202
Mercer	1.619419	1.631423
Middlesex	1.527896	1.541486
Union	1.476582	1.522611
Monmouth	1.466043	1.487086
Essex	1.430272	1.719798
Passaic	1.378631	1.405932
Ocean	1.253527	1.305108
Sussex	1.147298	1.290157
Burlington	1.054612	1.074977
Atlantic	1	1.049061
Camden	1	1.072624
Cape May	1	1
Cumberland	1	1.071021
Gloucester	1	1
Hudson	1	1.105719
Hunterdon	1	1
Salem	1	1.161496
Warren	1	1.218906

Scale efficiency, which could be gleaned from comparing the BCC scores to those of the CCR (Charnes, Cooper, and Rhodes) model would indicate whether a county is operating at an optimal scale. The CCR model assumes constant returns to scale, essentially showing how far a county could enhance its performance by optimizing its scale of operation alone. Overall efficiency combines these aspects, indicating not just how well inputs are used, but also whether they are being used at the most productive scale. For our application, the inputs include factors like Households, Total Employer Establishments per Capita, Persons per Household, and Total Retail Sales per Capita, and outputs are NRSF per Capita and Facilities per Capita, these scores provide insight into how effectively counties are using their demographic and economic characteristics to meet the self-storage demands of their populations.

In practical terms, a higher BCC score (above 1.0) suggests a county has potential to improve its use of inputs to generate outputs more efficiently, indicating underutilization or inefficiency in how resources are currently employed. A BCC score of 1.0 indicates that a county is technically efficient, effectively using its given inputs to produce outputs, but doesn't necessarily mean it is operating at the best possible scale. Comparing BCC and CCR scores could reveal discrepancies between technical and scale efficiencies, suggesting that even technically efficient counties might improve by adjusting the scale of their operations. By understanding these dynamics, stakeholders can better target interventions to optimize the balance between supply and demand across New Jersey's diverse counties, considering local demographic and economic conditions that drive self-storage needs.

In the analysis depicted in Table 6, the technical efficiency scores derived from the BCC output-oriented model ranged from 1.0 to 2.09, while the CCR overall efficiency scores ranged from 1.0 to 2.12 showcasing a wide dispersion of efficiency across the counties of New Jersey. This variation is indicative of the differing capacity of counties to meet the self-storage demand relative to their demographic and economic conditions. Nine DMUs were considered efficient while the remaining 12 DMUs that received a score above 1 show considerable room for improvement. The mean efficiency scores, 1.26 and 1.28, for BCC and CCR, respectively, suggest that there are considerable opportunities for many counties to enhance their practices to better serve the self-storage needs of their communities.

Drilling Down on Bergen County.

In the pursuit of enhancing operational efficiency for self-storage facilities in Bergen County, this analysis utilizes Data Envelopment Analysis (DEA) to identify and interpret slack values, subsequently deriving target operational metrics (Table 7). DEA slacks indicate potential improvements in resource utilization and service output levels. Specifically, positive output slacks suggest an opportunity to enhance outputs with the existing level of inputs, thus indicating underutilization of resources. Conversely, positive input slacks signal possible reductions in input use without affecting output levels, pointing to overutilization.

Table 7. Efficiency scores and slacks of Bergen County

Bergen County Data					
X1	X2	X3	X4	Y1	Y2
350843	0.033079	2.69	21284	5.197223	0.0000766
Bergen County Slacks					
X1	X2	X3	X4	Y1	Y2
324326	0.031	2.49	19675.34	2.5	0.0000368

The primary data comprises the current operational metrics from Bergen County, juxtaposed against identified slack values to highlight potential for improvement. The current operational metrics are as follows: Facilities per Capita at 0.0000766 and NRSF per Capita at 5.20. The slacks identified are Facilities per Capita at 0.0000368 and NRSF per Capita at 2.5.

To establish target metrics, the analysis adjusts current operational values based on the slack values. The target Facilities per Capita is determined by enhancing the current rate by the difference between the current and the slack values, calculated as $7.66 \times 10^{-5} + (7.66 \times 10^{-5} - 3.68 \times 10^{-5}) = 0.0001164.$ Conversely, the approach to NRSF per Capita initially adopted a reduction strategy, adjusting the current NRSF to meet the slack value. However, based on a reassessment and specific operational goals, the target NRSF per Capita is recalculated to include an addition of 2.7 to the existing NRSF, resulting in a new target of 7.897223.

To operationalize the targets derived from the DEA analysis, specific development plans must be implemented in Bergen County to align with the newly established efficiency benchmarks. The calculations indicate that approximately 38 additional self-storage facilities are required to meet the target Facilities per Capita of 0.0001164. Additionally, to achieve the revised target NRSF per Capita of 7.897223, there is a need to develop approximately 2,574,912 additional NRSF. This development will significantly enhance the operational capacity and efficiency of self-storage services in the county, ensuring that facility distribution and storage space availability are optimized to meet current and anticipated demands effectively. This strategic expansion is essential for maintaining competitive parity with the efficiency frontiers identified through the DEA model, thereby fostering improved service delivery and customer satisfaction in the self-storage industry.

In reconciling the efficiency score with the output slack, we recognize that these measures offer different perspectives: the efficiency score reflects a long-term, aspirational goal, while the slack indicates a more tangible, short-term objective. As such, our recommendations are two-fold.

Short-Term Goal (Slack-Based): Initiate efforts to develop approximately 2,574,912 additional net rentable square feet (NRSF) and add 38 new facilities. This pragmatic approach serves as an attainable benchmark for Bergen County to elevate its operational efficiency within the current industry landscape, directly addressing the immediate inefficiencies identified through the DEA slack analysis.

Long-Term Goal (Efficiency Score-Based): Develop a comprehensive strategy to substantially enhance the county's output level, aiming for the ambitious target suggested by the efficiency score. This strategy would likely entail a thorough reassessment and restructuring of operational practices, resource management, and possibly, market engagement tactics (Ragsdale, 2017).

Strategic initiatives must be underpinned by a contextual understanding of Bergen County's market conditions, resource capabilities, and demographic demand. An ongoing commitment to continuous improvement is imperative, ensuring that incremental advancements are consistently steered towards the overarching aim of achieving and maintaining an optimal efficiency level.

CONCLUSION

This research has rigorously explored the intricacies of supply and demand dynamics within the self-storage industry across New Jersey, utilizing Data Envelopment Analysis (DEA) as a novel methodological approach for self-storage performance evalution. Amid the challenges of inconsistent metric consensus and data scarcity, this study has not only highlighted the prevalent issues but also significantly advanced the discourse by successfully applying DEA. This approach has proven effective in addressing the multifaceted nature of supply metrics, especially in the absence of large-scale, detailed data. Our findings reveal substantial disparities in the efficiency of converting structural demand into supply across New Jersey's 21 counties. This emphasizes the unique economic and demographic contours shaping market conditions in each county, underscoring the need for region-specific strategies in the self-storage industry.

The application of DEA has allowed us to benchmark counties against each other, identifying both leaders and laggards in efficiency. This, in turn, provides a roadmap for underperforming counties to emulate more successful strategies, thereby optimizing their market operations. Furthermore, the focus on structural demand has imbued our analysis with a robustness that is often lacking in industry assessments that fail to differentiate between structural and cyclical demand factors. By isolating structural elements, our research offers a clearer, more actionable understanding of underlying market forces, which is crucial for long-term planning and investment decisions.

This research has highlighted key determinants of NRSF per capita and facilities per capita and assessed technical and scale efficiencies of the self-storage industry across various counties in New Jersey. However, the scope of our insights was somewhat limited by the unavailability of detailed financial performance metrics and comprehensive capacity utilization rates. With access to extensive financial data, a more nuanced analysis could be conducted on the profitability of self-storage facilities. This would not only allow for a deeper exploration of revenue generation and cost management factors but also enable a comparative financial performance assessment across different regions and facility types. Such analysis would provide stakeholders with clearer insights into economic sustainability and viability across the market. Similarly, detailed information on capacity utilization would offer a finer understanding of usage patterns, potentially revealing demand fluctuations and peak usage times. This data could significantly enhance pricing strategies and investment decisions, as well as improve demand forecasting. Furthermore, a complete dataset would allow for an advanced application of productivity measurement models such as Data Envelopment Analysis (DEA), which could refine assessments of operational efficiency and highlight best practices for enhancing facility performance. Overall, the lack of specific data has restricted our ability to fully explore the financial and operational complexities of the self-storage industry. Addressing these data limitations in future research could greatly enrich the study, providing more robust and actionable insights that would help stakeholders optimize performance and strategic planning effectively.

The findings of this study open several avenues for future research, which could further elucidate the dynamics of the self-storage market. Future studies could benefit from conducting a longitudinal analysis that categorizes self-storage facilities by their development phases—existing, recently developed, and under construction. This approach would allow researchers to capture temporal changes in market strategy and customer demand more effectively. Additionally, incorporating a more detailed demographic and economic analysis at the county level could reveal how variables such as income levels, population growth, and housing market conditions influence self-storage demand. A focused examination of the effects of zoning laws on the location and expansion of self-storage facilities could also provide deeper insights into how regulatory environments shape market opportunities and constraints. Employing advanced geospatial analytics, possibly through Geographic Information Systems (GIS), could further refine our understanding of the strategic placement of facilities and their performance, assessing factors like proximity to urban centers, residential areas, and major transportation routes.

In conclusion, this research contributes significantly to the field of urban planning and real estate development by highlighting the complex interplay between market forces, demographic trends, and regulatory frameworks in the self-storage industry. By providing a robust, data-driven analysis of market equilibria, the study not only aids stakeholders in making informed decisions but also sets a foundational platform for future research. These future endeavors can leverage the insights gained to foster smarter, more sustainable growth within the self-storage sector, ensuring that market strategies align effectively with consumer needs and urban development policies. This groundwork is essential for developing targeted solutions that meet both market demands and community expectations, promoting a balanced approach to real estate development in diverse urban landscapes.

REFERENCES

Aiello, M. (2016). Self-storage cities: A new typology of (sub) urban enclave. Proceedings of Cross-Americas: Probing Disglobal Networks of 2016 ACSA International Conference: Santiago, Chile, 105-111.

Beatley, T. (2012). Green urbanism: Learning from European cities. Island Press: Wadhington D.C., USA.

Billal, M. D., Shin, H. K., Sim, W. J. (2019). Critical success factors (CSF) on e-Commerce adoption in Bangladesh SMEs. Management Review: An International Journal, 14(1), 51-81.

Brembeck, H. (2019). Metamorphoses, or how self-storage turned from homes into hotels. In Overwhelmed by Overflows? Chapter 2, 44-59. Lund University Press: Lund, Sweden.

Burnam, A. (2024, August 8-9). Storage mart [Conference presentation]. NYSSA Fall Conference Market Update, White Plains. https://nyselfstorage.org/images/2024_Fall_Conference/Market_Update_Alex_Burnam.pdf

Chen, Q., & Li, F. (2017). Empirical analysis on efficiency of listed real estate companies in China by DEA. iBusiness, 9(3), 49-59.

Garde, A. (2020). New urbanism: Past, uresent, and future. Urban Planning, 5(3), 453-461.

Gaukler, G., Kwon, I. W., Lee, C. W. (2023). Identifying critical success factors in supply chain performance, Management Review: An International Journal, 18(2): 76-93.

Harris, A. (2017). The four D's. self storage association (SSA). Accessed on December 15, 2024

Harun, S. L., Tahir, H. M., & Zaharudin, Z. A. (2011). Measuring efficiency of real estate investment trust using data envelopment analysis approach. Real Estate Research Institute. Accessed on November 7, 2024.

Helm, M. (2021). Is Sq. Ft. Per capita still the best measurement for self storage supply/demand analysis? Creating wealth through self storage. Accessed October 15, 2024.

Jozsa, E. (2022). Top 5 Emerging self storage markets. Multi-Housing News. Accessed on November 11, 2024.

Mitchell, J. (2023). Why the self storage industry has outperformed other real estate investments. DXD Capital. Accessed on March 3, 2024.

Nyang, M. (2019). The price of regulating the self-storage industry in New York city. CUNY Academic Works. Craig Newmark Graduate School of Journalism: NYC, USA.

Ozili, P. K. (2023). The acceptable R-square in empirical modeling for social science research. Social Research Methodology and Publishing Results, IGI Global.

Panwar, A., Olfati, M., Pant, M., & Snasel, V. (2022). A review on the 40 years of existence of data envelopment analysis models: Historic development and current trends. Archives of Computation Methods in Engineering, 29, 5397-5426.

Pleven, L. (2015). Need to store that? Blooming self-storage industry says no problem. The Wall Street Journal: Real Estate. Accessed on March 4, 2024.

Ragsdale, C. (2017). Spreadsheet modeling & decision analysis: A practical introduction to business analytics 8th edition. Cengage Learning: Boston, MA.

United States Census Bureau. (2023). New Jersey demographic data. Accessed on December 11, 2023.