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The following report describes an economic model that could provide significant support for the Postal Service's initiative to optimize its retail network. The model was developed by a well-known economist who specializes in the placement of facilities to offer universal access. The report discusses at some length the model, its considerable strengths, and its limitations.

The model takes a powerful first look at the network, illuminating geographic areas where the retail services provided by the Postal Service overwhelm the demand for such services by the American public. The model is scalable from small regions to a national profile, and decision makers are directed to areas that require optimization efforts and those that appear to be optimized or even underserved.

The model also provides a top-down analytical tool for senior leadership. This complements the bottom-up evaluative process already in place to create a comprehensive planning process. The same analytical capability also allows stakeholders and oversight authorities the ability to evaluate the decisions being made about the retail network in a transparent environment. A modernization program using the model could help align retail services to a changing society and provide opportunities to improve access, service, and convenience. For example, a network of fewer, larger facilities would make offering extended hours easier.

The principal limits of the model are the reliability of the data used and the lack of comprehensive data, especially certain types of labor data, for individual retail units. While Postal Service data becomes stronger and more useful, the model results regarding the amount of labor spent on retail activities require validation at the local area. Local knowledge is also needed to provide information about the unique characteristics of the area and its retail facilities.

Secondly, many Post Offices, stations, and branches provide retail operations as well as carrier operations. The front office, containing the lobby and retail windows, is supported by the back office staff, who also support carrier operations. The division of duties is not well chronicled at individual facilities, and the data deficiency provides difficult challenges for the model. The model attempts to quantify operational duties caused by front office activities, but until the facility-level data specifically separates out those efforts, local analysis or cautious progress toward optimization efforts seems most prudent. Many other retail facilities do not have carriers operating out of them. The data there is obviously cleaner.

In summary, the model serves as a powerful guide and first-level screening device, directing planners to areas where retail capacity is misaligned with customer demand. At a corporate level, the model suggests that the Postal Service optimization effort will be substantial. The model directs planners to focus at a first look on the $5.5 billion portion of the Postal Service's annual retail investment where the Postal Service's retail capacity appears to exceed demand by the public. It can then guide planners through the first stage of a more detailed examination and validation process. This study varies from a normal audit report in that it provides an instrument to be used by planners, rather than identifying a specific savings opportunity that should be achieved. The large universe identified in the report serves more as a map for exploration than a cost reduction target.

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UNITED STATES POSTAL SERVICE

Analyzing the Postal Service's Retail Network Using an Objective Modeling Approach

June 14, 2010

Prepared by **U.S. Postal Service Office of Inspector General**
Risk Analysis Research Center
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Analyzing the Postal Service's Retail Network Using an Objective Modeling Approach

Executive Summary

There is an emerging consensus in the postal community on the need to review the U.S. Postal Service's retail network. The recent Government Accountability Office report, Congressional hearings, and the Postal Service's 2020 plan all discuss optimizing the Postal Service's retail network as one possible strategy to reduce costs in the face of declining revenues.[1] The debate is shifting from whether the Postal Service needs to adjust its network to how it should adjust the network. What is missing is a thorough, transparent, and objective approach to guide the Postal Service's efforts for the next stage of optimization. A model is needed both to guide decision makers and allow stakeholders to review the decision process.

The Postal Service's current retail facility planning appears to be a "bottom-up" process, based upon the district offices' local management recommendations. By contrast, an approach using economic modeling adds a "top-down" dimension to the planning process, by offering consistent economic criteria for locating and sizing retail facilities. The approaches complement each other. Economic modeling can inform the decisions made by local planners, and local knowledge is critical to validating and implementing the model results. An approach combining top-down economic modeling with adequate bottom-up local review is well suited to support the consolidation of existing facilities and any opening of new locations.

The U.S. Postal Service Office of Inspector General sponsored research by George Washington University Professor of Economics Anthony Yezer to develop an economic model that could inform the debate. Dr. Yezer is a nationally recognized expert in real estate location and applied economic analysis. In this effort, he attempted to determine what the Postal Service's retail network would look like if it were to be optimized based on research on optimal public facility location and the best practices used by private industry. Dr. Yezer built an economic model to estimate the optimal number, size, spacing, and staffing of Postal Service retail facilities within any specific area. The model demonstrates how to locate and size facilities to maximize the benefit to the public by matching the demand for retail services to the cost of providing them.

Modernizing the Postal Service's retail network would not only save costs but is also intended to increase revenue, improve service, and enhance the welfare of the American public. By adopting a thorough, transparent, and objective approach to retail

[1] U.S. Government Accountability Office, *Strategies and Options to Facilitate Progress toward Financial Viability,* Report No. GAO-10-455, April 12, 2010, http://www.gao.gov/new.items/d10455.pdf. pp. 33-5, and U.S. Postal Service, *Ensuring a Viable Postal Service for America: An Action Plan for the Future*, March 2, 2010, available at http://www.usps.com/strategicplanning/_pdf/ActionPlanfortheFuture_March2010.pdf, pp.8-9.

modernization, the Postal Service can respond to stakeholder concerns and optimize its retail network. Modernization should not be thought of as solely a cost-saving response to the Postal Service's financial problems. Instead, it should be seen as a way to meet demand more efficiently and equitably in a way that cuts costs, encourages constant reevaluation and improvement, and aligns the Postal Service's retail network to the way people live now. It is also important to recognize that this modernization effort is not starting from scratch but must instead retrofit a legacy network of retail facilities.

Our research effort produced the following key findings:

- Overall, based on the model's results, the Postal Service's network has too many retail facilities located too closely together and with too many retail windows.

- In large urban areas, where 13 percent of the facilities in this study are located, the size and spacing of retail units appear to be near optimal on average. However, the number of open windows and staffing may be too low in some areas to meet demand, perhaps resulting in lost revenue and lines that are too long.

- In smaller towns and rural areas, where 87 percent of the facilities used in this study are located, the model indicates the Postal Service has on average too many facilities spaced too closely together to match customer demand efficiently. The model also suggests these facilities may have too many windows and excess staffing beyond what is required to efficiently match demand.

- Evaluating the scope of the Postal Service's retail effort is more complicated at the Postal Service than at other retailers, because many Postal Service retail facilities also contain delivery carriers. This frequently results in the commingling of labor activities in the back office. Many clerks engage in window activities and also support delivery efforts through various back office mail processing activities.

- The model directs planners to the $5.5 billion portion of the Postal Service's annual retail investment where the Postal Service's retail capacity appears to exceed demand by the public. While Dr. Yezer describes this estimate of the universe of possible financial benefits as a rough estimate complicated by limitations in the data, the potential savings from optimizing the network are surely large. Because the model is designed to be customized for local use, ultimately, the size of any cost savings must be determined by applying the model to individual localities after local decision makers verify the data.

- The Postal Service should improve its retail data and financial analysis at the local facility level. The Postal Service needs upgraded and improved data systems to fully support retail optimization and modernization efforts in an automated environment rather than a labor intensive process prone to subjective bias.

- It is possible to predict the retail revenue at an existing facility based on the demographic and business characteristics of the surrounding market area, the number of competitors in the area, and its distance from other Postal Service retail facilities.

- By comparing the predicted revenue at an existing facility to its actual revenue, the Postal Service can use the model as a tool to evaluate facility performance, highlight best practices, and determine whether retail units can be profit centers.

- The model can also be used to plan new facilities or the expansion of alternative access points such as contract postal units by allowing managers to input the expected growth in households and businesses in a given area and predict the resultant demand for Postal Service retail services.

- This research effort can inform the public policy debate on two key issues. It offers an objective, economic evaluation of what the Postal Service retail network would look like if it were to be optimized to meet customer demand. It also can be used to estimate the costs of inefficiency and inaction from maintaining the legacy network of retail facilities.

Analyzing the Postal Service's Retail Network Using an Objective Modeling Approach

Overview

The Postal Service's past attempts to adjust its network by closing retail facilities have resulted in a long history of public debate and controversy. We believe the Postal Service has the opportunity to modernize its retail network, not only to save costs, but also to increase revenue and improve service. We also believe that by adopting a thorough, transparent, and objective approach, the Postal Service would have the best chance of optimizing its retail network and balancing stakeholder concerns.

To begin addressing these issues, the U.S. Postal Service Office of Inspector General (OIG) contracted with Global Insight, Inc. and Dr. Anthony Yezer, Professor of Economics at George Washington University. Dr. Yezer is a nationally recognized expert on facility location and applied economics.[2] We asked him to develop a quantitative model designed to estimate the optimal number, size, spacing, and staffing of Postal Service retail facilities based on the current academic research on public facility location and the best practices of private industry. This research was limited to separately considering the retail component of the Postal Service's overall network and assumes the Postal Service could flexibly operate and optimally manage its network. The OIG also asked Dr. Yezer to attempt to estimate the financial impact of the difference between the Postal Service's current network and an optimized retail network.

While quite complex in practice, the underlying concepts and methods that Dr. Yezer uses are straightforward and accepted within the business, public, and academic communities. Using a similar approach would provide the Postal Service with an objective framework to explain to regulators, policy makers, and other stakeholders its efforts to match the retail network to current needs.

Before describing the model, it is useful to discuss two factors that affect the application of the model: (1) the Postal Service's retail network is unique and (2) the Postal Service is required to provide universal service.

The Postal Service's Retail Network Is Unique

The U.S. Postal Service manages one of the largest retail networks in the country. Its 36,000 retail facilities provide unparalleled access and reach, but the locations of postal

[2] Dr. Yezer is an economist specializing in real estate, business location, and applied econometrics, authoring 41 professional journal articles and providing consulting services to a variety of private sector organizations.

retail facilities are largely based on historic needs and patterns. Moreover, the Postal Service is a unique retailer and differs from standard private retailers in a number of important ways.

First, Postal Service retail and delivery operations are frequently co-located. Retail units often house carriers and Post Office Box service, and clerks often serve the needs of all functions. Distribution and Window Clerks not only engage in non-revenue activities at the window such as retrieving packages and held mail, but they also may work part of the day in the back office supporting activities unrelated to retail transactions. For example, clerks sort and distribute mail to carriers and distribute mail to Post Office Boxes and Caller Service sacks. Second, while many retailers adjust their products and prices based on their location, choosing products and setting prices based on what the market will bear, the Postal Service offers uniform pricing for most of its products.[3] The price of a stamp is the same across the country. Finally, the Postal Service network is part of the national and cultural infrastructure. In many places, it is the only outpost of the federal government, and in some small towns, the post office serves as the anchor of the community. All of these factors affect the task of optimizing the Postal Service's retail network.

Retail Optimization and Universal Service

If the Postal Service were to rebuild its retail network from scratch, focusing on today's customers' needs, few observers would expect it to look as it currently does. But, what processes are needed to develop a more efficient network for the 21st century? Answering this question is difficult. It requires balancing public policy goals and competing stakeholder interests while considering the financial implications of its decisions. To be responsive, policymakers and decision makers must consider how to effectively address service changes in local communities as well as review complex postal policies and legal procedures regarding closing or moving postal facilities. Constraints such as these have resulted in a legacy retail network that may not be reflective of current needs. Our research suggests that rectifying this situation requires an objective approach implemented equitably. It also suggests that the processes are complex and that many challenges lie ahead.

One key question that must be addressed by stakeholders and policymakers is the meaning of universal service. Historically, it has often been defined in terms of the number of Postal Service retail facilities. However, the network has been unresponsive to changes in society. For example, when both spouses in a family are in the workforce, the importance of access before work, after work, at lunch, and on weekends might need to be addressed. In fact, fewer larger facilities that are open longer hours could actually provide better service based on today's needs. For customers working during normal business hours, a nearby postal retail unit that opens at 9:00 a.m. and closes at 5:00 p.m. may be far less convenient than a larger unit, slightly farther away, that stays open into the evening or opens earlier in the morning. Such a unit could serve a larger number of customers, making a broader range of services economically viable. These

[3] Pricing for Post Office Box service is an exception as it is based on location.

practices are common among today's retailers who understand modern lifestyles, consumer needs, and buying patterns. It is important to note that historical practice involved opening at least one retail facility per ZIP code regardless of demand or proximity to other units, but times have changed making this clearly inconsistent with modern facility location practices.

On the whole, fewer, modern, appropriately-sized retail facilities could also make extending operating hours more cost efficient. It is unreasonable to demand that a small Post Office staffed by one employee stay open for extended hours. Longer hours allow customers to access postal services more conveniently and should improve sales as well as customer perceptions of the Postal Service. Moreover, larger facilities typically cost less per square foot of space because of economies of size. Higher service levels offered at fewer facilities could help the Postal Service keep prices low, reduce the time customers wait in lines, meet competitive forces, and conserve financial as well as physical resources. Of course, policymakers may decide that in some underserved areas more retail units are needed than strict efficiency requires. In this case, the model would allow policymakers to determine the cost of providing additional retail services.

Lastly, objective analytic techniques beyond the scope of this effort could allow the estimation of retail demand for alternative sales channels such as grocery store outlets, kiosks, and contract postal units (CPUs) — all of which can increase customer service levels and perhaps network efficiency. Alternate access channels that could sensibly stay open even later than consolidated Postal Service facilities and are located where customers already go may provide an additional way to provide retail services and address universal service obligations.

Like private sector retailers, the Postal Service must balance the revenue from retail services against the cost of maintaining and staffing retail facilities. Knowing how facility location influences the demand for retail services and how the demand for retail services can be met most efficiently will allow the Postal Service to make these trade-offs most effectively.

In sum, our research indicates that adopting objective retail performance measures could significantly improve the financial performance of the Postal Service's retail operations and likely increase customer service while lowering the cost to provide it.

Modeling Approach

Dr. Yezer's model and results are described in the following paper: *The Postal Service Retail Facility Location and Size Problem.* In simple terms, Dr. Yezer's model estimates potential retail sales by geographic market area using business and demographic data, and then calculates the amount of labor and facility space needed to respond to the retail demand. The model has two parts.

The first part of the model estimates the amount of revenue a facility will generate based on the size of its market area and local characteristics such as the number of households, the number of employees working at businesses in the area, the amount of nearby competition, and whether the retail unit is in a large urban area. A key insight from location economics is that people will buy less the farther they must travel to a retail location as the travel time adds to their purchase costs. All of these details can be entered into the model's demand equation to produce a revenue estimate. For example, the model estimates an urban retail unit with a market area of 10 square miles, serving 10,000 households and businesses employing 1,000 workers, and having one competitor nearby will generate $932,952 in annual revenue.

The second part of the model determines the cost of meeting the retail demand. The important cost relationships are based around the number of windows:

- How many windows are needed to serve the revenue expected to be generated by a retail unit?
- How many employees are needed to staff those windows? What is the cost of this labor?
- How does the amount of facility space required vary depending on the number of windows? How much will this facility space cost in a particular area?

Once these relationships are estimated, the model predicts the labor and space costs associated with a particular level of revenue. For example, the model estimates a retail unit in a typical large urban area generating $1 million in revenue a year should need 2.5 windows, 3.7 employees, and around 4,115 square feet of retail space at an annual combined cost of $308,184.[4] Of course, this cost estimate would vary depending on the cost of renting space in a particular city, so the model should always be calibrated to the local area under consideration. The model estimates can be used to check whether current facilities have the optimal staffing and floor space. By joining the revenue and cost parts of the model together, the model may be solved to determine how far apart to place retail facilities to produce the most net revenue (revenue minus cost) and the greatest benefit to consumers for any selected market area. The model solution also determines the optimal number of retail employees, number of windows, and square footage.

Model Results

Dr. Yezer applies the model to five broad segments of the country including the United States as a whole. He breaks the country into large urban areas and non-urban areas and also highlights two extreme but important subsets of the country: high-density downtown areas and very low-density rural areas.[5] Table 1 shows his results. For each area, the number of employees working at area businesses per square mile, number of households per square mile, current average distance between locations, optimal

[4] Co-located delivery operations are not considered in the model.
[5] Urban areas include large cities and their suburbs. Non-urban areas include areas outside of large cities such as smaller cities, towns, and rural areas. Together urban and non-urban areas cover the continental United States.

distance between locations, optimal number of windows, optimal facility size, and optimal net revenue per square mile are shown. The first row shows the U.S. average, and the other rows are arranged by employment and household density.

Table 1: Model Results by Type of Area

Type of Area	Employees at Area Businesses per Square Mile*	Households per Square Mile*	Current Average Distance Between Locations*	Optimal Average Distance Between Locations	Optimal Number of Windows	Optimal Facility Size (Interior Sq. Feet)	Avg. Net Revenue per Sq. Mile
U.S. Average	20	350	9 miles	11 miles	4.0	6,276	$3,788
High-Density, Downtown	2,000	6,900	2 miles	2 miles	3.0	4,844	$77,366
Large Urban	355	2,259	4 miles	4 miles	4.2	6,568	$29,801
Non-Urban	26	130	9 miles	12 miles	5.4	8,146	$4,589
Very Low-Density, Rural	1	11	12 miles	16 miles	0.6	1,095	$128

* In addition to employment, the number of households, and the size of the facility's service or market area, other factors are used to estimate demand in the model. They include measures of competition, median household income, and whether an area is urban.

- *U.S. Average* — Dr. Yezer calculated the U.S. average for illustrative purposes. Comparing the U.S. average results to the large urban and non-urban results shows the challenges of aggregating results. The optimal distance between facilities, 11 miles, is similar to the non-urban results, but the optimal number of windows, four, is closer to the large urban results. Thus, the optimal retail unit predicted for the U.S. average would not serve either one well. This also demonstrates the need for modeling efforts at local levels to obtain more valuable results.

- *High-Density Downtown Areas* — The study used 271 facilities for the analysis of high-density downtown areas. The model suggests that the size and spacing of retail units in this category is near optimal on average or that perhaps slight increases in service might need to be provided to meet demand. Lack of service could be resulting in lost revenue and wait times that are too long in some locations.

- *Large Urban Areas* — A total of 3,423 facilities were used for the analysis of large urban areas. While the average spacing of Postal Service retail units in this category is consistent with the optimal, the number of open windows and workers may be too low here to optimally serve the demand, and this may be resulting in overly long retail lines in some areas. The removal of simple vending machines may be increasing wait times and decreasing window sales efficiency.[6] Increased staffing and alternative access might need to be considered. It is important to note, however, that this analysis is based on the average, and actual distribution in a given city may be very different.

- *Non-Urban Areas* — There were 22,811 facilities used in the analysis of non-urban areas. Moving from an average distance of approximately 9 miles to 12 miles increases the area served by each postal facility to be nearly twice as large. The model results also suggest too many windows and too many employees per facility, on average, to efficiently match demand.

- *Very Low-Density Rural Areas* —13,616 facilities were used to analyze very low-density rural areas. The average actual distance between facilities is well below the optimal. The results also show the optimal facility for these areas would have only 0.6 windows. Moving to the optimal distance between facilities would help, but individual units with one window would still be likely to lose money on average.

Insights

We gained several insights from the model and our related research into this topic:

- Nationally, from the sole perspective of economic efficiency, the model suggests that the Postal Service has too many retail units located too closely together. In an optimal network, designed to meet demand on a cost-effective basis, there would be fewer retail units, but many of those remaining would offer more accessible hours and more services. There may, however, be areas of the country where adding facilities would be beneficial.

- The model suggests that large numbers of retail units have excess windows and staff. However, there are exceptions. Retail units in large urban retail areas may actually have too few windows and staff. As a result the Postal Service may not be able to provide the best service or capture all of the demand for retail services.

- According to the model, there may be more savings from optimizing the labor force than from the closing of small facilities.

- In very low-density rural areas, it may not be possible to find any distribution of facilities that generates positive net revenue (revenue minus cost). In these cases, the Postal Service may want to consider CPUs and other low-cost methods of providing service to avoid having Post Offices that lose money or are so thinly staffed that they cannot provide reasonable access.

[6] Anecdotal evidence suggests that the removal of simple vending machines may have increased small revenue transactions at retail windows, reducing their efficiency. While Automated Postal Centers (APCs) are available in some locations, they require credit cards. To be efficient, highly trained window clerks should be primarily focused on more complex transactions.

- Because of the difficulties in addressing demand during peak hours, a significant expansion of labor flexibility such as using part-time employees and allowing employees to cross crafts by working on tasks primarily assigned to positions in other unions might need to be explored.

- Demographic differences between customers at different Postal Service facilities need to be explored and understood before proceeding with significant changes. While some retail units sell much Express and Priority Mail, some sell mostly small dollar value money orders and single stamps.

- The Postal Service should re-examine its unique, historical model of co-locating its retail units with its delivery operations. Private package delivery firms such as UPS use a very different model. They have many retail facilities where people live and work but have a few large, centralized delivery operations where land is cheap and access to highways is easy. At the very least, the Postal Service needs to recognize it operates with its current, unique shared model and produce data that sensibly separates facility space and labor usage for the two disparate activities at each individual unit.

- The mystery shopper data the Postal Service collects on customer wait time in line could be an extraordinarily valuable piece of information in attempting to optimize the retail network to meet demand. Unfortunately, the mystery shopper data available to us did not include the time of day and could not, therefore, be linked to sales revenue measures. Providing the time of day with this data would supply an important source of information as the Postal Service moves forward in trying to optimize its retail network.

Additional Uses of the Model

In addition to determining the optimal size, spacing, and staffing of the Postal Service's retail network, there are other uses of the model:

- The model can be used to estimate expected revenue of any existing retail unit based on its size and the business and demographic characteristics of its market area such as population, income, employment, and competitors. This can be compared to actual revenue to help evaluate performance and benchmark successes across the country.

- The model can be used to plan new facilities by allowing managers to input the expected growth in households and businesses and predict the likely demand for Postal Service retail services. By estimating costs, the model can also help guide where new demand might be better addressed by alternative access models such as CPUs or other options.

- While the model does not address the universal service requirement directly, it can be used to roughly estimate its cost. For example, it is possible to estimate the loss experienced by the Postal Service if it is required to locate retail units in low demand areas even if these facilities were optimally sized and spaced. The model can also estimate the loss in net revenue of having facilities incorrectly spaced in a given area.

Estimated Financial Impacts from the Model

Developing a national estimate of the financial impact of optimizing the Postal Service's retail network is inherently difficult but nonetheless useful to provide an order of magnitude of the large cost of inefficiency in the existing network and implicitly estimate the cost of failing to optimize.

The model directs planners to the $5.5 billion portion of the Postal Service's annual retail investment where the Postal Service's retail capacity appears to exceed demand by the public. Dr. Yezer notes that this is a rough estimate as he was constrained by limited data in producing his model and made certain necessary assumptions. First, due to limitations in the data, the model treats employees who spent at least 10 hours in a week logged into a window terminal as dedicated retail workers. In reality, we know qualitatively that some such clerks have shared duties unrelated to retail transactions, but we do not have quantitative data readily available to do the separation properly for each retail unit. Second, because of the lack of data for retail facilities not on the POS (Point of Sale) system, Dr. Yezer applied results from the facilities that do have POS units, which are typically larger facilities, to those that do not, which are typically smaller facilities. This could influence results. Third, this estimate is based on the averages for urban and non-urban regions within the United States, but there is a significant amount of variation within these large regions. A precise estimate of the cost savings can only be reached by analyzing much smaller areas individually, preferably after the data has been validated by local decision makers.

Dr. Yezer's estimate does provide, however, a reasonable order of magnitude for the potential improvement in net revenue from optimizing the Postal Service's retail network. To fully realize and continue potential savings, decision makers should envision a continuing, multiyear effort requiring many adjustments and improvements to meet shifting demographic and buying patterns.

Application of the Model

The current model is not an operational blueprint. Customization is necessary to implement it in any particular location, and any implementation program requires actions outside the scope of the model. The model assumes the Postal Service has the flexibility to reassign labor and relocate facilities easily. It does not take into account constraints resulting from existing lease commitments, the costs of moving or renovating facilities, or other transition costs. Addressing community and stakeholder concerns generated by a modernization program is also, obviously, a key issue.

An implementation program should experiment with pilot locations, explore options, and then learn from the results produced. Those who use the model should have a mindset of continuous improvement, so that the feedback from the implementation process is used to enhance the model. Because the Postal Service is restructuring an existing network rather than entering a new area, an incremental and experimental approach is important.

Applying the model operationally involves several considerations:

- One or two pilot locations the size of a county or small postal district should be selected to demonstrate the application of the model. Locations that are representative of many other locations would be preferable for the pilot. The planners would also want to choose a place where making network changes is easier — for example, a location having many facility leases that will expire in the next few years.

- All of the data used in the model for the pilot locations should be verified by local retail experts who can make sure that any special circumstances are known. In addition, the model allows for a dialogue between national planners and local offices to conform it to local and regional differences.

- After the model is applied to a pilot location, an operational plan should be developed to respond to the results. Precise matching to model results is not required; making improvements and moving closer to the optimum is the key. The operational plan should take into account staffing changes, the effect on carrier operations, any need to change leasing arrangements or sell property, and other operational concerns.

- Early implementation could focus on areas where there is gross misalignment between supply and demand. As experience and better data lead to improvements in the model, the planners could continue in areas where the imbalance is more marginal.

Conclusion

Based on Dr. Yezer's analysis, the Postal Service has a mismatch between the provision of retail services and customer needs. Some areas have too many facilities, staffed with too many clerks and sales windows. Retail facilities in other areas may not be able to meet demand, so that the Postal Service provides inadequate service and does not realize all of the potential revenue available.

The Postal Service could improve its net revenue by continuing to review and optimize its retail network. Moreover, by adopting an objective approach, the Postal Service could begin to restructure its retail network in a way similar to the best public facilities location practices and the best practices of private retailers. When combined with local expertise, the Postal Service could become more efficient and at the same time actually increase service to its customers. In some high-growth areas, expanded facilities or alternative services might be needed to match new demand. In many other places, however, facilities might need to be closed, moved, or consolidated into larger offices.

Efficiency should not be the only consideration when evaluating the closure or consolidation of retail facilities. While the model gives direction on how the Postal Service's retail network can be optimized to address revenue, cost, and service concerns, it does not directly address what is reasonable access. When using Dr. Yezer's model or any similar objective, economic criteria, the Postal Service and policymakers should evaluate the universal service obligation and ensure that economically depressed communities are treated appropriately. While a private business may sensibly choose not to locate in areas where income is low or the population is sparse, the Postal Service has a responsibility to provide service within a reasonable distance of where Americans live regardless of their economic circumstances. One option beyond the scope of this model is for the Postal Service to find additional services to sustain low-revenue retail units needed for universal service. By turning them from cost centers into profit centers, the Postal Service can only strengthen universal service and its retail network.

For the retail network as a whole, the OIG encourages the Postal Service to move forward with the goal of establishing a retail network optimization program that better matches customer demand. The results embodied in our research seem an effective beginning to lowering costs, increasing revenues, and improving service. For these efforts, the OIG urges the Postal Service to improve its retail financial data and analysis capabilities at the local facility level. We recognize that the Postal Service faces many constraints and that implementation of these practices will be difficult and time consuming. However, modernizing the retail network is long overdue and the costs of inaction are high. The time to start a proactive effort is now, and our research suggests good ways to start. Adopting objective measures and a consistent approach, shared widely among stakeholders, should put the Postal Service on the best possible pathway towards success.

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The Postal Service Retail Facility Location and Size Problem

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The Postal Service Retail Facility Location and Size Problem

1. Introduction

The U.S. Postal Service has a continuing interest in providing service facilities that meet the demands of its retail customers. It has engaged in innovative strategies to bring expanded retail services to areas where demand is growing rapidly. The Postal Accountability and Enhancement Act has prompted increased scrutiny of costs and benefits of existing facilities and expansion plans.

Recently the Government Accountability Office raised a number of questions regarding both the current spatial distribution of facilities and the databases used in planning and maintaining those facilities.[1] While the report provided no economic analysis of benefits and costs of facilities, it noted a substantial variation in the numbers of facilities in counties that appeared otherwise similar in size and population. The conclusion was that areas with large numbers of facilities were "over-served" and that the Postal Service needed to develop processes to reduce the number of facilities in such areas. The report further concluded that current USPS databases, particularly the Facilities Data Base, were inadequate to support the task of managing facilities.

The goal of this study is to build and demonstrate the application of a model for determining the size and spacing of retail facilities based on the existing academic literature on facility location and consistent with best practices used by industry. The academic approach to public facility location has been applied to and is used by a number of local public services including fire stations, police stations, ambulance location, public schools, emergency medical care, etc. Like the USPS, these activities all have a universal service requirement. Because this model is being applied to USPS operations, the goal of the model is to suggest design parameters for size, spacing, and clerical employment that are consistent with maximizing consumer welfare. Once such a model is built and operational, the actual number of facilities in an area can be compared to the welfare-maximizing number estimated by the model in order to determine which areas need more or fewer facilities. At the same time that the model solution provides the optimal spacing of facilities, it also gives information on other aspects of "right sizing" including requirements for numbers of windows, registers, interior space, and workers.[2] Finally, it provides estimates of revenue that should be expected for each facility that can be useful in monitoring performance.

[1] U.S. G.A.O., "U.S. Postal Service Facilities: Improvements in Data Would Strengthen Maintenance and Alignment of Access to Retail Services," (GAO-08-41), December, 2007.

[2] In the fall of 2008, a previous iteration of this report, "The Postal Service Retail Facility Location and Size Problem," demonstrated the feasibility of the current modeling effort. In that report, the modeling effort concentrated only on space cost as a criterion for facility spacing. This report adds the other major element of retail cost, clerical labor, to the computation of an optimal network.

One major contribution of this report is the estimation of a spatial revenue function for USPS retail services. This is an equation that relates the characteristics of a particular area, in this case the amount of employment, number and income of households, and presence of competitors, to the market area served by a particular postal store. It appears that this is the first time such a model has been estimated for the USPS. The spatial revenue function can predict the revenue of a particular facility given knowledge of the population, employment, and competition in an area. The model is constructed based on measures of household characteristics, employment by industry and competitors that are readily available. Given that the model can predict the relation between the size and location of retail facilities and revenue, it can be used in a planning mode to predict the change in total revenue from a given area when the size and spacing of postal facilities is changed. In the literature on facility location, the spatial revenue function is the key to producing a model of the optimal size, spacing, and location of facilities.

The report considers both facility space and labor cost required to produce postal services. As with revenue estimates, facility space cost estimates are based on 2008 data. The model requires estimation of the relation among facility size, labor use, and revenue generation. Many issues are involved in going from actual USPS data on labor used in each postal store to statements about the efficient use of labor in facilities of different sizes that are necessary if a model of optimal facility size and location is to be formulated. Fortunately, there is data on number of employees, number of active windows, and revenue by facility to estimate the relation among facility size, labor effort, and revenue generated for facilities that appear to be operating at a high level of capacity utilization. Some improvements in USPS data systems are needed to remove any ambiguity or lack of precision in the relations developed here.

This report combines the spatial revenue function with the facility and labor cost functions to take very detailed look at the question of whether the nation's network of post offices is spatially aligned to meet the needs of consumers and businesses for postal services. It reports the results of an economic analysis of the relationship between the number and size of facilities in a given market area and the costs and benefits generated by those facilities. The analysis is based on a model, which generates estimates of the optimal number of facilities in an area that can be compared to the actual number. Optimal is determined by a welfare-maximizing calculation of the surplus of benefits over costs generated as the number of facilities is changed. This model is based on the current academic literature on the facility location problem and is related to standard practice for store location decision-making in the private sector.

While the methods used in solving the public facility size problem here are very different from the approach taken in the GAO report, the conclusion that, in some areas, the USPS operates with too many retail facilities spaced too closely together appears to hold. In other areas, the USPS may have too few facilities. Furthermore, the model produces a computation of the welfare loss associated with the current configuration of Postal Service retail facilities compared to an optimal configuration, and the difference in welfare is very substantial.

In addition to the statements about inefficiency in the GAO report, it is possible to use data from the Window Operations Survey (WOS) to document and quantify some sources of technical inefficiency in retail operations. The WOS data for FY 2008 show 15,043 postal stores with reliable observations. Approximately 250 observations were dropped due to obvious measurement error problems. Total WOS revenue at these facilities was $12.6 billion, which was approximately 94% of all retail revenue.[3] The average revenue at the 15,043 WOS facilities was $839,418.

The WOS data system contains a data item recording actual terminal staffing hours for all the front office terminals in which there was a least 1 transaction meeting WOS criteria. Hours of staffing on back office terminals are also shown if there were at least 4 passport transactions or one mailing with cash tender in the last 90 days. For the FY2008 period under study, the 15,043 postal stores had an average of 4,330 terminal hours per facility, or 65,139,190 hours total. Assuming 2,000 hours of terminal time per employee year, this implies 32,570 full time employee equivalents were needed to staff these terminals during their actual hours of use.

The WOS system records transactions by type and the USPS has adopted a system of "earned hours use time factors" that can be used to calculate a time for each transaction including some soft time and open and close. One approach to estimating x-inefficiency is to compare actual hours with earned hours and treat all, or some portion, of the difference as a measure of inefficiency in time spent in terminal operation. For example, if the standard for technical efficiency is based on earned hours, then all actual hours in excess of earned hours reflect x-inefficiency. Adopting this standard, there are 13,414 facilities with some excess of hours over earned hours with the average facility having a ratio of earned to actual hours of 0.67, of the 58,189,932 hours at these facilities fully one third reflect x-inefficiency and the annual cost of this x-inefficient terminal time is $768,110,000. Alternatively one could adopt a lower standard that technical efficiency only requires that earned hours equal 90% of actual hours. Using this standard, x-inefficiency is found at only 12,347 facilities and its annual cost falls to $604,750,000. Further relaxing the efficiency criterion to 80% of actual hours reduces the facilities with any measure of inefficiency to 10,239 and the annual cost to $404,240,000. In any case, applying the USPS standard for earned hours to the 15,043 facilities which have reliable data produces rather substantial estimates for the annual amount of x-inefficiency that is apparent even from the data on actual terminal operating time compared to tasks performed. These, of course, are labor costs only and do not include facility size considerations. Also they do not consider the productivity of these workers during the time when they are not at their terminals. At facilities where the marginal product of additional terminal time is very low or zero, it is likely that the marginal product of these workers when their terminals are off is also close to zero. The alternative is that management is misallocating too much labor time to staffing terminals while other productive tasks remain undone.

[3] Total retail revenue was estimated as the sum across the 30,922 facilities that had revenue greater than or equal to $1,000 in 2008.

The previous analysis only considered the 15,043 facilities that account for 93% of revenue. According to the USPS data systems there were 30,922 facilities with walk in revenue greater than $1000 per year. What is happening at the other 15,879 facilities? Detailed data on labor, terminals, terminal times, etc are not available. However, the revenue data indicates that 12,557 of these facilities have total annual revenue under $90,000 and indeed the mean revenue is $41,259 for these facilities. The $90,000 annual revenue mark is meaningful for allocative efficiency in that it reflects a standard likely necessary to generate revenue that is greater than operating cost even if all revenue is recognized as return to retail services.

This discussion of WOS data is not formally a part of the public facility location modeling process undertaken here. However, it together with the GAO study paints a picture of some likely outcomes that should be expected from a properly constructed economic model of the welfare gains from moving to an optimal configuration of facility sizes and locations. Clearly the current system has substantial x-inefficiency. Examination of the 15,043 high-revenue facilities for which WOS data on earned versus actual terminal staffing hours are available indicates x-inefficiency in labor allocated to terminal operating hours that ranges from $404 to $768 million per year without consideration of x-inefficiency at the 15,879 very low revenue facilities. The point is that, even without detailed economic analysis and planning, the expectation should be that the modeling process will show significantly larger gains from achieving technical and allocative efficiency than these already substantial estimates obtained without significant effort. Of course, the major gain from the economic modeling effort is that it will provide a specific guide to the facility planning and staffing process that can move the USPS toward a welfare-maximizing system of postal stores.

This report begins with a general statement of the location problem facing the USPS that is formulated in a fashion consistent with the literature on facility location. Then the model is adapted to the specific circumstances facing the USPS, including the policy of charging equal prices at all locations and the need to serve the entire market area. This model is solved to produce a mathematical statement of the determinants of welfare-maximizing facility location, which naturally depends specifically on the demand and cost parameters facing the USPS. The next section takes USPS data and estimates these crucial demand and cost parameters. This produces an operational version of the model that is capable of estimating the relation between facility location decisions (choices of the size or spacing of facilities) and revenues and costs. The model can then be solved for a variety of choices of spacing, and the welfare-maximizing spacing can be determined. The results provide an understanding of the facility location problem facing the USPS. In some cases there is substantial difference between the number and size of facilities that currently exist and the choices that would maximize welfare. In some cases, the number and spacing of facilities may be reasonable but the size is non-optimal. In others the size may be appropriate but the spacing incorrect. Finally, it is possible for both size and spacing to deviate from the welfare-maximizing combination. Indeed, the model is able to compute the difference in estimated welfare between that computed for current location choices and the welfare-maximizing location choices.

The model is welfare-maximizing subject to the constraint that local service must be provided everywhere. When mail processing costs, including sorting, transportation, and delivery, are deducted from revenue, it is possible that the welfare-maximizing net revenue is negative. In such areas, the model is suggesting that a welfare-maximum would involve providing no retail stores. To the extent that this is not an option, the model can be used to compute the loss suffered by the USPS in providing services to these areas.

In addition to estimating the optimal configuration of facilities, the model provides a number of other useful outputs. It predicts revenue and cost for specific facilities and provides a basis for judging differences in performance of operations between actual and predicted. In the case of postal store planning, the model can provide an estimate of future revenue so that an appropriate size can be selected. Finally, the model predicts the conditions under which a "traditional" postal store does not provide the optimal service option. Under conditions of low demand density, the model shows that it is optimal to provide postal retail services in an alternative environment, i.e. a Contract Postal Unit (CPU). While the model was not calibrated based on detailed information on cost and revenue performance of actual CPUs, to the extent that they function as fractional postal stores, the market identifies conditions under which they provide economically efficient delivery of postal services.

In this study, the baseline model has been estimated and solved for some general prototype cases. Application of the model to a specific location, the Buffalo-Niagara MSA, is also illustrated. In the final analysis, incorporation of this type of model in a facility planning and management process should involve consultation with those involved so that the model outputs can contribute to the decisions being made. The final choice of location and size of facilities should include a significant measure of local knowledge, and judgment is required to supplement the guidelines coming from any location model.

2. General Statement of the Problem and its Solution

The USPS provides retail services at postal stores.[4] Prices are essentially spatially invariant with the exception of P.O. Box rental fees where there is some adjustment for differences in real estate pricing that will be ignored in the analysis conducted in this report. Given that price is fixed, demand is determined by the cost of access to these postal stores, the presence of competitors and population and employment in the area. There are labor and facility costs associated with meeting this demand. In this study, both facility and labor costs are considered. Because rent increases with store size at a decreasing rate and revenue increases at an increasing rate with size, there are economies of scale at the individual facility level in providing postal services.
Thus, the economic problem arises because decreasing the market radius of stores increases demand for services but raises the cost per unit of service as rent per square foot

[4] The terms 'postal store' and facility designate a Facilities Database observation and the 10 digit finance numbers which are attributable to that observation, including CPU and APC revenue.

rises and revenue per square foot falls. It is infeasible to provide a postal store for every user, but production in a very small number of large stores is equally unattractive because most demand would be choked off by the lack of convenient access.

Components of a model determining demand for and cost of retail operations

This is a special version of the facility location problem that has been studied in the academic literature. The nature of the problem may be understood by setting up a simple mathematical model. Given that price is fixed, it is possible to write total revenue per square mile, R, in the following form:

$$R = PQ = f(D, r) \tag{1}$$

where R = revenue per square mile, P is the fixed price per unit service, Q is the quantity of services provided, D is the density of postal customers (households and firms) per square mile, r is the market radius of the store (half the distance between postal stores), and the function $f(D, r)$ is an empirical relation to be determined using USPS data on revenue and market characteristics. It is anticipated that $f_D > 0$ because greater density of customers yields greater demand density and that $f_r < 0$ because a longer market radius makes access to the store more expensive.

Retail postal services at a store are produced through "windows," W, and there is a fundamental production relation between windows and revenue that is given by:[5]

$$W = g(R) \tag{2}$$

In this case, $g(R)$ is a function to be determined empirically using USPS data on revenue and windows of facilities serving different market areas. There should be a capacity constraint on the ability to deliver retail services and generate revenue from a given number of windows, and it is anticipated that $g_R > 0$. The fact that (2) is measured per unit area does not alter the fact that windows per unit area rises with revenue per unit area.

There is a relation between the number of windows in a postal store and the required labor, L, that is given by:

$$L = h(W) \tag{3}$$

Windows generate staffing requirements and, based on USPS data, there is a clear relation between the number of windows operating and the number of USPS personnel in the facility so that $h_W > 0$. Once again the fact that the analysis is conducted in terms of labor and windows per unit market area has no effect on the sign of the relation between the two variables. Employees who staff windows have other duties. Some of these are

[5] For facilities that are connected to the POS system, a window is a register that is generating significant amounts of revenue. This will be discussed in some detail below.

directly related to revenue generation, handling incoming mail. Others may involve sorting mail for delivery. These issues will be discussed later in this report.

Similarly, there is a relation between interior space per square mile of market area, S, at a store and the number of windows given by:

$$S = i(W) \tag{4}$$

Where: $i(W)$ is a function to be determined empirically using USPS data and design criteria. But it is clear that $i_W > 0$ because more space is required to accommodate the additional windows.

Translating clerical labor and facility space into USPS costs is fairly straightforward. Labor cost per square mile, C_L, is the product of the number of workers per square mile and the earnings per worker, E, or $C_L = EL$. The cost of space to serve demand generated by each square mile of market area will depend on space per square mile and on the size of the market area, i.e. on r,

$$C_S = j(S, r) \tag{5}$$

where: C_S is the cost per square mile of market area, and $j(S, r)$ is a facility rent equation that gives the relation between the space per square mile of market and the facility rent per square mile. Estimates of the rent function have already been made in connection with P.O. Box fee setting and, of course, are generally available in the literature for office space. These indicate that $j_S > 0$, $j_{SS} < 0$, and $j_r < 0$ because additional space costs more but larger facilities that serve a larger market radius cost less per square foot.

Bringing components together and solving the model for optimal size of facilities

Solving a model of the optimal spacing between facilities is straightforward once a criterion for judging optimal facility provision is selected.[6] One standard choice is maximization of the surplus of revenue over cost. Note that this is NOT a monopoly solution because price is fixed and the USPS is a non-profit producer. Instead this corresponds to a welfare criterion for consumers who ultimately must pay a higher price for the cost of additional facilities.[7] There is one special consideration in this problem because the USPS is producing more than retail services. The revenue collected implies that the USPS will incur costs of mail handling, processing, transportation, and delivery, hereafter referred to as "mailing cost." These operations impose costs on the USPS that are a substantial fraction of total revenue. Accordingly, mailing costs should be deducted

[6] For an excellent discussion of the literature on location theory see Martin Beckmann & J-F Thisse, Location Theory, Chapter 2, in the *Handbook of Regional and Urban Economics,* Edited by Edwin Mills and Peter Nijkamp, or Martin J. Beckmann, *Lectures on Location Theory*, Springer 1999.

[7] For a specific discussion of the public facility location problem in continuous space see: M-H Ye and A. Yezer, "Location and Spatial Pricing For Public Facilities", *Journal of Regional Science*, (May 1992), and M-H Ye and A. Yezer, "Local Government and Supervised Spatial Multiplant Monopoly," *Southern Economic Journal,* (April 1993).

from revenue collected as part of the net revenue maximization problem. Based on recent annual reports, over 75% of USPS operating cost is associated with the costs of handling, processing, transporting and delivering mail. It is not at all clear that this average cost figure should be deducted from revenue for purposes of the analysis conducted here, particularly given that marginal cost is likely well below average cost. This report will take no firm position on the fraction of revenue that should be attributed to retail activity because these issues were well outside the purview of the research.[8] Instead, a fraction, $0 < (1 - \psi) < 1$ of revenue will be attributed to covering mailing cost, which leaves a fraction ψ of revenue to be counted as net revenue associated with retail services.

Based on equations 1-5 above, the welfare criterion may be stated as:

$$\omega = \psi R - C_L - C_S = f(D,r) - Eh(W) - j(i(w),r) \qquad (6)$$
$$\omega = \psi f(D,r) - Eh\big(g(f(D,r))\big) - j(i\left(g(f(D,r))\right),r)$$

where ω is welfare per square mile. Observe that maximizing welfare per square mile maximizes welfare for the entire system. The important insight from equation (6) is that, given the density of customers that determines demand per unit area, welfare maximization is based on the selection of postal store spacing at intervals of $2r$. This also determines facility size because D and r determine postal store revenue from equation (1), $R = f(D, r)$. Once revenue is determined, all the other operating parameters of the model such as number of windows, facility size, and workers per facility follow automatically. Thus, the facility location problem can be solved by choosing the appropriate plant spacing, r, and tracing the implications of this for all other postal store characteristics using the model.

For given demand density, welfare per square mile is maximized by setting the derivative of (6) with respect to r equal to zero:

$$\frac{d\omega}{dr} = \psi f_r - Eh_W g_R f_r - j_S i_W g_R f_r - j_r \qquad (7)$$

Equation (7) can be solved to determine the optimal market radius between stores in areas where demand density is given. Recall from the above discussion that $f_r < 0$, $g_R > 0$, $h_W > 0$, $i_W > 0$, $j_r < 0$, and $j_S > 0$, which implies that the first term on the right side of (7) is negative, while the other terms are positive. As expected, increasing r tends to have a negative effect on welfare per unit area due to the fall in revenue as average demand per square mile falls, but there is a compensating rise in welfare as larger sales per postal store lowers space cost per square foot. Labor cost per square mile of market area falls as revenue falls. Clearly the necessary condition to maximize welfare in equation (7) is a

[8] In the general facility location literature, the marginal cost of production would be considered in determining the location and size of facilities. In the case of the USPS, that marginal cost is the cost of providing the retail services (buildings and workers) as well as the cost of producing the service (generally delivery services) which is not formally considered in the analysis. Insertion of the ψ factor is a way of adjusting gross revenues downward to account for these costs.

function of demand density, *D*. In these models, the effects of demand density are complex because a rise in demand density tends to increase costs of additional r because the fall in revenue with added market area is larger but the fall in cost is larger also.

Relation between the optimum in the model and current USPS operations

The preceding discussion has provided a general outline of the facility location problem facing the USPS. The model being constructed is one designed to identify a pattern of facility location, size, design, and employment that is allocatively or economically efficient. In order to achieve allocative efficiency, it is necessary that operations be technically efficient, or to achieve x-efficiency, which requires that all inputs to the production process be fully utilized and that they be used in the correct proportions.

The various functions introduced above, *f(.), g(.), h(.), i(.),* and *j(.)*, implicitly assume that technical efficiency has been achieved. The challenge is to use USPS data to obtain statistically valid empirical estimates of the functions *f(.), g(.), h(.), i(.),* and *j(.)*. The model then takes these functions and finds the combination of facility spacing, numbers, size, windows, employees, revenues, etc that maximizes net welfare, i.e. that achieves allocative efficiency. In order to do this, the functions must be based on technically efficient patterns of operation, or on x-efficiency.

Put another way, the number of windows and employees engaged in revenue-related functions must be based on facilities that are operating at or near capacity. Even casual examination of the data on USPS postal store operations indicates that many facilities have substantial redundancy in windows, space, and perhaps personnel. Consider, for example, ratios of revenue per window or revenue per clerical employee. Using POS data, revenue per year (per week in December) per window varied from \$5,700,000 to \$4,600 (\$80,120 to \$126) and revenue per employee per year (per week in December) varied from \$5,810,511 to \$1600 (\$40,063 to \$126).[9] Part of this distribution reflects measurement error, but the mean and standard deviation of revenue per window per year (per week in December) were \$255,915 and \$176,916 (\$8,285 and \$4,013) and for revenue per employee per year (per week in December) were \$164,174 and \$152,955 (\$5,409 and \$2,894) respectively. These facilities with low ratios of revenue per window or per employee are not technically efficient. In some cases, they clearly have significant amounts of excess capacity.

It is also possible to find facilities that appear to be x-inefficient by examining the ratio of windows to workers. Of 15,182 facilities for which POS data allowed determination of the number of different clerical employees logged on to registers during a given week and the number of active windows (registers), the ratio of windows to employees varied substantially. Taking the busy second week in December as a time when, if ever, operations should approach capacity, there were 1,986 facilities where the

[9] POS data from approximately 14,700 facilities, accounting for over 80% of revenue, were the basis of these statements about high and low revenue postal stores.

ratio of employees to windows was between 0.1 and 0.6. For these facilities, the number of windows is clearly too large compared to labor to staff them. In the same week, for 765 facilities, there were two employees per window. Again, this appears to be an unusually high ratio. These examples illustrate the general point that, in the data on postal store operations, there are many cases in which the ratio of windows to employees is far removed from an allocation that would hold under technical efficiency. This leads to two important points about the relation between the optimum in the model and current USPS operations.

First, at many facilities, the costs of producing given postal services are not currently being minimized. Elimination of this x-inefficiency is partly a problem of proper facility size and spacing. However, the model is not designed to produce technically inefficient outcomes so that the gains from elimination of x-inefficiency are not generated within the model. In order to estimate the gains from elimination of x-inefficiency, it is necessary to know operating costs of the current facilities and to compare those operating costs with the costs of technically efficient facilities where technical efficiency is based on the cost-minimizing combination of windows, interior space, and retail workers needed to produce the current level of retail services. The gains from elimination of x-inefficiency have nothing to do with the location and spacing of facilities that is the object of the modeling effort here. Instead they arise from redundancy (excess capacity) or inappropriate input ratios of space, windows, and employees in the current system. The section of this report that applies the model to a small region contains a rough estimate of the amount of x-inefficiency in the current USPS system for an area sufficiently small to make the computation tractable given available data.

Second, given that the purpose of the model is to optimize facility size and location, it should be based on estimates of the capacity of windows and employees to produce revenue when they are being fully occupied by customers. Estimating the capacity to generate revenue from given inputs of windows, registers, and employees was a major challenge for this report. As noted above, the ratio of interior space to windows varies widely across postal stores, in part because of other postal activities occupying the space. Fortunately, USPS has adopted design and operating standards governing what $i(W)$ should actually be. These design criteria were used to supplement data on actual facilities in order to determine the relation between windows and interior space allowing room for carrier services and P.O. boxes. The ratio of employees to revenue also varies in the available data but fortunately a very significant and robust relation between number of windows and employees was found. In order to determine the appropriate ratio, i.e. in order to calibrate the $L = h(W)$, function, only observations on the L/W ratio for facilities whose revenue per window indicated that they were operating near capacity were used. Data from other facilities was discarded. The result is presumably a function that reflects the relation between windows and employees when production is x-efficient.

It is important to keep the considerations about the goals of technical and allocative efficiency in mind when interpreting the results and use of the model developed here. There are many cases of obvious x-inefficiency in the data. These are likely evident to managers in USPS. The POS data indicates that, in 10% of facilities, revenue per window is less than $80,000 per year and revenue per employee is less than $60,000 per year. X-efficiency would require production with fewer windows and/or employees. While this modeling effort is consistent with such a finding, the result should be obvious. Elimination of obvious cases of excess capacity and getting the right ratios among windows, employees, space and revenue can result in substantial cost savings for USPS and move the system toward x-efficiency.

The model developed here is designed to take the USPS facility system to the goal of allocative or economic efficiency by producing the correct postal store sizes and locations. Making the system x-efficient does not optimize it. The model generates estimates of the surplus obtained from different sizes and spacing of technically efficient facilities. Then the model selects the precise size and spacing that, among all technically efficient options, achieves allocative efficiency. The gains in surplus reported based on the model simulations reflect the increase in efficiency due to movement between two technically efficient postal store designs. Given the current system is not even technically efficient, if USPS moves to a postal store design system based on the model, it will achieve gains due to the achievement of BOTH technical and allocative efficiency. This is a very important point. The current x-inefficiency in the USPS system should provide motivation for adjusting the size of facilities. If changes are to be made in order to achieve technical efficiency, making those changes consistent with allocative efficiency can result in significant additional gains for the USPS.

Given that the model simulations easily demonstrate the gains in allocative efficiency between a technically efficient set of facilities characterized by the current pattern of facility spacing and the optimal pattern of size and spacing, some readers will ask that the full efficiency gains from changing from the current x-inefficient set of facilities and an allocatively efficient set of facilities be estimated by the model. The problem is that the model is based on functions that impose technical efficiency on the solution even though the radius between facilities is not consistent with allocative efficiency. The model simply will not allow facilities to have five windows, ten thousand feet of interior space, twelve employees and only produce one million dollars per year in revenue even if the real world does include such cases of obvious x-inefficiency. Measurement of the full gain from moving from the present x-inefficient system to an allocatively efficient alternative requires detailed information on the current state of actual costs and revenues that would have to be produced from USPS data sources. Some of this information was not available for this project. The model itself only generates technically efficient solutions.

In order to satisfy curiosity regarding the likely relation between gains due to movement from x-inefficiency to x-efficiency compared to the further gains from moving to allocative efficiency, a special application of the model to a sample market area has been implemented as section 6 of this report and section 7 contains rough national estimates.

3. Specific Statement of the Problem and Solution

Going from a general to a specific statement of the postal store location problem requires that the general functional forms be replaced by specific equations. There are two steps in this process. First, functions must be replaced with equations that can be justified in terms of economic theory. Second, the parameters of the equations must be estimated using USPS data on revenue and facility characteristics.

This section discusses the first of these tasks. As suggested in the general solution, there are three fundamental relations to be understood: the determinants of revenue per square mile (*f(D, r),* and then the relations between revenue and windows (*g(R)*), space and windows (*i(W)*), employees and windows (*h(W)*), and space and rents (*j(S, r)*. As noted above, each of these relations should be based on a facility operating at or near capacity. In this section, each of these issues is discussed in turn.

Determinants of revenue per square mile of market area

Demand for retail postal facilities is based on local employment and residential population. Following standard practice in the literature, assume that demand for retail postal services is given by:

$$q = \alpha - \beta(P + tx) \qquad (8)$$

where q is the quantity of services used by an individual household or firm, P is the price of postal services, t is the cost of transportation to and from the facility, x is the distance to the nearest facility and $\alpha > 0$ and $\beta < 0$ are parameters. This is a simple linear demand curve where the total cost of the services is the sum of the price and the transportation cost, tx, to access the facility. The problem is simplified by the fact that P is known to be constant across facilities.

Assuming that facilities serve a circular market area of radius r so that the market area is $\pi r^2 = A$, the distance between facilities is $2r$, and that demand for postal services comes from households or firms (the illustrative equation could apply to either group although α, β, and t would be different for households and firms), total demand at any facility is given by:

$$QA = \frac{f(D,r)}{P} = \int_0^r 2\pi x D(\alpha - \beta(P + tx))dx \qquad (9)$$

where QA is total sales per facility and D = the density of households or firms measured as households or employees per square mile. There is a direct connection between equation (9) and equation (1) above, and multiplying by P gives an expression for total revenue that is equivalent to (1):

$$RA = PQA = Pf(D,r) = P\int_0^r 2\pi x D(\alpha - \beta(P + tx))dx \qquad (10)$$

Evaluating (10) we find that total revenue per facility can be written as:

$$RA = Pf(D,r) = P2\pi r^2 D[\left(\frac{a}{2}\right) - \left(\frac{bP}{2}\right) - \left(\frac{brt}{3}\right)] \quad (11)$$

Recognizing that P is a constant, this equation says that total revenue of a facility is the product of the total number of households or employees in the market area *($\pi r^2 D$)* and a constant, *2P[(a/2)-bP/2)],* and a constant multiplied by the radius of the facility service area, *2P(-bt/3)r*. It is convenient to write equation (11) as:

$$RA = Pf(D,r) = (\pi r^2 D)[P(a - bP) - \left(\frac{2bPt}{3}\right) r] \quad (12)$$

or

$$RA = Pf(D,r) = (\pi r^2 D)[\theta - \tau r] \quad (13)$$

where $\pi r^2 D = N$ is the total number of households or employees (i.e. potential customers) in the service area of the facility, θ is the constant *($aP\text{-}bP^2$)*, and τ is another constant, *(2Pbt/3)* which includes the effects of transportation cost on demand. Note that the effect of increasing market radius on revenue depends on two effects. First is the negative effect due to the τr term as higher transportation cost cuts demand by effectively raising the cost of accessing retail services. As suggested above, $f_r < 0$ as average revenue per square mile falls when r rises. However, raising r increases market area and hence raises the number of customers (dN/dr = $2\pi rD > 0$). The second effect on *f(D,r)A* dominates, and total revenue per facility rises when r increases.[10] In the next section, equation (13) will be shown to provide the basis for the empirical estimation of the facility revenue equation that is vital to the exercise conducted here.

Relation between revenue and retail input needs

Postal stores produce retail postal services principally using inputs of labor and space.[11] The challenge is to relate revenue generated, principally walk in revenue, at stores to required inputs of labor and space that can then be priced to form a cost function. Fortunately, the USPS collects revenue data through the POS system of wired registers in a substantial number of retail stores. It is possible to observe the relation between the number of registers in a store and the amount of revenue. There are obvious technical reasons to expect that a given quality of service can only be maintained in a postal store experiencing additional walk-in demand by increasing the number of operating registers. In the POS data some registers are clearly dedicated to retail services and are termed "front" and others are "back," although they sometimes take in significant amounts of revenue. Some front registers are located at formal front windows and others at counters. In the POS data it is possible to identify all registers that perform a significant revenue-generating function and, as noted above, these are termed

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[10] There are technical reasons for this result that need not concern us here.

[11] The emphasis here is on operating inputs and operating costs, and general and administrative costs are ignored.

"windows," W. It is expected that there should be a relation between total postal store revenue and required windows that takes the following specific functional form:

$$WA = \kappa(RA)^{\lambda} \quad (14)$$

where: κ is a constant approximately equal to the reciprocal of the annual revenue expected from operation of a single window and λ is the relation between additional revenue and the need for added windows.[12] It is expected that λ will be slightly less than unity because adding more registers permits specialization in services and should raise revenue per window slightly. Note that (14) expresses the relation between annual revenue per store and number of windows per store assuming that the windows are kept busy. Clearly, the causality runs from revenue to windows. Doubling windows should have no effect on revenue unless the previous number of windows was inadequate to deal with demand and significant lines and wait times were experienced by patrons. Sometimes window services are used by customers who are not generating revenue. For purposes of this model, it is assumed that these activities are proportional to revenue generation and simply reduce the potential of windows to generate revenue. It is possible in the USPS data to find cases in which facilities with several windows generate very little revenue. It is important to evaluate (14) based on facilities where the registers are operating near capacity.

Relation between windows and labor requirements

Registers must be staffed. While employees have duties beyond direct revenue generation, the data reveal a reliable relation between windows and the number of clerical employees operating the registers at each facility.[13] The general form of this relation was determined to be:

$$LA = \varphi(WA)^{\chi} = \varphi(\kappa(RA)^{\lambda})^{\chi} \quad (15)$$

where φ indicates the clerical employees required to staff a postal store with a single window and $0 < \chi < 1$ indicates the rate at which employment expands with additional windows.[14] Returns to scale in staffing arising from the ability to relieve workers systematically suggests that doubling the number of windows does not require doubling the number of employees, and the data confirms this expectation.

Translating labor inputs into labor cost requires an estimate of unit labor cost for employees. Because workers can be reassigned across facility size categories in a flexible manner, a constant labor cost was used for all units of clerical labor.

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[12] Equation (14) relates to the function in (2) as $W = g(R) = \kappa(RA)^{\lambda}/A$

[13] The analysis relies on the assumption that the non-register activities of employees observed in the data do not vary systematically with the number of windows. Estimation of equations designed to explain retail employees consistently revealed that the number of windows is the dominant factor determining employment. To the extent that this is not true, some adjustment of the relation between size and labor cost attributed to revenue generation is needed.

[14] Equation (15) relates to the function in (3) as $L = h(w) = \varphi(WA)^{\chi}/A$

Relation between windows and postal store space needs

There appear are be two ways to develop the relation between windows and required postal store space needs. The first is to use the traditional economic approach of taking data from actual USPS operations to estimate a production relation. Alternatively, design criteria for facilities and operating standards developed for services can be used to infer a relation between revenue and space needs. Current postal store designs relate number of windows to overall area. These two approaches will be discussed in turn.

First, the traditional economic approach to relate inputs to outputs is through a production function. In this case, the labor input is ignored, leaving only space input, and the general form of the postal services production function may be written as:

$$SA = \mu(WA)^{\nu} = \mu(\kappa(RA)^{\lambda})^{\nu} \tag{16}$$

where *SA* is the total size of the facility in square feet expressed as the product of size per square mile (*S*) and market area in square miles (*A*), *W* is windows per square mile, and μ and ν are parameters to be determined empirically.[15] It is anticipated that μ reflects the space required for a facility with a single window and $0 < \nu < 1$ because space needs increase at a decreasing rate with windows due to certain indivisible space requirements for doorways, bathrooms, etc. The discussion here is in terms of total space per facility because that is what is observed in the data and this section is designed to set up the empirical analysis to follow.

The second method that could be used to relate postal store size and revenue would be to use facility design criteria that have been established by the USPS along with current criteria that relate window operation time to retail revenue. This might be termed an engineering approach to the production function relation. Currently, the USPS has postal store design criteria that relate the number of windows and number of carriers assigned to a facility to the physical size of the facility. This is done through a form of "look up" table in which different combinations of windows and carriers are related to different designs.[16]

In this report both methods were employed. However, the final model calibration was based primarily on the second, engineering, approach because it presumably reflects current USPS thinking about the relation between space and windows. The economic approach gave larger space requirements which may reflect past policies of providing greater space per window.

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[15] Equation (16) relates to the function in (4) as $S = i(W) = \mu(WA)^{\nu}/A$.

[16] At the same time, USPS has standards for labor productivity that relate window operating time to revenue. Taken together, these standards would allow one to work backwards from retail revenue expectations for each facility to the size of facility needed to meet those expectations.

Relation between postal store size and cost

In connection with the setting of P.O. Box fees, the USPS has established a procedure for estimating the current rental price of its facilities. Based on this work, as well as the general literature on the relation between the size and rent of office space, the costs of space should increase at a decreasing rate with facility size. This leads to the following basic specification of a postal store rental cost equation:

$$C_S A = \Upsilon(SA)^{\phi} = \Upsilon(\mu(WA)^{\nu})^{\phi} = \Upsilon(\mu(\kappa(RA)^{\lambda})^{\nu})^{\phi} \qquad (17)$$

where $C_S A$ is the total rental cost of the facility written as the product of rent per square mile of market area (C_S) and market area (A), and ϒ and ϕ are parameters to be determined. Because rent increases at a decreasing rate with size, it is expected that $0 < \phi < 1$.

Obviously space costs depend on many factors other than size. Space in an enclosed mall is usually much more expensive than in a standalone structure. Decisions regarding location in more or less expensive settings are not part of this study. Space cost also varies with location, and the model formulated here does consider the effect of location on rents through variation in the ϒ parameter whenever more expensive space is being considered.

Solving the model

Recall from equation (6) above that welfare per square mile may be written as the difference of revenue net of mailing cost and the sum of labor and space cost per square mile or that:

$$\omega = \psi f(D,r) - Eh(g(f(D,r))) - j(i\left(g(f(D,r))\right),r) \qquad (6)$$

Or

$$\omega = \psi R - C_S - C_L$$

Furthermore, when welfare per square mile is maximized, overall welfare is maximized. The discussion presented above has demonstrated that $RA = (\pi r^2 D)[\theta - \tau r]$, $C_S A = \Upsilon(SA)^{\phi} = \Upsilon(\mu(WA)^{\nu})^{\phi} = \Upsilon(\mu(\kappa(RA)^{\lambda})^{\nu})^{\phi} = \Upsilon(\mu(\kappa[(\pi r^2 D)(\theta - \tau r)]^{\lambda})^{\nu})^{\phi}$ and $C_L A = LA = E\varphi(WA)^{\chi} = E\varphi(\kappa(RA)^{\lambda})^{\chi} = E\varphi(\kappa[(\pi r^2 D)(\theta - \tau r)]^{\lambda}))^{\chi}$ Market area of these circular markets is given by $A = \pi r^2$. Then dividing through the expressions for RA, $C_S A$, and $C_L A$ by A and collecting terms a bit gives an expression for ω that is not too messy:

$$\omega = \psi D(\theta - \tau r) - E\varphi\kappa^{\lambda\chi}\pi^{\lambda\chi-1}r^{2(\lambda\chi-1)}(D(\theta - \tau r))^{\lambda\chi}$$
$$-\Upsilon(\mu^{\phi}\kappa^{\lambda\nu\phi}\pi^{\lambda\nu\phi-1}r^{2(\lambda\nu\phi-1)}(D(\theta - \tau r))^{\lambda\nu\phi} \qquad (18)$$

The problem is to choose the value of r to maximize ω. This is done by setting the derivative of (18) equal to zero, i.e. $d\omega/dr = 0$. To get some insight into this result note that λ, ν, λ, χ are all on the (0, 1) interval (actually empirically they all lie on the [0.8, 0.95] interval. This means that the exponents of r such as $2(\lambda\chi - 1)$, and $2(\lambda\nu\phi - 1)$, are both negative. Consider the three terms in (18). The derivative of the first with respect to r is negative and the derivatives of the second two terms with respect to r are both positive. The second derivative of the first term with respect to r is zero and the second derivatives of the other terms with respect to r are negative. Taken together, this means that, provided the first derivative is initially positive for lower values of r, equation (18) should produce an internal maximum of welfare at some level of r as the first derivative changes from initially being positive so that increasing radius increases surplus, to negative where increasing surplus decreases surplus.[17]

4. Estimation of the Parameters Needed to Solve the Model

Based on the above discussion, it is evident that estimates of a number of critical parameters, specifically $\psi, \theta, \tau, \kappa, \lambda, \mu, \nu, \Upsilon,$ and ϕ will be needed to evaluate the model. This estimation problem is solved by relying on the theory discussed in the previous sections, and specifically on equations (13), (14), (15), (16) and (17). This effort involved bringing together USPS data from a number of sources along with census data on the characteristics of the areas being served, specifically the number and median income of households and the numbers of employees by type of enterprise. These data issues will be discussed first, followed by the estimation results.

Data sources and characteristics

To perform the statistical estimation and calibration of equations (13), (14), (15), (16), and (17), it was necessary to collect data from a variety of postal and publicly available databases. The integration of these data sources to yield the observed relationships described above is not a straightforward task. However, significant care was given to understanding the nature of these data prior to integrating them. The core data collection process is described below.

It is important to understand that the two major data systems that were identified in conducting this analysis cannot be linked directly. Relating USPS accounting data to facility data is critical to the understanding of the facility size problem. This linkage was conducted through systematic logical merging and visual inspection of the data for this effort. Serious consideration should be given to developing permanent, and completely defined, linkages between these two major USPS data sources to ensure postal retail efficiency.

To perform the analysis of demand for USPS services in equation (13), revenue data per postal facility were collected using USPS's Accounting Data Mart (ADM). Revenue from postal retail services are taken as revenue attributable to either 'walk-in'

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[17] The possibility of a corner solution at $r = 0$ is not important here. As a practical matter, solutions for sufficiently small radius are not feasible because they would imply operation with fractional, windows and employees. There is a minimum size of feasible facility due to the need to have at least one window and retail worker.

revenue or retail revenue based on a detailed analysis that established a relation between General Ledger Accounting and the Account Identification Codes. Household and business, including competitive, activity for a given facility was related directly using US Census ZIP Code Tabulation Area (ZCTA) data and that facility's assigned delivery area. Finally, the radius of a facility was determined using a standard calculation of distance between facilities using facility latitude and longitude as provided by the Facilities Database (FDB).

The relations between revenue and windows in equation (14) and between windows and retail employees in equation (15) are based on the above ADM data used in the demand analysis and on the POS data for individual facilities in 2008. POS data for two "high demand" weeks (the second weeks in April and December) and one "low demand" week (the second week in August) were extracted. The ADM data had annual revenue, the FDB had windows, and the POS data had hourly revenue by register by employee. This allowed two separate estimates of the relations among revenue, windows, and employees.

The calibration of the relation between windows and interior space in equation (16) is based both on a table of the design criteria for new facilities for engineering estimates and on estimates from data from the FDB on the relation between USPS interior area and number of windows. Finally, equation (17) is estimated strictly using FDB data provided on USPS interior area and FMSWIN data on facility rent.

Specification and estimation of the USPS postal store revenue equation

Based on the previous discussion which builds the demand for USPS services from the individual to the market area, the total revenue at a given postal store is given in general by equation (13) above.

$$RA = Pf(D,r) = (\pi r^2 D)[\theta - \tau r] \qquad (13)$$

In this particular formulation there is only one type of customer whose density is given by D, and the total number of customers in the market area of the facility is $\pi r^2 D$. In practice, two types of customers can be identified, households and firms. Household demand is based on the number of households and their median income level. Firm demand is based on total employment. It may be that some household demand is expressed at the workplace rather than the residence.

The τr term reflects the effects of transportation cost to and from the store. To the extent that this reflects travel by automobile, it is well know that vehicle velocity varies substantially across space. In particular, travel speed slows in larger cities. The measurement of travel cost is complicated because travel speeds for various cities vary substantially by time of day. It is also possible that demand by households and firms in urban areas is different than that in other areas. Estimates of equation (13) performed here allow for differences in the effects of population and employment and transportation cost between larger urban areas and the rest of the U.S.

One other consideration influencing total retail revenue at USPS facilities is the presence of competition from other mail delivery services. Thanks to the efforts of IHS Global Insight, two different measures of local competition are available. One is the total employment in private mail services located in the ZIP Codes served by the postal store, and the other is the number of these facilities within the market area of the facility. Given that either measure of competition could reduce effective demand, both were included in the estimated revenue equation.

Based on these considerations, the final form of the total revenue equation is:

$$RA = \alpha_0 + \alpha_1 N_E + \alpha_2 N_E U + \alpha_4 N_H + \alpha_5 N_H U + \alpha_6 N_H M + \alpha_7 N_E I_P + \alpha_8 N_E I_C + \alpha_9 N_E r + \alpha_{10} N_E r U + \alpha_{11} N_H r + \alpha_{12} N_H r U + \varepsilon \quad (20)$$

where N_E is total employment in the market area of the facility, N_H is total households in the market area, U is a 0-1 dummy variable equal to unity in large urban areas, M is median household income in the area, I_P is an index of private mail employment in the area, I_C is an index of competing private mail establishments in the market area, r is the market radius of the facility (half the distance to nearby postal facilities), ε is a random error term, and the α*'s* are parameters to be estimated.[18] There is particular interest in α_9, α_{10}, α_{11}, and α_{12} because these reflect the effect of increased radius on demand, that is, they reflect transportation cost to the facility, represented by τ in equation (13). The terms multiplied by the urban dummy, U, allow the effect of households and firms on demand to be different in large cities and the effects of market radius to differ because of higher transportation costs. The other estimated coefficients reflect the components of θ in equation (13).

Estimates of equation (20) were performed using a variety of statistical techniques on USPS data for facilities, excluding those in Alaska, Hawaii and the territories. Facilities reporting revenue under \$100 and those with a market area less than one-tenth of a square mile were eliminated. The preferred estimation was accomplished using robust regression and is displayed below as equation (20b):[19]

$$RA = 13{,}244.7 + 971.9\, N_E + 13.6\, N_E U + 48.8\, N_H - 15.2\, N_H U + 0.0000344\, N_H M - 188.2\, N_E I_P - 117.3\, N_E I_C - 14.0\, N_E r - 39.9\, N_E r U - 4.7\, N_H r + 3.5\, N_H r U \quad (21)$$

The number of households and employees in the market area of the store has a major effect on revenue. Additional employment is more important than additional households. This may reflect demand by workers based on their workplace or demand by the firms themselves. Higher household income has a modest positive effect on demand. As

[18] The index I_P is 0 when there is 0 private mail employment in the service area of the facility, 1 if employment is between > 0 and < 10, 2 if employment is at least 10 and < 20, 3 if employment is at least 20 and < 30, etc. Similarly, the I_C index is 0 if there are 0 competitors in the service area, 1 if there is 1 competitor, 2 if there are 2 competitors, 3 if there are 3-5 competitors, and 4 if there are 5 or more competitors.

[19] This equation was estimated using 21,898 observations with F(11, 21,886) = 38,000. The t-ratios of the estimated coefficients were all larger than 4.0.

expected, the presence of competitors reduces demand, and the effect of a larger market area also reduces demand.   Location in a large urban area increases the effect of market radius on demand for employment as expected, but it also reduces the effect of households on demand. It is not surprising that, relative to household demand, employment demand is more important in larger urban areas. In general, the effect of households on demand for USPS services is lower in large urban areas. All estimated coefficients are highly statistically significant. This will be used as the basic demand equation in the simulation experiments performed in the next section.

The results in equation (21) provide some insight into the determinants of demand at individual postal stores. It is encouraging that the signs of the estimated coefficients and their general magnitudes agree with prior expectations. This effort to understand demand is directed toward the purpose of a spatial model in which the effect of proximity is of major importance. The results presented here should not be confused with a more fundamental examination of the determinants of the demand for retail services which should involve, at a minimum, greater disaggregation of both household and employment by type as well as greater consideration of the relation between distance and actual transportation cost.[20]

Issues in model calibration due to nonlinear relation between radius and area

In this report, models will be calibrated based on data on actual USPS postal store operations. Similarly, model solutions will be related to the current state of USPS facility size and spacing. When this is done, some caution must be exercised because comparisons will be based on averages for a given area but averages are a linear aggregation of magnitudes and spatial aggregation is often nonlinear. Indeed, the model itself is very nonlinear.

Consider the follow illustration of a potential confusion that can arise in the spatial aggregation process. Assume that there are two facilities and that each has a market radius of 2 miles. The average radius will be 2 miles and the average market area will be $3.14(2^2) = 12.56$ square miles because each market area is identical. Now assume that there are two facilities whose market radii are 1 and 3 miles. The average market radius is still 2 but the market areas are 3.14 (for the 1 mile radius) and $3.14(3^2) = 28.26$ (for the 3 mile radius). Thus the average market area is (3.14 + 28.26) = 15.7. Average area in the "real world" where the radius varies, will be larger than average area in the model solution where radius is constant. In general, the greater the variance in the radius, the larger the excess market area above that calculated based on the average radius.

When comparing results from the model simulations where radius is constant with magnitudes in actual USPS data, the difference between the market area of an average radius when radius is uniform and the real world where the variance in the radius is significant, should be considered. The difficulty can usually be overcome, in this case, by working in average area per postal store. Alternatively, analysis can only be done for facilities with similar market radius. In the calibrations reported here, one or the other of

[20] It would also be useful to consider the precise shape of the market area.

these approaches is taken to avoid aggregation problems. This example is illustrative of the care that is needed when interpolating between model outcomes presented here and current USPS operations.

Specification and calibration of the USPS revenue per window equation

The relation between revenue and number of windows in the postal store was estimated using the same dataset that served as the basis for the demand estimation and the POS dataset discussed above. Measures of the number of "front" registers and "back" registers along with their time of operation and revenue generation are included in the POS data along with the number of windows in the store.

The general form of equation (14) relating windows to revenue, $WA = \kappa(RA)^{\lambda}$, appears straightforward. There are difficulties in estimating the values of the parameters κ and λ. First, the total number of windows, WA, is an integer, whose value at $RA = 0$ should, of course, equal 0. The analysis should focus on values for $WA = 1, 2, 3$, or 4 as these constitute the relevant range for most retail stores. Second, this is a frontier relation in that it reflects the revenue per window achievable under x-efficiency. Observations from the many facilities that have more windows than necessary, as evidenced by the fact that they are never, or hardly ever, shown to be open in the POS data, should be ignored.

Because of the need to observe a frontier, where the relation between windows is based on high rates of utilization, is so important, three approaches were taken to screen out observations from inside the frontier. First, mean revenue per window for different numbers of windows was computed using only observations in which revenue per window was more than one standard deviation above the mean. Second, only facilities where all the windows were operating for most of the time during selected high-demand weeks (the second week in December and April) were used. Third, the demand equation in (21) was used to estimate demand at each facility, and those facilities where demand per window was predicted to be one standard deviation above the mean were used. In all three cases, a clear pattern was observed in which, for facilities judged to be on the frontier, revenue per window for facilities with one window was approximately \$400,000 per year and revenue per window increased slightly as the number of windows increased.[21] As a result of this, the value of κ was set at 0.000005 and the value of λ was set at 0.95. Under these parameters, the relation between windows and revenue reflects a postal store that is technically efficient.

A further check on the calibration of revenue per window was done using data from the Window Operations Survey (WOS) for FY 2008. All of the facilities reporting actual hours equal to earned hours were examined. Average annual revenue per hour of actual window operation was computed and, when this was multiplied by annual hours per window, the average annual revenue per full time window in operation at these facilities was found to be \$642,720, well above the \$400,000 set as efficient revenue per window in this model calibration. Indeed, taking the facilities for which earned hours

[21] The pattern of revenue per window was also tested for the two high demand weeks, and the small increase in revenue per window with number of windows was observed.

were only 75% of actual hours as a standard, average annual revenue per window in full time operation at these facilities was $483,049 and this is also significantly above the standard for technically efficient revenue per window used in this model calibration. Clearly the standard for technically efficient window operation adopted here is not particularly rigorous compared to USPS standards for earned hours.

Specification and calibration of the USPS labor per window equation

Like the revenue per window equation, the labor per window function, given in equation (15) above as $LA = \varphi(WA)^{\chi} = \varphi(\kappa(RA)^{\lambda})^{\chi}$, is also a frontier concept. It is supposed to reflect use of labor in a technically efficient fashion, i.e. at facilities where revenue per employee and window is high. There are some facilities for which the ratio of clerical workers per window is quite high, i.e. greater than two. In such cases, it is likely that these workers are performing a variety of duties unrelated to revenue generation. Fortunately, the POS data allow observation of the hours spent logged in to a register by individual employee identification code by day for each facility. It is possible to identify the number of different employees who spent a significant amount of time at terminals during each of the three weeks that were observed (the second weeks in December, April, and August). Employees who logged on for less than 10 hours per week were not counted as retail employees. Estimates of the parameters in equation (15) were based on facilities where the same numbers of workers were spending significant time logged on to a register during each of these three weeks.[22] The estimates were all based on facilities where the retail operation appears to be operating near capacity so that they were judged to be technically efficient. In this case, facilities with revenue per window above $250,000 per year were selected.

As anticipated, employees per window falls with the number of windows, and the fitted parameters of equation (15) were $\varphi = 1.6$ and $\chi = 0.9$. Thus, within the data on facilities with revenue per window greater than $250,000, those with one window had an average of 1.6 employees per window and this ratio fell slowly as the number of windows increased. Essentially, fitting the ϕ and χ parameters was accomplished based on a table of the mean values of retail workers for facilities with different numbers of windows subject to the requirement that revenue per window exceeded $250,000. The ϕ value was the mean for facilities with one window and χ was fitted based on the rate of decline in retail workers per window as windows expanded beyond one.

To be counted as a retail employee in this analysis, a worker must be logged on to a retail terminal for a significant amount of time in a week and three separate weeks in the year were observed. Clearly workers counted as retail employees did not need to be logged on to the terminal 8 hours per day. It is assumed that they have a variety of other activities to perform that are based on retail activity that are performed when they are not at the window. The crucial relation in the model is that there is a stable relation between windows and workers so that reducing the number of windows should permit reduction in

[22] This does not mean that the employees in one month were the same as those in another month. The employee counts were based on a single week in each month. It does mean that the number of retail workers counted in each of the three months was constant.

employment. In addition to the other tests noted above, this hypothesis was tested by using the number of windows to measure the number of workers in each facility, regardless of revenue. Then other variables were added to the model to see if the number of windows was actually the cause of the number of employees. The testing demonstrated that this was the case. Windows explains workers and the relation is remarkably stable even when other possible intervening factors are added to the model. Accordingly, if windows cause workers, reduction in windows should permit reduction in workers.

Specification and calibration of interior space per window

The functional form selected for the relation between interior space and number of windows was given in equation (16) by: $SA = \mu(WA)^{\nu} = \mu(\kappa(RA)^{\lambda})^{\nu}$. This is also a frontier relation which should be measured for facilities operating under x-efficiency. Empirical estimation of (16) using data from the FDB produced estimates of space required that were well in excess of the standards embodied in current USPS designs in the 2007 USPS SSDB Re-Sizing Table (revised 6/28/2007). Given the forward-looking nature of this report, an engineering approach was taken to the evaluation of the parameters of (16) using the standards for retail facilities in the table. These standards allow for P.O. Box sections and carrier workroom space that is an increasing function of the number of windows (or counters as they are termed in the table). While there are several alternative designs in the table, it appears that 1,800 square feet is an average standard for a postal store with a single counter and that space increases at a slightly decreasing rate with the number of counters. Accordingly, equation (16) was parameterized by setting $\mu = 1{,}800$ and $\nu = 0.9$. Thus, a facility with one window occupies 1,800 square feet of interior space, including the service lobby, P.O. Box lobby, workroom for mail processing, bathrooms, etc. This increases to 3,359 square feet for two windows, 4,839 square feet for three windows, etc.

Specification and calibration of cost per square foot

Estimation of cost per square foot has been accomplished using the FDB in support of P.O. Box fee-setting for over a decade. This provides substantial evidence on the parameters of equation (17), $C_SA = \Upsilon(SA)^{\phi} = \Upsilon(\mu(WA)^{\nu})^{\phi} = \Upsilon(\mu^{\phi}(\kappa^{\nu}(RA)^{\lambda})^{\nu})^{\phi}$. Specifically, it is well established that the cost per square foot falls with facility size and that the elasticity of cost with respect to size is about 0.8, i.e. $\phi = 0.8$. Υ is the cost per square foot appropriate for the real estate market under consideration and ranges from under $5 per square foot in rural areas to over $25 per square foot in the higher density portions of larger urban areas. Cost per square foot also varies with quality of the space, with retail space in malls being particular costly. Decisions regarding structure quality, beyond the minimum needed to meet USPS criteria, are not the objective of this model and will play no role in the analysis. Any cost differences or cost savings reported here are not based on changing the quality of the retail space occupied by the USPS.

5. Demonstrating Characteristics of the Fitted Model

The model described above can be solved to determine the welfare-maximizing spacing and size of retail postal facilities as a function of the density of market demand, including both households and firms, the presence of competitors, household income, and location effects, including differences in the rental price of retail facilities and indicators of transportation costs that vary spatially. The model can also be operated to generate the general level of expected performance of facilities in different locations. Both of these ends are nicely demonstrated by solving the model numerically and demonstrating its predictions for the market for postal services. This section demonstrates some of these model capabilities by using the model to simulate a number of alternative market conditions that the USPS faces and answer some hopefully interesting questions about current USPS operations.

Economics of postal store location in large urban areas versus rest of the U.S.

Investigation of the demand for USPS services indicated that the structure of demand was different in large urban areas than in the rest of the U.S. This is evident in the estimation results for equation (21) reported above where the effect of households and employment on demand is different in large urban areas than in the rest of the data. Compared to residential households, employment is a relatively more important determinant of demand in large urban areas. Also, the effect of market radius on demand for services is greater in large urban areas.

In addition to differences in the parameters of the demand equation, the costs of space are higher in large cities. There are also differences in the density of households and employment and in the density of competition. These differences lead to rather different implications for the allocatively efficient size and spacing of facilities between large urban areas and the rest of the U.S., and the nature of postal store operations is generally very different. All this is illustrated in Tables 1 and 2 and the accompanying figures below.

Table 1 and the associated Figure 1 show the solution of the model for postal stores located in large urban areas based on both the demand function in those areas and the higher density of households and firms and high space cost. A total of 3,423 postal stores fall into this category.[23] The average household density in these areas is 2,259 per square mile, employment density is 355 per square mile, and median household income is $62,382 per year. The model shows that allocative efficiency is achieved when net revenue per square mile is maximized at about $29,801 per square mile with a market radius of 2 miles. The postal store associated with this maximum has approximately 4 windows, 6 retail workers, 6,600 square feet of interior space and 1.73 million dollars per year in revenue. The table also shows the performance characteristics of choosing alternative patterns of postal store spacing.

[23] The 3,423 also reflects the number of facilities with sufficiently complete data to be used in computation of characteristics of the actual condition of facilities in this group.

The actual radius of all the postal stores in these urban areas was 2.1 miles and revenue per facility was 1.25 million dollars. The model estimate of allocatively efficient radius of 2.0 miles matches the average for this group of 3,423 postal stores. The fact that spacing of postal stores in this sample of urban areas is consistent with the spacing suggested for allocative efficiency does not imply that the size or spacing of these facilities is efficient for two reasons. First, the analysis is based on "average" spacing and, in a sample that aggregates over all large urban areas, the average may be appropriate but its detailed distribution on a city by city basis may be flawed. However, the evidence is that, the spacing of these facilities is not grossly inefficient. There may still be problems of lack of technical efficiency as the analysis is disaggregated to the individual MSA level. Nevertheless, the fact that the average size for all postal stores in the sample is about 7,000 square feet, compared to the optimal 6,600 square feet indicates that facility size is not, on average, inconsistent with allocative efficiency either.[24]

Second, the discussion thus far has not considered technical efficiency of the actual postal stores found in these large urban areas. The results for allocative efficiency above were based on the assumption that the actual size, in terms of interior space, number of windows, and clerical staffing was technically efficient. Technical efficiency requires that the actual sizes be efficient given the actual demand for services at each postal store. Measurement of technical efficiency for over 25,000 postal stores is limited because the number of windows in operation and the level of clerical staffing are only observed for facilities with POS terminals. Nevertheless, a rough estimate of technical efficiency can be obtained by using data from the POS facilities to impute windows and retail workers for the non-POS postal stores. In the case of the following analysis, this imputation was done by relating facility size (interior space) to numbers of windows and workers for those facilities with POS terminals and then using the resulting relation to estimate windows and workers for non-POS postal stores.

The result of the imputation is that the average numbers of windows, retail workers, and interior space can be substituted into the cost equations and the imputed characteristics of the actual postal stores in large urban areas can be compared to the technically efficient costs. In Table 1 below, a technically-efficient facility serving the allocatively efficient average market radius of 2 miles has 4.2 windows, 5.8 retail workers, 6,568 square feet of interior space. Total cost for the 12.56 square mile market area is $489,733 or $38,991 per square mile. The imputed characteristics of the current average postal store in large urban areas, where actual market radius is about 2 miles, are 2.95 windows, 4.63 workers, and 16,484 square feet of interior space. This yields an imputed cost per square mile of $33,275. This is a remarkable $5,716 less than the technically efficient cost per square mile.

Compared to the technically efficient postal store, actual facilities have fewer windows and retail workers but more interior space on average. Is it possible that the actual operation of USPS retail postal stores in large urban areas has achieved some kind

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[24] Specifically, average facility size for those facilities with < 20,000 square feet is 7,000 square feet. Larger facilities likely include significant mail processing and/or vehicle storage and maintenance activities.

of super efficiency? Are the standards for technical efficiency in the model too low? Alternatively, it may be that the numbers of windows and employees provided in these facilities in large urban areas are too small resulting in long lines and poor service. Insight into these questions is gained from comparing the actual revenue per facility with model estimates based on the demand equation. Actual revenue per facility is $1.25 million compared to the demand model estimate of $1.7 million, a difference of almost $40,000 per mile of market area. The reason that the model requires more windows and retail workers is that the model generates estimates of significantly more revenue than the actual postal stores generate. Although these are rough estimates based on averages over thousands of postal stores, the suggestion is that, while the average spacing of postal stores (and hence the average number of facilities) is consistent with allocative efficiency, the number of windows and clerical staffing per facility appears to be too low given the demand for postal services.

For reasons stated in the appendix, the Mystery Shopper Dataset could not be usefully related to the demand model but it may be that significant waiting time at postal stores in large urban areas deters potential customers from using the USPS. A rough estimate of the net revenue loss per square mile due to this under provision of window space would be $40,000 of extra revenue per square mile less approximately $6,000 in extra cost per square mile or $34,000 per square mile. This is slightly larger than the net benefit per square mile of the average postal store in a large urban area under allocative efficiency, i.e. it is substantial. Some caution is warranted here because these estimates are based on averages of very large and diverse facilities located across all large urban areas. Still, the analysis of technical and allocative efficiency is consistent in the conclusion that the number and spacing of postal stores in large urban areas is appropriate on average and that the number of windows and workers or alternative mechanisms for providing retail services should, if anything, be larger.

Table 1
Estimated Revenue and Cost at Different Radii for Large Urban Areas

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	146,186	0.4	0.7	795	60,711	15,773
0.75	302,700	0.8	1.3	1,481	112,208	22,161
1	510,656	1.3	2.1	2,316	174,552	25,725
1.5	1,055,126	2.6	3.8	4,308	322,503	29,025
2	**1,728,068**	**4.2**	**5.8**	**6,568**	**489,733**	**29,801**
2.5	2,477,950	5.9	7.9	8,939	664,648	29,265
3	3,253,245	7.7	10.0	11,282	837,166	27,935
3.5	4,002,422	9.4	12.0	13,469	998,012	26,081
4	4,673,953	10.8	13.7	15,379	1,138,339	23,858
4.5	5,216,309	12.0	15.0	16,892	1,249,452	21,368
5	5,577,959	12.8	15.9	17,889	1,322,572	18,680
5.5	5,707,375	13.1	16.2	18,243	1,348,563	15,846
6	5,553,028	12.8	15.8	17,820	1,317,554	12,907
6.5	5,063,387	11.7	14.6	16,468	1,218,306	9,900
7	4,186,925	9.8	12.4	13,998	1,036,897	6,867

Employment density = 355 workers/square mile; residential density = 2,259 households/square mile; income = $62,382.

Figure 1

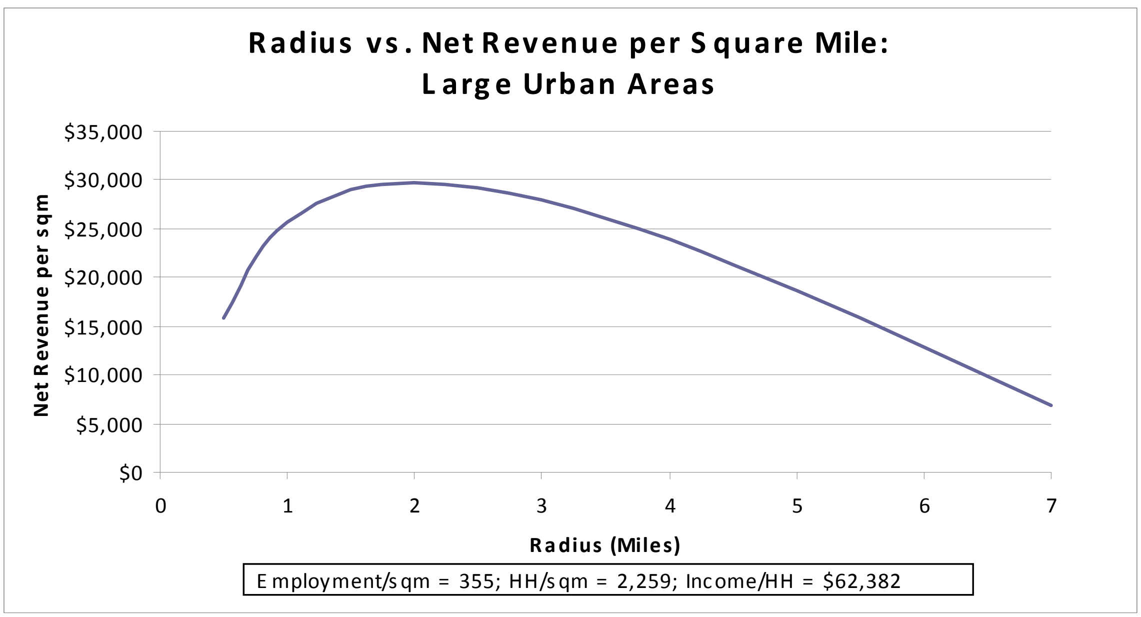


Table 2 and Figure 2 illustrate the model solution in the average area outside large cities. This includes smaller cities, towns, and rural areas. The average density of households is dramatically lower at 130 per square mile as opposed to 2,259 for large cities. Employment density is 26 per square mile compared to 355 and there are fewer competitors. The model is solved for the revenue, employment, and size implications of alternative market radii separating postal stores under conditions of technical efficiency. Allocative efficiency is achieved when net revenue per square mile is maximized at $4,589 when market radius is 6 miles. This is a substantial contrast to the large city solution where net revenue per square mile is larger by a factor of 6.5 and radius was one-third as great. The postal store that maximizes net revenue per square mile has between 5 windows, approximately 7 employees and 8,000 square feet of interior space.

Data on actual postal stores in this outside large city group indicates that the average radius is 4.7 miles, revenue is only about $410,000 per year, and the average facility size is only 3,100 square feet.[25] There are 22,811 postal stores in this group.

Comparing allocative efficiency with a radius of 6 miles with the actual radius of 4.7 miles from Table 1 it appears that net revenue per square mile is $75 ($4,589 - $4,514) per mile higher with a radius of 6 miles. This may seem like a small margin but the 22,811 postal stores in question have an average market area of 106 square miles and this means that the total difference in annual net revenue per square mile is approximately $180 million per year. This is a rough estimate of gains that could be achieved because it is an average over areas with very different levels of service. In general, the greater the geographic disaggregation, the larger the welfare gains from right-sizing and right-spacing the postal stores.

It is also possible to conduct an analysis of the technical efficiency with which retail services are currently produced. As discussed above for the case of postal stores in large urban areas, the challenge for measuring costs of current operations is that numbers of windows and retail workers are only observed for POS postal stores. Once again, the answer to the missing observations is to impute the numbers of windows and retail workers. The imputation produced estimates, for the average facility, of 2.13 windows, 3.46 retail workers, and 4,764 square feet of interior space for the 22,811 postal stores in the non-urban sample. This produced a cost per square mile of market area of $4,486. These magnitudes are all substantially above the technically efficient averages of 1.1 windows, 1.75 workers, 1,964 square feet of interior space, and $2,264 cost per square mile for technically efficient facilities located with a market radius averaging 4.5 miles. The difference in cost per mile, $2,222 = $4,486 - $2,264, when multiplied by the 22,811 postal stores and the 106 square miles of average market area produces an increase in total cost due to technical inefficiency of $5.4 billion dollars per year. The standard cautions regarding estimates based on imputed values of windows and employees as well as averages computed over all facilities located outside large urban areas are in order here. It may be that relation between the size and number of active retail windows in

[25] Note that predicted revenue at a radius of 4.5 miles is much larger than actual revenue. This illustrates the difficulty of applying the demand model to large diverse areas and also may point to a further problem in revenue generation in low demand density area.

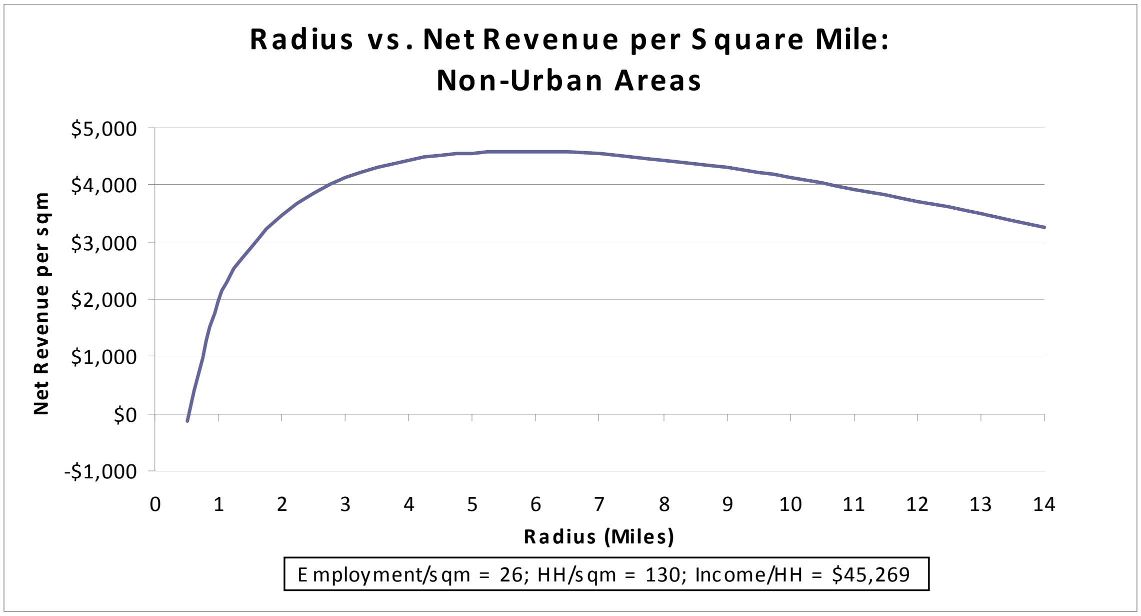
non-POS facilities is much lower than that for POS facilities. If true, the technical inefficiency estimate would be substantially lower. Furthermore, the ratio of employees per window for non-POS facilities may be significantly lower than that for POS facilities. This would also lower the $5.4 billion dollar per year estimate of technical inefficiency. Even if this cost figure were reduced by half due to systematic differences between POS and non-POS facilities, the annual cost of technical inefficiency is impressive and the question of differences between facility types should be investigated.

Table 2
Estimated Revenue and Cost at Different Radii for Non-Urban Areas

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	32,799	0.1	0.2	222	16,505	-134
1	89,932	0.3	0.5	525	38,814	1,959
1.5	182,347	0.5	0.9	960	70,721	2,895
2	307,748	0.8	1.3	1,502	110,308	3,469
2.5	463,839	1.2	1.9	2,133	156,320	3,852
3	648,324	1.7	2.5	2,841	207,797	4,118
3.5	858,907	2.2	3.2	3,613	263,945	4,303
4	1,093,291	2.7	3.9	4,441	324,072	4,430
4.5	1,349,181	3.3	4.7	5,316	387,561	4,514
5	1,624,280	4.0	5.5	6,230	453,848	4,564
5.5	1,916,292	4.6	6.4	7,175	522,408	4,587
6	**2,222,922**	**5.4**	**7.2**	**8,146**	**592,751**	**4,589**
6.5	2,541,872	6.1	8.1	9,136	664,408	4,572
7	2,870,847	6.8	9.0	10,138	736,934	4,540
7.5	3,207,551	7.6	9.9	11,146	809,899	4,495
8	3,549,687	8.3	10.8	12,155	882,889	4,438
8.5	3,894,960	9.1	11.7	13,159	955,498	4,373
9	4,241,073	9.9	12.6	14,153	1,027,335	4,298
9.5	4,585,731	10.6	13.4	15,130	1,098,012	4,216
10	4,926,636	11.4	14.3	16,087	1,167,151	4,128
11	5,588,007	12.8	15.9	17,916	1,299,323	3,934
12	6,206,816	14.2	17.4	19,600	1,420,905	3,721
13	6,764,695	15.4	18.8	21,096	1,528,985	3,493
14	7,243,276	16.4	19.9	22,366	1,620,654	3,251

Employment density = 26 workers/square mile; residential density = 130 households/square mile; income = $45,269.

Figure 2



Clearly, location in large cities generates far larger net revenue per unit area than in the rest of the country. Total surplus per postal store is the multiple of area and surplus per unit area. Because market area increases with the square of the radius, the total surplus of the large city postal store is $374,300 while the total surplus of the optimal facility outside a large city is $518,740. Differences in surplus per postal store are far smaller than differences in surplus per square mile, and total surplus is actually larger for the facility outside large cities because the market area is 113 square miles instead of 12.5 square miles.

Maximization of total surplus across the nation is achieved by maximizing net revenue per square mile and then multiplying by the 4.1 million square miles of U.S. territory. The dataset used in this study has 28,110 postal stores whose market area totals 2,681,694 square miles. The mean overall market radius is 4.33 miles. The mean market radius in large urban areas is 1.9 miles, virtually identical to the optimal radius produced in the results in Table 1. The mean market radius in the remainder of the sample is 4.7 miles, considerably smaller than the 6.0 miles characterizing the surplus-maximizing solution in Table 2. These results suggest that the actual market radius of postal stores, and by extension the number of postal stores, in larger urban areas is close to the optimum and that there are too many postal stores placed too close together in the rest of the country. Note that the implication for the number of facilities of having a radius of 6 miles is dramatically different than for 4.7 miles. The ratio of market areas is approximately 2 to 1 (actually 113/69 or 1.64 to 1), implying that the optimal number of facilities in the portion of the U.S. outside the largest cities is 61% of the current number.

The analysis of technical efficiency in large urban areas compared to the rest of the U.S. (the "non-urban areas), although requiring imputation of some very important data, produces results that are quite complementary with those from the analysis of allocative efficiency. For large urban areas, the number and spacing of current USPS facilities appears consistent with allocative efficiency and the numbers of windows and workers available appears to be slightly below that needed for technical efficiency. It may be that, in large urban areas, failure to provide adequate retail inputs is costing the USPS significant amounts of revenue. Further study of waiting times and revenue would be needed to make such a determination. For the rest of the U.S., just as allocative efficiency requires fewer postal stores located farther apart, technical efficiency implies a substantial reduction in the number of windows and workers. The estimated gain from moving from the current level of operations in these non-urban areas to a technically efficient condition is $5.4 billion per year and the further gain if these changes were associated with a move to an allocatively efficient number and spacing of postal stores is $180 million per year. Although these are estimates and better data on non-POS facilities might change them significantly, their magnitudes suggest that using modern modeling of facility location could achieve substantial gains for the USPS.

Solving the model for the average location in the U.S.

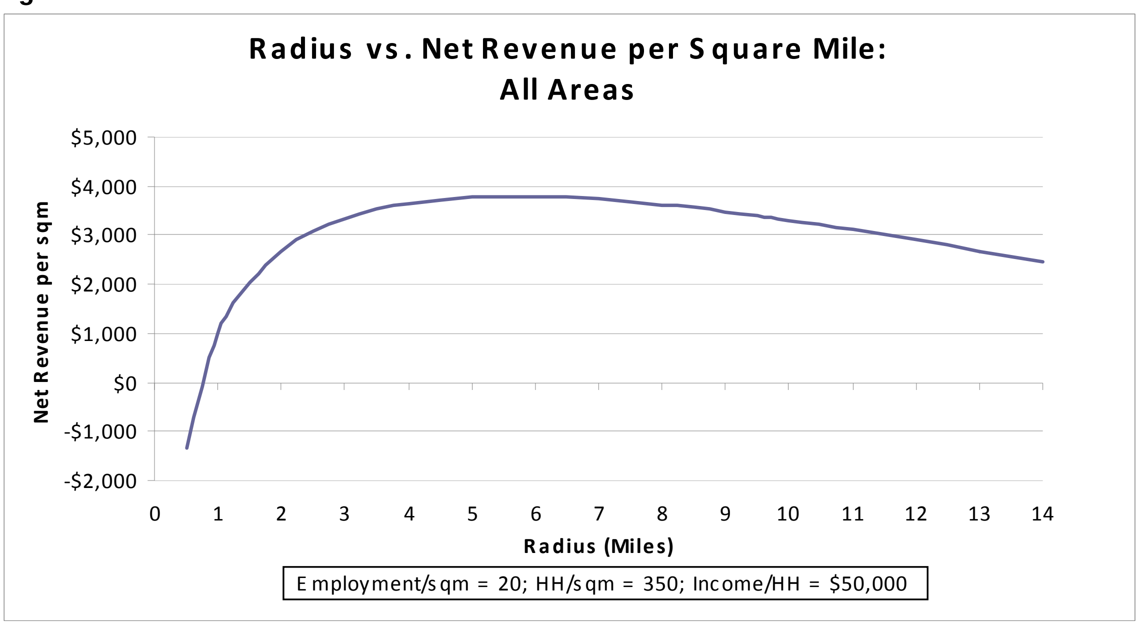
It is also possible to illustrate operation of the model by solving for the average location in the U.S. This involves reestimating the demand equation without the urban dummy variable, inserting the average household and employment densities and the overall median income for the country, and solving the model again. The results are displayed in Table 3, and the relation between radius and net revenue per square mile is shown in Figure 3.

Table 3
Estimated Revenue and Cost at Different Radii for
U.S. Average Employment and Residential Density Areas

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	17,277	0.1	0.1	128	9,688	-1,337
1	67,615	0.2	0.4	411	30,720	983
1.5	148,771	0.4	0.7	807	59,922	2,047
2	258,502	0.7	1.2	1,294	95,737	2,668
2.5	394,568	1.0	1.7	1,858	137,067	3,068
3	554,727	1.4	2.2	2,486	183,041	3,338
3.5	736,736	1.9	2.8	3,169	232,922	3,521
4	938,353	2.4	3.5	3,897	286,061	3,645
4.5	1,157,336	2.9	4.1	4,662	341,873	3,724
5	1,391,444	3.4	4.9	5,458	399,818	3,769
5.5	**1,638,434**	**4.0**	**5.6**	**6,276**	**459,394**	**3,788**
6	1,896,065	4.6	6.3	7,111	520,125	3,785
6.5	2,162,095	5.2	7.1	7,955	581,558	3,765
7	2,434,281	5.8	7.8	8,804	643,257	3,730
7.5	2,710,381	6.5	8.6	9,651	704,802	3,682
8	2,988,155	7.1	9.3	10,491	765,786	3,624
8.5	3,265,359	7.7	10.1	11,318	825,809	3,557
9	3,539,752	8.3	10.8	12,126	884,483	3,481
9.5	3,809,091	8.9	11.5	12,911	941,421	3,399
10	4,071,136	9.5	12.1	13,666	996,246	3,310
11	4,564,371	10.6	13.4	15,070	1,098,056	3,117
12	5,001,523	11.6	14.5	16,296	1,186,927	2,906
13	5,364,654	12.4	15.4	17,302	1,259,875	2,681
14	5,635,830	13.0	16.0	18,047	1,313,871	2,444

Employment density = 20 workers/square mile; residential density = 350 households/square mile; income = $50,000.

Figure 3



The radius that maximizes net revenue per square mile is 5.5 miles and the net revenue per square mile is $3,788. The facility size is fairly large, with about $1.64 million in annual revenue, 4 windows, 6 retail workers, and 6,300 square feet of interior space. The spacing of this average solution is close to that for the area outside large cities in Table 2, but the size of facility is much smaller. This is not surprising because only 3,452 of the 26,263 observations are in large cities.[26] However, this average result illustrates a general point. In a non-linear model, the average solution may not fit any given area very well. The previous result that radius in large cities is currently close to optimal, while that in the rest of the sample is far too large, is blurred as, for the entire sample, the optimal radius is 5.5 miles and the actual is only 4.33 miles. Clearly, aggregation in this model can conceal important information. The revenue per postal store reported in Table 3 is based on a single equation imposed on the entire country. Comparing these results with those in the other tables where revenue is based on estimates reported as equation (21) where large urban areas were allowed to have separate effects illustrates the general advantage of adapting the model to specific geographic areas. Such geographic disaggregation is illustrated in Section 6 of this report which reports results of a case study of the Buffalo area.

Solving the model for high density urban areas and low density rural areas

Given the substantial differences between large urban areas and the rest of the country, it is interesting to go a step further and consider the difference in allocatively efficient solutions between high density urban areas and low density "rural" areas. This is done by using the large urban demand equation for the high density urban areas and the non-urban demand equation for the rural areas. In Tables 1 and 2 the differences in outcomes were due both to differences in the demand equation and differences in density and rent. Any further differences between the results in Tables 4 and 5 in this section compared to Tables 1 and 2 is due to the effects of density and rent per square foot of space between high density urban areas and all large cities and between low density rural areas and the non-large city areas in Table 2.

Table 4 and Figure 4 illustrate that a radius of 1 mile maximizes net revenue per square mile at $77,365 in high density urban areas. This is half the radius and 2.6 times the surplus per unit area found in Table 1 for the average of all large cities. Greater density is, by itself, very important. Household density in the high density sample is 6,900 per square mile (compared to 2,259 for all urban areas) and employment density is 2,000 per square mile (compared to 355 for all urban areas).[27] The number of postal stores falls from 3,452 to 271.[28] With the smaller market area (radius = 1 mile rather than 2), revenue per facility is smaller (1.21 million versus 1.73 million), as are the number of windows (3 versus 4) and size (4,800 square feet as opposed to 6,600).

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[26] The 26,263 observations are facilities with sufficiently complete information that passed a process of casewise deletion to eliminate measurement error.

[27] To put these numbers in perspective, Montgomery County, Maryland, has employment density of 888 and household density of 1,530 while Washington, D.C. has employment density of 4,332 and household density of 4,072 per square mile.

[28] High density areas were selected so that household density was one standard deviation above the average density for all large urban areas.

The 271 postal stores that meet this high density urban criterion have an average market radius of 0.8 miles and revenue of $1.26 million per year. Comparing allocative efficiency of postal stores in high density urban areas with a radius of 1 mile compared to the actual 0.8, it appears that net revenue per square mile is $3,388 ($77,365 - $73,977) higher. Given that there are 271 postal stores with average market area of 2.3 square, the extra annual surplus associated with allocative efficiency totals $2.1 million per year. These results suggest that efficiency gains from adjusting the sizes and spacing of postal stores in high density urban areas are not likely to be large.

Table 4
Estimated Revenue and Cost at Different Radii for High-Density Urban Areas

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	358,152	1	1.5	1,710	129,339	63,359
0.75	737,941	2	2.8	3,173	238,307	73,978
1	**1,210,314**	**3**	**4.3**	**4,844**	**362,228**	**77,366**
1.5	2,295,891	6	7.4	8,374	623,024	74,299
2	3,341,044	8	10.3	11,542	856,284	64,828
2.5	4,071,933	10	12.1	13,669	1,012,693	52,141
3	4,214,720	10	12.5	14,077	1,042,733	37,673
3.5	3,495,564	8	10.7	11,996	889,748	22,307
4	1,640,627	4	5.6	6,283	468,659	6,999

Employment density = 2,000 workers/square mile; residential density = 6,900 households/square mile; income = $43,698.

Figure 4

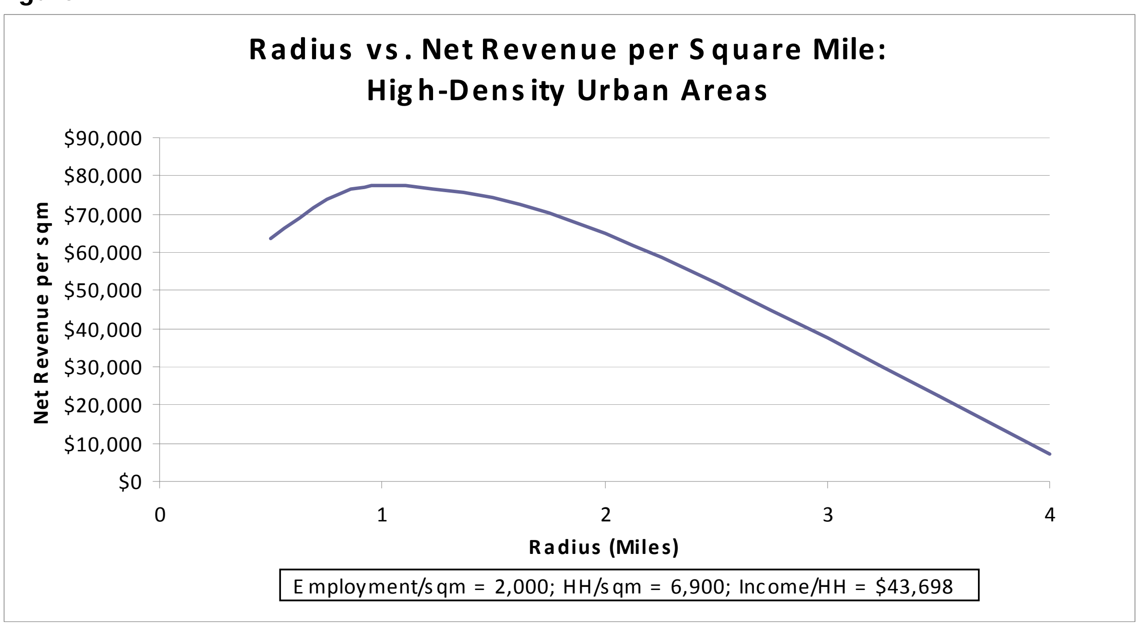


Table 5 and Figure 5 display results for low density rural areas which uses the demand function for areas outside large cities and lower density and rent. Specifically, household density is set at 11 and employment density at 1, well below the 130 and 26 for all observations outside larger urban areas. These densities were selected to reflect rural conditions that characterize a substantial fraction of USPS postal stores. There were 13,616 postal stores in the sample that were in market areas with this average density. Surprisingly the actual radius of these postal stores was only 5.9 miles, not much larger than the 4.7 miles for all non-large city facilities in the group of 22,811.

The optimal radius is 8 miles but net revenue per square mile is only $128. At this point the model solution is barely able to generate a positive surplus. If the ψ parameter introduced and discussed in connection with equation (6) and reflecting the share of revenue not allocated to processing and delivery of the mail were slightly smaller, the model could not produce a solution with positive net revenue. The suggestion here is that, given the cost structure of USPS operations through retail stores, even with an optimal structure of facilities, losses are inevitable on operations in low density areas. In such cases, the CPU offers an alternative business model whose cost structure might well be consistent with positive net revenue. Indeed the optimal facility is characterized by 0.6 windows, one worker, and about $212,000 per year in total revenue. If the solution were constrained to cases with at least one full window, the radius would rise to approximately 13 miles and the surplus per mile would approach $100.

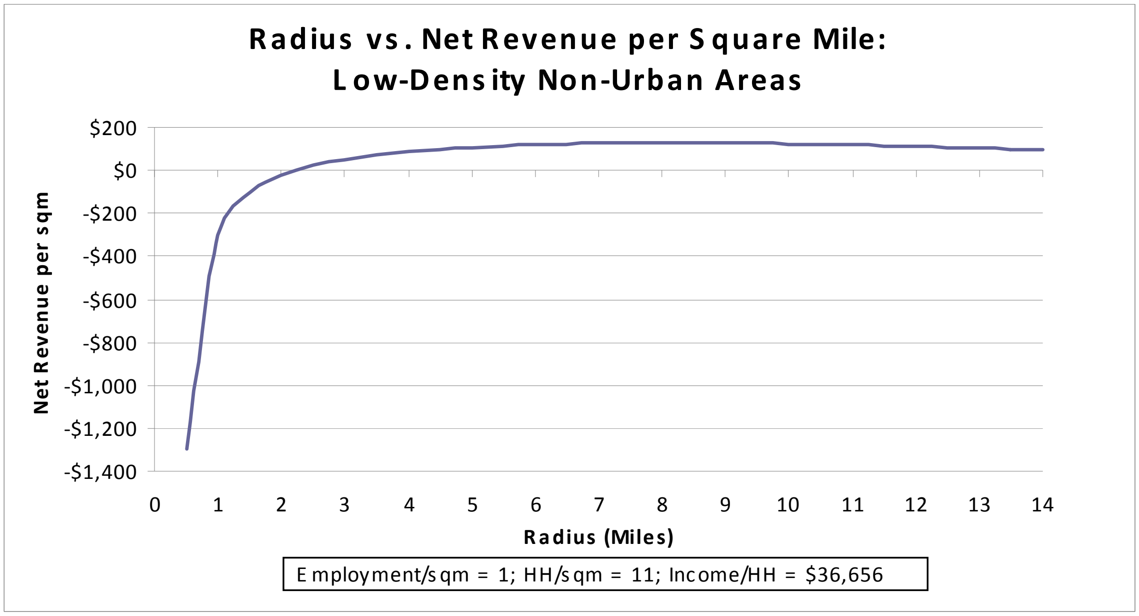
The model solution suggests that the surplus per square mile is $119 at 5.9 miles and $128 at the optimal 8 mile radius. The difference of $9 per square mile, if multiplied by the market area of all 13,616 facilities in these low density areas produces a gain from moving from the current market radius to the allocatively efficient market radius of $18.3 million dollars per year. However, there is a difficulty with this computation because, at the current radius of 5.9 miles and current revenue of $129,000 per postal store, there is clearly substantial technical inefficiency. Clearly these 13,616 facilities, even if they only have one window and one worker, are operating under conditions of substantial overcapacity and hence substantial x-inefficiency.

Table 5
Estimated Revenue and Cost at Different Radii for
Low-Density Non-Urban Areas

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	14,410	0.0	0.1	110	8,226	-1,300
1	17,804	0.1	0.1	131	9,838	-298
1.5	23,271	0.1	0.1	165	12,341	-100
2	30,656	0.1	0.2	209	15,586	-21
2.5	39,805	0.1	0.2	261	19,446	23
3	50,563	0.1	0.3	321	23,818	52
3.5	62,775	0.2	0.3	386	28,613	72
4	76,288	0.2	0.4	456	33,758	87
4.5	90,945	0.3	0.5	530	39,185	99
5	106,592	0.3	0.5	607	44,835	108
5.5	123,074	0.3	0.6	686	50,654	115
6	140,238	0.4	0.7	767	56,589	120
6.5	157,927	0.4	0.8	849	62,594	123
7	175,988	0.5	0.8	932	68,621	126
7.5	194,265	0.5	0.9	1,014	74,627	127
8	**212,604**	**0.6**	**1.0**	**1,095**	**80,569**	**128**
8.5	230,850	0.6	1.0	1,175	86,404	128
9	248,848	0.7	1.1	1,253	92,094	127
9.5	266,445	0.7	1.2	1,328	97,597	126
10	283,484	0.8	1.2	1,400	102,874	124
11	315,272	0.8	1.4	1,534	112,595	119
12	342,975	0.9	1.5	1,648	120,948	112
13	365,355	1.0	1.5	1,740	127,622	104
14	381,175	1.0	1.6	1,804	132,303	95

Employment density = 1 worker/square mile; residential density = 11 households/square mile; income = $36,656.

Figure 5



The exercises constructed in this section indicate that there are significant potential gains in allocative and technical efficiency possible by spacing and sizing USPS facilities using models of the type developed in this report. At the same time that these gains in allocative efficiency are obtained, the model automatically selects facility sizes, numbers of windows, and workers consistent with technical efficiency. Particularly in the model solution for areas outside large cities, it is evident that substantial gains in technical efficiency are possible. The exact form of the adjustments and the nature of the transitions that should be made are complex. For large urban areas, it may be that the size of some facilities, or at least the provision of retail windows, should be increased but the spacing is, on average, appropriate. For non-urban areas there are too many facilities, and readjusting the size and spacing to maximize welfare will reduce the number of facilities. There are also far too many windows. However, the average number of windows in the allocatively efficient postal store spaced at a radius of 6 miles is 1.75 while the average windows in current facilities spaced at 4.5 miles is 2.13. Thus the number of windows per current facility is not a major problem. The major problem is the sheer number of current facilities in non-urban areas.

Using the model to evaluate allocatively efficient facilities for low density areas demonstrates that the allocatively efficient postal store may be impractical because it is simply too small, i.e. 0.6 windows and one worker. This facility produces a surplus per square mile of market area that is about 20% larger than the minimum sized facility large enough to have a single window, and that facility has a 16 mile market radius.

The estimates of technical inefficiency conducted here have involved substantial imputation as well as averaging over very diverse market areas. It is easier to estimate gains in technical efficiency if the focus is on a single market area. Also the actual operation of the model in a planning context is best illustrated by focusing on a specific area. The next section provides such an illustration.

6. Applying the Model to a Market Area: the Case of Buffalo

This section applies the model to a particular market area in order to illustrate two points. First, the steps necessary to achieve such geographic focus are made apparent. Second, the gains from eliminating x-inefficiency as well as from promoting allocative efficiency can both be estimated. The area chosen for study is the Buffalo-Niagara Falls MSA (hereafter Buffalo). The population of this area has been steady since 1990 although, like most other cities, the center city has tended to lose population slowly to the suburbs.

Because population and household density are key driving forces in determining optimal facility size and spacing, it is necessary to explore the area in question to determine how these densities vary. Cursory examination of the Buffalo area indicates that densities generally fall with distance from the city center. Accordingly, the area was divided into three concentric rings for analysis. The first ring is the first 7 miles from downtown. The second ring or annulus covers the area greater than 7 and less than 20 miles from central Buffalo. The third ring includes the remainder of the two counties – Erie and Niagara – that constitute the MSA.[29]

Analysis of the region required solution of the model three times, once for each area. Household density varied from 2,483, to 465, to 120 households per square mile going out from the city center. Employment density also fell from 325, to 58, to 20 as distance increased. Numbers of competitors, employment in mail processing, and rental price of space also fell. Household income was the one exception, peaking in the 7 to 20 mile annulus.

This division of the market into three concentric circles is slightly artificial in that natural market boundaries between facilities are ignored. In an actual planning application of the model, the area under study would be divided into subareas based both on differences in demand density and on current market boundaries between facilities.

Discussion of the innermost circle: Buffalo, 0 to 7 miles from City Center

Table 6 and Figure 6 contain the simulation results for the innermost circle where densities of households, employment, and competitors are highest. Household income is lowest in this circle. According to the USPS Facilities Database, this area is currently occupied by 14 facilities serving an average market area of 6.8 miles, which implies an average market radius of 1.47 (the actual mean radius is 1.33 but recall the non-linear aggregation problem). This accounts for 95 square miles out of a possible 154 square miles in a circle of radius 7 miles. There are two CPU facilities and an air mail in this market area which are omitted from the analysis.[30] The difference presumably reflects the fact that much of the circle would fall over water, and some would even occupy Canadian territory. The model solution that maximizes welfare suggests that market radius should be 2 miles for a market area of 12.56 square miles. Dividing the 95 square miles produces a quotient that indicates an optimum of 8 facilities rather than 14. The gain in allocative efficiency from producing in 8 facilities with a radius of 2 miles rather than 14 facilities with an average radius of 1.47 is (36,904 – 35,457) = $1,447 per square mile or $137,465 per year.

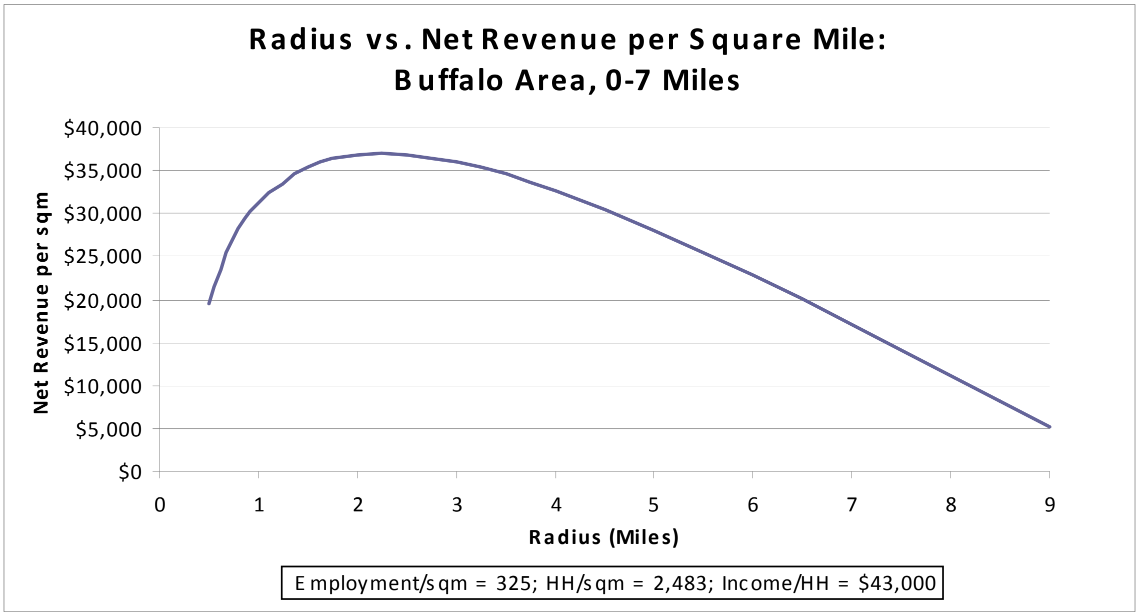
[29] This division of the area is not based on exhaustive study. The point of this exercise is to illustrate the application of the model rather than to make specific recommendations for changes in Buffalo.
[30] Lack of data on CPU facilities has forced their omission from the model.

Table 6
Estimated Revenue and Cost at Different Radii for Buffalo Area, 0-7 Miles from City Center

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	165,774	0.5	0.8	885	67,503	19,597
0.75	347,370	0.9	1.5	1,666	126,042	26,974
1	591,129	1.5	2.3	2,625	197,541	31,218
1.5	1,240,965	3.1	4.4	4,949	369,979	35,457
2	**2,066,932**	**5.0**	**6.8**	**7,655**	**569,958**	**36,904**
2.5	3,020,684	7.2	9.4	10,589	786,144	36,902
3	4,053,875	9.5	12.1	13,617	1,008,883	36,025
3.5	5,118,155	11.8	14.8	16,620	1,229,477	34,567
4	6,165,180	14.1	17.3	19,487	1,439,810	32,699
4.5	7,146,600	16.2	19.7	22,111	1,632,111	30,529
5	8,014,070	18.1	21.7	24,386	1,798,789	28,131
5.5	8,719,241	19.6	23.3	26,209	1,932,286	25,555
6	9,213,766	20.7	24.4	27,475	2,024,936	22,841
6.5	9,449,300	21.2	25.0	28,075	2,068,800	20,019
7	9,377,493	21.0	24.8	27,892	2,055,445	17,115
7.5	8,949,999	20.1	23.8	26,801	1,975,614	14,151
8	8,118,471	18.3	21.9	24,657	1,818,661	11,149
8.5	6,834,561	15.6	18.9	21,283	1,571,427	8,136
9	5,049,923	11.7	14.6	16,431	1,215,558	5,148

Employment density = 325 workers/square mile; residential density = 2,483 households/square mile; income = $43,000.

Figure 6



As noted above, this gain in allocative efficiency ignores the possibility of gains from technical efficiency because the current facilities may not produce given services at minimum cost. Unfortunately, it is not possible to observe detailed cost data for all facilities because information on windows in operation and workers comes from the POS system and not all facilities are on POS. Given this data deficiency, the operating cost characteristics of the facilities with POS data were ascribed to all 14 facilities in the market area. Because POS facilities tend to be larger and to have greater revenue, it is inappropriate to assume that the "missing" facilities in the POS data have the same size, employees, windows, or revenue as those in the data. Instead, they are assumed to have the same "operating ratios" of revenue per window, and revenue per worker. The cost differential between operating with these ratios and with the ratios used to generate the technically efficient results in the model may be compared and the cost of x-inefficiency computed.

In the inner circle, the average annual revenue per retail window is $242,058. Facilities have an average of 2.66 windows and 5.33 retail workers for a ratio of workers per window of 1.89. [31] Compared to the general sample, both the revenue per window and the workers per window are rather high. Given the cost functions in the model, the estimated cost of meeting the predicted total revenue of operating a facility with revenues of $242,058 per window and 1.89 workers per window is estimated to be $679,733 per year. Operating using the technically efficient conditions serving as the basis for the model developed here implies annual facility cost of $369,979. The cost saving per facility from elimination of x-inefficiency is estimated to be $309,754 per facility. Given 14 facilities, the total cost savings from elimination of x-inefficiency at all facilities inside the 7 mile limit is $4.3 million per year.[32] These savings arise largely from the elimination of excess windows and secondarily from a lower ratio of workers per window. To the extent that the high ratio of workers per window is based on non-retail duties of these workers, the amount of x-inefficiency is overestimated. It may also be that the nature of demand at such inner city facilities is different requiring more transaction time per dollar of final revenue.

Discussion of the middle annulus: Buffalo, 7 to 20 miles from City Center

Model results for suburban Buffalo, the area from 7 to 20 miles from the city center, are presented in Table 7 and Figure 7. The Facilities Database identifies 31 facilities in this annulus with an average market radius of 2.4 miles and market area of 21.1 square miles. Geometrically, an annulus ranging from 7 to 20 miles could contain 1,103 square miles, but the market areas cover only 651 square miles because much of the area in the annulus lies either over water, in Canada, or both.

Table 7 indicates that allocative efficiency is achieved with a market radius of 3.5 miles and market area of 38 square miles. Thus, allocative efficiency implies production in 17 rather than the current 31 facilities. The net revenue per square mile at this 3.5 mile radius is $10,611, which is well below net revenue per square mile for the inner annulus

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[31] Average annual revenue per facility is $688,539. Complete data were only available for 3 of the 14 facilities. This is significantly less than the average of $1.2 million per facility for the entire group of 14. Therefore the averages reported here may not reflect the characteristics of all central city facilities.

[32] The $4.3 million in annual savings from eliminating x-inefficiency exceed the $137,465 annual gains from moving further to allocative efficiency by a factor of 30. However, if the size distribution of facilities is to be altered to achieve technical efficiency, it would also appear desirable to achieve gains from shifting production to the correct number and spacing of facilities at the same time.

analyzed above because densities of population and employment are both significantly lower in the suburbs. Compared to the current radius of 2.4 miles, the net revenue per square mile is $531 = $10,611 – 10,080 dollars higher.[33] Multiplying this difference by the 651 square miles of market area gives an estimate of the gain from the increases in allocative efficiency involved in moving to an optimal radius from the current radius of $346,000 per year. This gain is a change due to allocative efficiency in that it is based on the assumption that the facilities in the current 2.4 mile radius are technically efficient. Of course this may not be the case, and the next task is to estimate the gain from eliminating x-inefficiency in the current system.

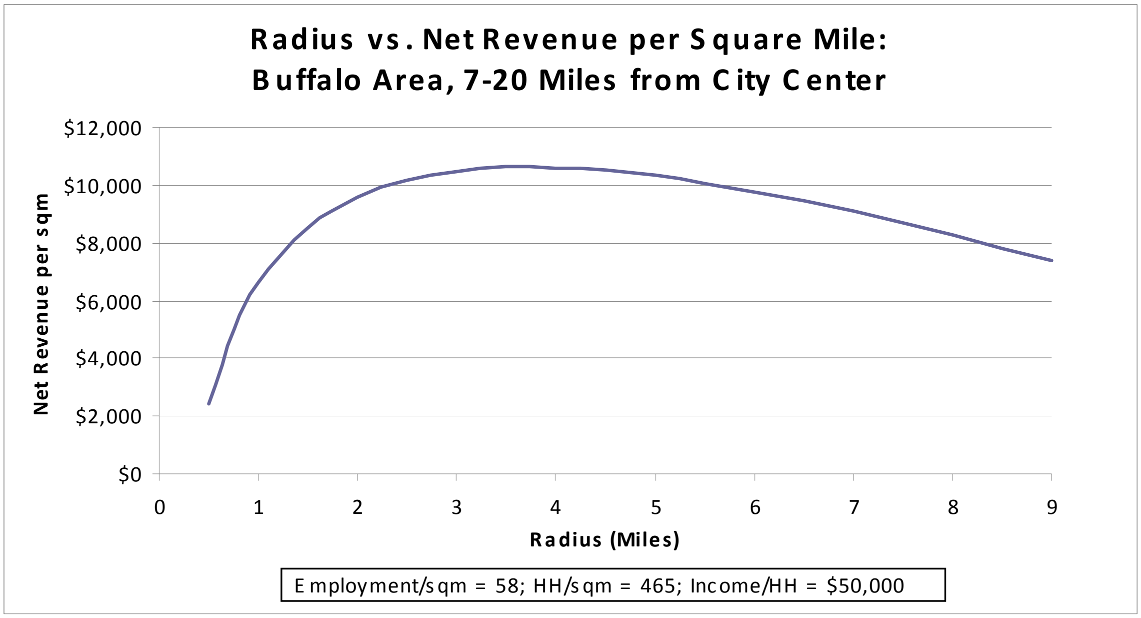
Table 7
Estimated Revenue and Cost at Different Radii for Buffalo Area, 7-20 Miles from City Center

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	59,026	0.2	0.3	366	27,607	2,428
0.75	114,623	0.3	0.6	646	48,394	5,049
1	190,576	0.5	0.9	997	74,425	6,644
1.5	399,206	1.0	1.7	1,877	139,265	8,540
2	676,225	1.7	2.6	2,945	217,761	9,582
2.5	1,012,943	2.5	3.7	4,160	306,842	10,172
3	1,400,671	3.5	4.9	5,489	404,032	10,485
3.5	**1,830,717**	**4.5**	**6.1**	**6,901**	**507,200**	**10,611**
4	2,294,394	5.5	7.4	8,370	614,432	10,604
4.5	2,783,010	6.6	8.8	9,872	723,971	10,498
5	3,287,875	7.8	10.1	11,384	834,167	10,316
5.5	3,800,300	8.9	11.5	12,885	943,455	10,072
6	4,311,595	10.0	12.8	14,354	1,050,328	9,779
6.5	4,813,070	11.1	14.0	15,769	1,153,326	9,446
7	5,296,034	12.2	15.2	17,113	1,251,019	9,080
7.5	5,751,798	13.2	16.3	18,364	1,341,999	8,685
8	6,171,672	14.1	17.3	19,505	1,424,868	8,265
8.5	6,546,966	14.9	18.2	20,514	1,498,230	7,825
9	6,868,990	15.6	19.0	21,374	1,560,681	7,367

Employment density = 58 workers/square mile; residential density = 465 households/square mile; income = $50,000.

[33] Figures for a radius of 2.4 miles are not shown in Table 7. However, the model can be run for any radius and these results were produced using r = 2.4.

Figure 7



Relying on the operating ratios from the 13 facilities in the 7 to 20 mile range of central Buffalo that produce available POS data, it appears that current annual revenue per window is $302,440, and there are 1.60 workers per window.[34] These numbers are far closer to capacity limits set in the model than was the case for facilities in the central annulus analyzed above, and the expectation is that x-inefficiency is far smaller. Generating a cost per facility estimate using these lower operating ratios, produces an estimated annual cost per facility of $450,538 compared to the technically efficient cost estimate of $321,341 in the model. Taking the difference in cost per facility and multiplying by the 31 facilities, produces an estimate of the gain from eliminating x-inefficiency of $4,005,107 per year. While this total gain is comparable to the savings from eliminating x-inefficiency in the innermost circle, the number of facilities has doubled and hence, the gain from "right sizing" per facility is slightly less than half as large as for the facilities in the central area of Buffalo.

Discussion of the outer annulus: 20+ miles outside central Buffalo

The outer annulus has much lower average densities than the suburban annulus and includes a combination of rural and urban places. The edge of this annulus is the boundaries of the two counties, Erie and Niagara, that comprise the MSA, along with the southern Canadian border. The FDB lists 20 facilities in this annulus with an average

[34] In this case the average annual revenue per facility observed in the POS data is $849,113, which is comparable to the average annual revenue of $939,323 for all facilities observed in the FDB. Accordingly, it is likely that the sample of 13 facilities in POS is representative of the population of 31 facilities in the area.

area of 38.2 square miles, i.e. a total area of 764 square miles. The mean radius is 3.25 miles.[35]

The model solution shown in Table 8 and Figure 8 demonstrates that allocative efficiency is achieved with a market radius of 4 miles. Given the total market area of 764 square miles, this implies production in 15 rather than 20 facilities. This change results in an annual surplus of $2,075 per square mile rather than the $2,045 per square mile achieved with technically efficient facilities at a radius of 3.25 miles. The difference in allocative efficiency per mile of $30, when multiplied by the 764 square miles served, results in an annual gain in surplus of $22,920 per year from moving to the larger market radius. This is certainly a modest gain compared to other cases studied. In part that is because the surplus per unit area, even under allocative efficiency, is quite small.

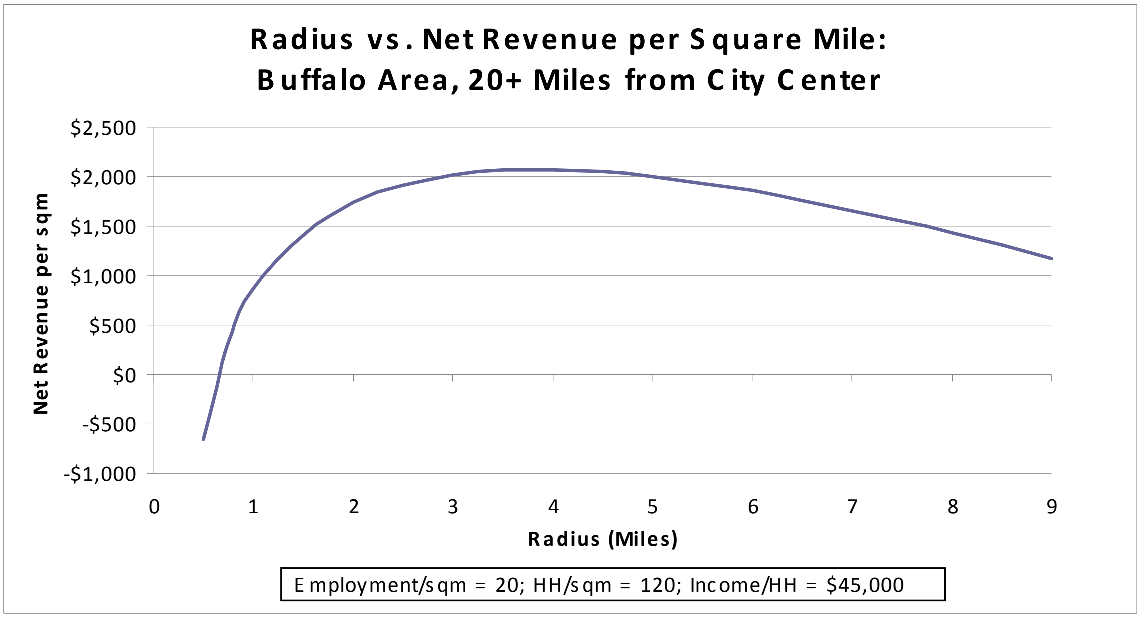
Table 8
Estimated Revenue and Cost at Different Radii for
Buffalo Area, 20+ Miles from City Center

Radius (miles)	Revenue ($)	Windows	Employees	Interior Space (sf)	Cost ($)	NetRev ($)/SqMi
0.5	25,654	0.1	0.2	180	13,340	-653
0.75	40,625	0.1	0.2	266	19,698	348
1	60,959	0.2	0.3	376	27,795	855
1.5	116,279	0.3	0.6	654	48,091	1,422
2	188,730	0.5	0.9	989	72,569	1,735
2.5	275,430	0.7	1.2	1,366	100,063	1,919
3	373,497	1.0	1.6	1,773	129,637	2,021
3.5	480,047	1.2	2.0	2,197	160,479	2,068
4	**592,199**	**1.5**	**2.3**	**2,629**	**191,856**	**2,075**
4.5	707,070	1.8	2.7	3,059	223,087	2,052
5	821,777	2.1	3.1	3,479	253,528	2,005
5.5	933,438	2.3	3.4	3,879	282,558	1,939
6	1,039,170	2.6	3.8	4,252	309,575	1,858
6.5	1,136,092	2.8	4.1	4,589	333,983	1,764
7	1,221,319	3.0	4.3	4,882	355,191	1,660
7.5	1,291,970	3.2	4.6	5,122	372,606	1,548
8	1,345,163	3.3	4.7	5,302	385,624	1,428
8.5	1,378,014	3.4	4.8	5,413	393,626	1,302
9	1,387,641	3.4	4.8	5,445	395,966	1,171

Employment density = 20 workers/square mile; residential density = 120 households/square mile; income = $45,000.

[35] An average radius of 3.25 suggests an average market area of 33.2 square miles. The larger average market area is due to the variation in market areas among the 20 facilities. As discussed earlier in this report, variation in market radius causes the mean market area to be larger than the market area generated by the mean radius.

Figure 8



The POS system contains information on 7 of the 20 facilities in the outer annulus of Buffalo that can be used to estimate operating ratios for use in computing the degree of x-inefficiency or excess capacity in this outer area. Average revenue per postal store in POS is $583,662 per year, which is substantially larger than the average of $328,210 for all 20 facilities. It is not surprising to find that POS facilities are selected from among the largest in this outer area. This may bias estimates of the amount of x-inefficiency downward as the units with greatest excess capacity may not be in POS.[36] For the 7 facilities that are observed in POS, revenue per window is $213,631 and there are 2 clerical employees per window. Compared to the operation of technically efficient facilities serving a radius of 3.25 miles, production with these x-inefficient operating ratios adds $181,286 per year to facility cost. Given the 20 facilities currently in operation, this implies an increase in annual cost due to x-inefficiency of $3,625,720. Clearly, the relative importance of excess capacity or x-inefficiency compared to allocative efficiency as a source of loss of social welfare in this outer annulus is huge.

Lessons from application of the analysis to the Buffalo-Niagara Falls MSA

Because the model of optimal facility size and spacing is very non-linear, it is best to apply it to areas that are relatively homogenous in determinants of the demand for postal facilities. Specifically, it should be applied to areas where the variation in population and employment density is moderate. In the case of the application to Buffalo, the area was split into three subareas, based on distance from the city center, where densities were relatively homogenous. Solution of the model for the optimal size

[36] For example, some facilities not appearing in POS have total annual revenue of less than $50,000. Given the operating ratios associated with efficiency, this suggests very large excess capacity. In the conclusion of this report, some observations about such cases of low revenue due to low demand density will be made. These are cases in which the current business model likely will not permit operations to generate a positive surplus of revenue over cost regardless of the size and spacing of facilities.

and spacing of facilities in these three areas produced allocatively optimal patterns that appear to differ moderately as market radius increases from 2 to 3.5 to 4 miles as distance from the center increases from 0-7 to 7-20 to 20+ miles. These differences in radius are associated with variation in market area from 12.56 to 38.46 to 59.66 square miles. Differences in annual surplus of net revenue over cost per mile fall from $36,904 to $10,611, to $2,075. Differences in optimal facility size are more modest but still consequential.

It would be useful to inform results from Buffalo by using performance data from USPS surveys of service quality and performance. Unfortunately, Mystery Shopper Data were only collected for a small number of facilities covered in this analysis but, if the entire Western New York district is used as a reference point, waiting time was, on average 2 minutes and 38 seconds compared to a national average of 3 minutes 1 second. Further comparisons of earned hours to actual hours of retail terminal activity could be used to verify the model solution suggesting high levels of technical inefficiency.

It is important to keep in mind that the process of moving to technical efficiency will likely involve moving to different facilities, not simply closing selected facilities where operating ratios like revenue per window or revenue per worker are low. Once it is conceded that the process of achieving greater technical efficiency will involve migration of facilities, not just selective closing of facilities, then considerations of allocative efficiency follow automatically. If facilities are going to be resized, then they should be spaced and located in a manner consistent with both technical efficiency and allocative efficiency so that the gains in welfare from both sources of efficiency can accrue to the USPS and its patrons.

7. Summary and Conclusions Regarding the Recommended Size and Location of USPS Retail Facilities

Summary of the research effort

This study is based on the proposition that the spatial approach to location of retail outlets and public facilities found in the academic literature and currently applied in modern business practice can be adapted to the problem of building a model of the welfare effects of the size and spacing of retail postal facilities. The first step in advancing this proposition is to develop a theoretical model of the problem and to adapt it to the particular circumstances of USPS retail operations. Second, this model is calibrated using estimates of the spatial demand for and cost of postal services. The resulting model fits the data on retail revenue remarkably well. The result was a model that is very effective at taking the characteristics of the residential population and employment in an area, along with the presence of competing mail services and the current size and spacing of facilities, and generating estimates of retail revenue received. Third, the implications and potential application of the model are demonstrated by solving for the optimal size and spacing of USPS retail facilities first in fairly general terms and then with a specific application to the Buffalo-Niagara MSA. These applications demonstrate a significant difference between the current size and spacing of retail facilities and an optimal network. Generally speaking, the current network has too many facilities located too close together. The size of facilities may or may not be appropriate. There are cases in which current operations include many facilities with substantial excess capacity that could be fully used if there were fewer facilities. While the results presented in this report may appear similar to other studies, in particular the GAO report of December, 2007, these results are based on a structural model of the benefits and costs of providing postal services that identifies an optimal spatial pattern of production. In reviewing the available literature and discussions with USPS personal no comparable model was found. Indeed, no other spatial model of the demand for USPS retail services that could be found.

The model created as part of this exercise has a number of potential applications to problems of USPS management beyond the decision to close, open, relocate, or resize facilities. First, it allows managers to estimate the expected revenue from a postal store as a function of the population, employment, competitors, etc that surround it. This expected performance can be compared to actual performance to evaluate the performance of a postal store. Second, cost estimates can be made and combined with revenue estimates to evaluate expected contribution to surplus and this can be compared to the actual contribution. Both these first two applications can be useful in evaluating the quality of facility management. Third, in growing areas where there are needs for service expansion, the model can transform projections of future population and employment into estimates of future demand for services and then optimize the retail facilities provided to serve that future development. Fourth, the model can be used to estimate the true incremental cost to the USPS of the universal service requirement because it can estimate the difference in net revenue between allocatively inefficient numbers and sizes of facilities needed to provide universal service and the surplus that could be produced under allocative efficiency. The universal service requirement does not force x-inefficiency on the USPS except insofar as it prevents replacing large facilities with small ones. But, it does force inefficiently small market radii on the USPS, and the differences in allocative efficiency can be large. Fifth, and perhaps most important, is that the model can be used to plan the restructuring of sizes and locations of facilities as part of a program directed at removing both technical and allocative inefficiencies. As illustrated in the case of the Buffalo-Niagara MSA, x-inefficiency is much larger than allocative inefficiency. Nevertheless, any program that reorders the sizes and spacing of retail facilities in that area to achieve technical efficiency could, if directed by the model developed here, also achieve the further gains associated with allocative efficiency at the same time.

All of the above applications of the model have been illustrated in this report. There is another, or sixth, important potential use of the model. Running the model for low density areas demonstrates that the allocatively efficient postal store may be impractical because it is simply too small, i.e. 0.6 windows and one worker. This facility produces a surplus per square mile of market area that is about 20% larger than the minimum sized facility large enough to have a single window, and that facility has a 16 mile market radius. These results are based on the standard USPS post office branch business model that is built into the computations. Recently the USPS has been expanding services through contract postal units, CPUs, whose business model provides retail services at much lower cost. The model developed here is capable of identifying the circumstances under which the CPU in combination with the traditional postal retail store produces larger surplus than branches alone. Furthermore, the model could potentially be modified to estimate the gains from considering this alternative business model.

Overall, the potential gains from moving to a retail system characterized by technical and allocative efficiency appear to be substantial. Two approaches, one general and the other detailed, are taken here. The general approach divides the U.S. into large urban areas and the rest of the U.S. ("non-urban") samples. For large urban areas, the number and spacing of postal stores appears consistent with allocative efficiency and average postal store size is, if anything, smaller than the technically efficient size, perhaps resulting in high waiting times and lost revenue. In the non-urban, allocative efficiency implies producing in substantially fewer facilities located further apart, a six-mile radius rather than 4.5 miles. Technical efficiency would require producing with fewer total windows and workers. The gain from achieving technical efficiency in providing postal stores to non-urban areas is estimated at $5.4 billion per year with a further gain from moving to an allocatively efficient spacing of facilities of $180 million per year. While these are only estimates of the gains from change based on imputed values for non-POS facilities that may have substantial errors, they certainly establish the point that the estimated returns from moving toward a welfare-maximizing solution are substantial.

Detailed analysis of the Buffalo-Niagara MSA, which contains 65 retail facilities, indicates that these would be reduced to 46 facilities in an allocatively efficient solution. Gains in technical efficiency are estimated at $11.9 million per year and those in allocative efficiency at $0.5 million per year for a total of $12.4 million per year. To put this in perspective, the 65 facilities in this two-county area constitute only 0.23% of all USPS retail facilities. To the extent that the gains in this region are typical of the entire country, the total net benefit from using the model to realign the USPS postal store network would be approximately $5.4 billion per year. Of course, scaling returns from 0.23% of the country to the entire U.S. gives, at best, a rough approximation to the true gains. Nevertheless, it is interesting that the results of evaluating gains from achieving technical and allocative efficiency using two independent estimation methods are remarkably consistent.

Conclusions and recommendations

The USPS has much to gain from using modern facility location models to inform decisions regarding expansion and contraction of its postal store system. It does not currently have such a model, indeed the USPS does not even have a model which allows it to estimate the relation between characteristics of the residential population and employment in an area and the demand for postal services. The basic characteristics of such a model are illustrated in this report along with its operational use in a detailed postal store planning process.

Overall, the number and spacing of postal stores in large urban areas appears close to optimal although there is evidence that the numbers of windows and workers should be increased. It is not clear that this requires changing facilities because current facility size is more than adequate.

There at too many postal stores spaced too close together outside large urban areas. Using two different techniques, the loss in net revenue to the USPS from this inefficiency is estimated to be as large as $5.5 billion per year. While this is a very rough estimate due in part to the lack of information on retail employment, particularly in non-POS facilities, the potential social welfare gains from moving to technically and allocatively efficient production are surely large.

In low density, rural areas, the current USPS business model for a postal store results in negative net revenue (losses) attributable to retail operations. Currently these losses are balanced, in part, by cross subsidies from facilities in large cities. Provision of retail postal services through another business model in such areas, possibly through CPUs, should be investigated.

USPS data systems should be directed to support the type of modeling necessary to implement modern facility location models, including measurement of the effects of service quality and waiting time on the demand for services. Mystery Shopper Data should include the exact time when shopping was done. Measurement of retail labor effort, particularly in non-POS locations, is also essential.

Appendix on USPS Data System Constraints

In the course of doing the analysis for this report, a number of problems with current USPS data were encountered that limited the ability to calibrate the model. Removal of these impediments does not seem unreasonable or difficult, and it would allow further improvements to the model and more precise statements about optimal USPS facility planning and management. These data challenges are enumerated below.

Information on numbers of windows (defined as terminals or registers engaged in front office activity and recording significant walk-in revenue) is only available through the POS system. Such detailed information should be in the Facilities Database so that it can be observed for all postal stores. Furthermore, the amount of labor effort needed to accomplish the retail mission at each facility is difficult to measure, even for POS facilities.

For each postal store, questions should be added and serious answers required so that the observation of total interior space is divided into retail functions, mail processing functions, and other activity types as USPS sees fit. Inability to observe space dedicated to retail operations makes it difficult to estimate the productivity of retail space and the amount of excess space in each facility.

The number of retail workers working at each postal store can only be obtained by indirect methods. For purposes of this report, a system was developed for measuring retail workers per facility by noting the frequency with which each different employee appears logged into a terminal. This indirect technique is not an ideal way to measure clerical effort, and it is only available for the subset of facilities connected to the POS system.

The Mystery Shopper Dataset is potentially a valuable source of information on the capacity to serve walk-in revenue. Existence or lack of lines and significant waiting time provides potentially valuable information on the degree of capacity utilization. Unfortunately, the Mystery Shopper Dataset does not give the time of day that the facility was "shopped." This means that it cannot be linked to POS data on revenue which is available by terminal by half-hour interval. The resolution to this problem is exceedingly simple. Among the dozens of data items recorded when a postal store is mystery shopped, record the time of day that the test was performed so that the shopping results can be related to specific POS data for that date and time.