Marginal Cost Pricing and Subsidy of Transit in Small Urban Areas

Jeremy Mattson
David Ripplinger

Small Urban & Rural Transit Center
Upper Great Plains Transportation Institute
North Dakota State University

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Disclaimer

ABSTRACT

This study analyzes economies of scale and density as a rationale for subsidizing transit agencies in small urban areas. A long-run cost model is estimated using data from 2006 to 2009 for 168 transit agencies that directly operated fixed-route bus service in small urban areas. Using vehicle revenue miles as transit output, results show that small urban transit agencies experience economies of scale and density. A full cost model is estimated that includes the addition of external costs and benefits. External benefits result from reduced waiting times following an increase in service frequency. Results are then used to estimate the optimal fare, which is equal to marginal social cost of service. The needed subsidy is calculated as the difference between the revenue generated by the optimal fare and that needed to maintain efficient levels of production. The rationale for subsidies is an important issue as many agencies have experienced recent reductions in operational funding. A survey was conducted that found that close to half of transit agencies in small urban areas have either reduced service or increased fares over the last two years, and the main reason for these actions has been a decrease in operational funding.

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1. INTRODUCTION

1.1 Purpose of Study

The objectives of this study are to quantify the internal and external costs of transit operations in small urbanized areas, determine if there are increasing returns to scale and density for these agencies, and estimate the subsidy required to maintain marginal cost pricing.

A full social cost function for transit operations in small urbanized areas, which accounts for economies of scale and externalities, is estimated. Results are then used to estimate the optimal fare, which is equal to the marginal social cost of service. The needed subsidy is calculated as the difference between the revenue generated by the optimal fare and that needed to maintain efficient levels of production. This method expands on Vickrey's (1980) seminal paper beyond a simple mathematical model to a more detailed econometric model with real-world data.

1.2 Background

Recent economic conditions have forced public transportation agencies across the country to make significant changes to their service and fare structure (APTA 2010). The resulting impacts on system users and social welfare have been considerable. At the same time advocates are emphasizing the importance of transit and its role in community livability and sustainability.

Studying the impacts of transit on the community, the environment, and other transportation system users is necessary to ensure that discussion of national transit policies under consideration are fully informed. This requires identifying the costs and benefits that result from transit, which in turn impacts how the system should be financed, including fare structure and level of subsidy.

Optimal pricing of fares and determination of subsidy levels requires a full accounting of externalities. Like other modes of passenger travel, transit operations results in often unpriced external impacts, including congestion, noise, air pollution, accidents, and land use impacts. Changes in service frequency impact passenger waiting time, a significant, mode-specific externality (Mohring 1972).

The determination of fares and subsidies for transit gains an added level of complexity when the transit provider's cost structure and the behavior and market for other users of the transportation network are considered. In the first case, the presence of increasing returns to scale often allow for monopoly pricing with firms charging prices higher than marginal cost, although this practice for transit in small urbanized areas is not known. In the second case, other passenger modes, especially travel by automobile, are not priced at their marginal social cost. Consequently, second-best pricing of transit becomes a policy alternative to achieve a socially optimal outcome.

Public transportation agencies serving small urbanized areas, those with populations between 50,000 and 200,000, face challenges unique from those in major metropolitan areas. Key among these is low population density, which makes transit a less viable mode of travel. Small urban transit agencies may be providing service efficiently in terms of vehicle miles or hours (intermediate outputs), but due to spread out demand, passenger trips (the final output) may be lower. While in many circumstances, this reduces or eliminates the justification for subsidizing transit to alleviate congestion, it amplifies the impact of passenger waiting times. At the same time, transit agencies that serve small urbanized areas have been found to have different cost structures than their peers (Karlaftis and McCarthy 2002).

Government activity in public transportation includes the creation of monopolies, where transit authorities have exclusive rights to provide public transportation, as well as providing operating and capital subsidies. This intervention in public transportation is often justified on an economic basis. Arguments include the presence of increasing returns to scale and mitigating congestion and other externalities of automobile travel.

In practice and policy development, these economic arguments are often anecdotal. Furthermore, while intervention may be justified, the level of intervention may not. The appropriate type and level of intervention likely varies by community and agency.

1.3 Report Organization

The paper is organized as follows. The next section contains a review of the literature on transit subsidies, marginal cost pricing, cost models, and transit externalities. Section three provides the results of a survey of transit agencies. The target population was those agencies serving communities between 50,000 and 200,000 as reported in the National Transit Database. The survey collected information on changes in service levels, fares, operational funding, and ridership and inquired about the motivation behind service and fare changes, thoughts about the rationale for transit subsidies, and the role that factors such as congestion, safety, and environmental issues play in marketing transit services and obtaining funding.
In section four, a long-run cost function model for transit agencies serving small urbanized areas is developed. The full social cost function accounts for internal costs, as estimated using traditional economic modeling techniques, as well as external costs that include pollution, greenhouse gas emissions, accidents, roadway facilities costs, and waiting time. The model is estimated using data from the National Transit Database. Descriptive statistics for the small urban transit systems analyzed are presented in section five, and results from the cost function model are given in section six. A discussion of the results, conclusions, research limitations, and areas for future study are presented in the final section.

2. BACKGROUND

2.1 Rationale for Subsidies

As Vickrey (1980) wrote, there are three basic elements that provide justification for subsidizing transit: 1) special needs for transit by the underprivileged, such as people with disabilities or low-income individuals who are unable or cannot afford to drive or access other forms of transportation; 2) the existence of subsidies to other modes of travel; and 3) the fact that transit operates under conditions of substantial economies of scale. In addition, there may also be positive externalities associated with transit, including changes to land use and arrangement of the built environment, which could justify subsidies (Elgar and Kennedy 2005).

The first rationale is that transit provides mobility and access to those who would otherwise not have it. By providing this service, transit systems can create substantial benefits to the users and the community. These benefits include increased access to jobs, health care, education, shopping, social activities, etc.; greater economic activity in the community; and a general, unquantifiable, improvement in quality of life for individuals who use the service.

Second, transit subsidies could be justified if automobile travel is also subsidized. One way that automobile travel is subsidized is that there are many social costs to automobile travel not paid by the user. For example, additional automobile travel can increase congestion, air pollution, greenhouse gas emissions, and automobile accidents. These are costs that are borne by society and are referred to as negative externalities. In addition, the cost of supplying parking can often be great, and automobile users often do not pay these costs. Automobile travel can also strengthen dependence on foreign energy supplies. Lower transit fares could reduce automobile travel and the corresponding externalities. In large urban areas, many of these social costs, such as congestion, air pollution, and parking, are serious concerns, while in small urban or rural areas, they may be of lesser concern or no concern at all. Transit vehicles themselves also contribute to externalities such as congestion, pollution, greenhouse gas emissions, and accidents, which need to be measured when evaluating the benefit of transit subsidies.

Economies of scale is also an important element for justifying transit subsidies. With economies of scale, as the number of riders or the level of service increases, the average cost per trip decreases, or the quality of the service improves. Improved service could also result in less cost to the user in terms of less time waiting. Providing these services, though, involves large upfront capital costs. When economies of scale exist, the least costly way to serve users is to have a single entity provide the service. An alternative to subsidizing the transit agency would be to provide payments to underprivileged individuals who lack access to transportation to pay for transportation. Theoretically, there could be multiple organizations competing to provide such rides. However, such a setup would not be as cost effective if economies of scale exist. Subsidies are needed to take advantage of the cost effectiveness of the single agency providing a higher level of service. Scale economies may arise from high fixed costs, but they also arise from the "Mohring effect," whereby waiting or access costs decrease as service frequency or route density increases (Mohring 1972).

Lastly, the positive impacts transit can have on land use and the built environment is sometimes cited as a rationale for subsidies. Transit affects land use by allowing for denser developments and enabling more economically efficient built environments. It can impact locations of households and firms, production and consumption patterns, and land-use values, and it can yield increased agglomeration economies and higher productivity (Elgar and Kennedy 2005). In cities that have higher densities of housing and business as well as mixed-use developments, energy consumption can also be significantly lower because distances between destinations are reduced. Quantifying these positive impacts from transit investments is difficult, however, and while the land use effects might be substantial in large urban areas, they may be quite small in small urban areas.

2.2 Marginal Cost Pricing and Optimal Subsidies

The optimal subsidy can be defined as that which will maximize social welfare, and social welfare can be calculated as total revenues minus total cost plus consumer surplus. From this, it can be shown that social welfare is maximized when prices equal marginal cost (Elgar and Kennedy 2005). Figure 2.1 illustrates how social welfare is maximized when price equals marginal cost (Shy 1995). When price is at P_0, the consumer surplus is equal to α, and revenues minus cost equals β, so total welfare is given by $W = \alpha + \beta$. At this price, the area associated with γ is considered a deadweight loss associated with higher-than-marginal-cost pricing. When the price is reduced from P_0 to P_1, which is equal to marginal cost, then total welfare increases, as $W = \alpha + \beta + \gamma$.

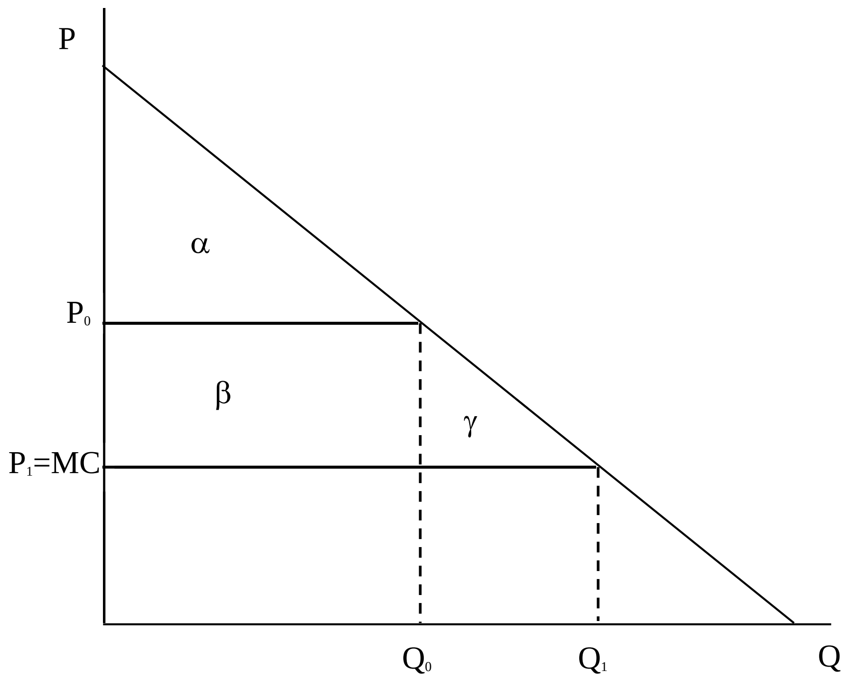

Figure 2.1 Marginal Cost Pricing and Social Welfare

Figure 2.2 illustrates the relationship between long-run marginal cost (LMC) and long-run average cost (LAC). When marginal cost is less than average cost, then average cost decreases with increases in output. Conversely, when marginal cost is greater than average cost, then average cost will increase with output. A production process with the cost curves depicted in Figure 2 experiences increasing returns to scale up to the Q_1 level of output and decreasing returns to scale with output greater than Q_1.

If a transit agency has increasing returns to scale, then marginal cost is lower than average cost. The agency would need to set fares equal to average total cost for it to cover all of its costs, but doing so would result in a decrease in consumer surplus and total social welfare. Setting price equal to marginal cost, therefore, would require a subsidy. The subsidy is required to maintain optimal allocation of resources and efficient levels of production (Elgar and Kennedy 2005).

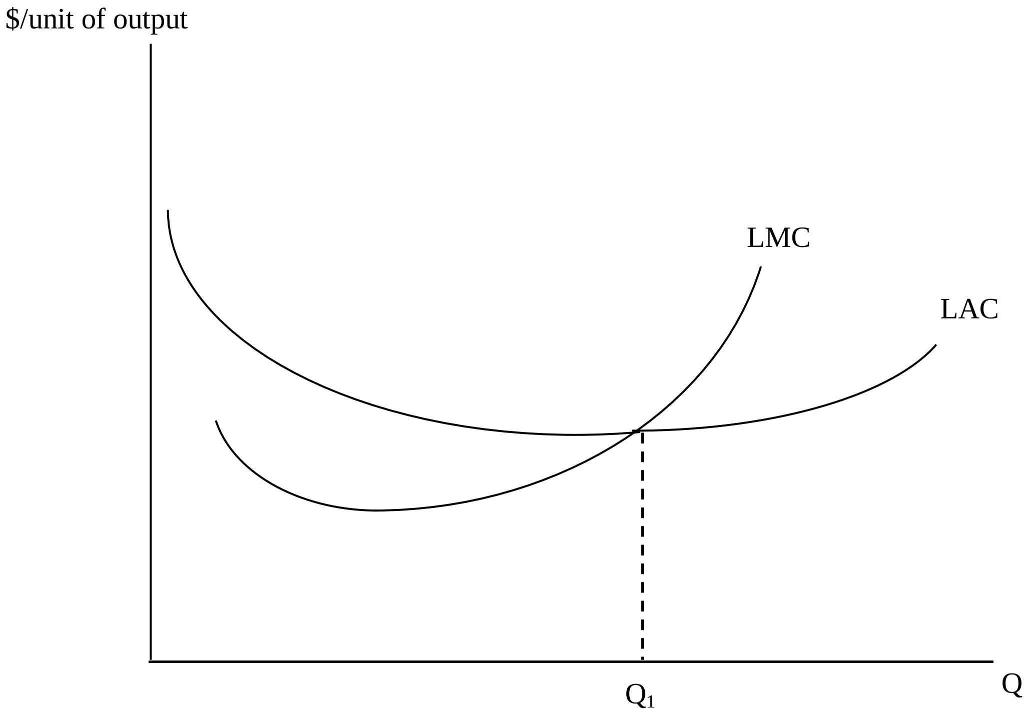

Figure 2.2 Long-Run Average and Marginal Cost Curves

2.3 Cost Models and Estimates of Economies of Scale

Studies commonly use the translog cost function for estimating transit cost models. Flexible forms such as the translog function are favored over the Cobb-Douglas function (Harmatuck 2005). One of the major advantages of the translog functional form is that it places no *a priori* restrictions on the economics effects characterizing bus operations, and it contains all the relevant economic information via its value and its first and second derivatives (Viton 1981).

Previous research suggests that intermediate outputs, such as vehicle miles, are produced under approximately constant returns to scale, with slightly increasing returns to scale for small transit operators and slightly decreasing returns to scale for large operators, and that final outputs, such as passenger trips, are more likely to experience increasing returns to scale (Elgar and Kennedy 2005). Increasing returns may exist for passenger trips because higher passenger volumes allow for more intensive use of vehicles, thereby reducing average labor and maintenance costs per passenger trip. Harmatuck (2005) estimated short-run variable cost functions using data for 69 bus systems in the U.S. Midwest from 1996 to 2002 and found constant returns with vehicle outputs, increasing returns with passenger outputs, inelastic input demands, and substantial technical efficiencies that vary by transit provider and by state.

Some studies have found increasing returns to scale for small firms, decreasing or constant returns to scale for medium-sized firms, and decreasing returns to scale for large firms, with a transition point somewhere between 250 and 400 buses (Iseki 2008 citing Berechman 1993 and Cowie and Asenova 1999). Meanwhile, Viton (1981) found short-run economies of density for U.S. urban bus systems. Differences in previous results could be due to a few reasons. Differences in data samples, estimation function, variables used to measure the scale of agency, and short- or long-term costs could result in different estimates (Iseki 2008). Differences are also likely to exist due to difference in the size or characteristics of the transit agencies studied. Some studies have concluded that separate cost functions should be estimated for different groups of agencies (Karlaftis and McCarthy 2002, Harmatuck 2005, Iseki 2008).

Karlaftis and McCarthy (2002) used cluster analysis to classify transit systems into homogenous groups and developed separate cost functions for each group. They found that studies that do not group agencies into homogenous groups will fail to account for potential differences in scale economies between sub-groups of firms and that production characteristics of transit systems vary significantly by size. Harmatuck (2005) also argued for analyzing a group of systems with limited variability in extraneous factors such as climate, physical surroundings, labor relations, subsidies, and regulations. Iseki (2008) examined economies of scale for fixed-route bus systems taking into account different levels of contracting, using data from the National Transit Database from 1992 to 2000, and found that level of contracting is an important variable for classifying agencies, as agencies with different levels of contracting were found to exhibit very different relationships between cost per vehicle and agency size.

2.4 External Costs and Benefits

In addition to the internal costs included in traditional cost models, a number of external costs also exist for vehicle travel. These can include congestion, pollution, greenhouse gas emission, accidents, and roadway facilities costs, as well as waiting costs and other factors. A few studies have developed multi-modal models incorporating these external costs. De Borger and Wouters (1998) studied the joint optimization of transport prices and supply decisions of urban transport services, taking into account all relevant external effects, including congestion, environmental, and accident costs, as well as marginal reductions in waiting times. Parry and Small (2009) also developed a multi-modal model accounting for congestion, pollution, and accident externalities, which can be used to evaluate transit subsidies and pricing. Research on estimating these external costs have been conducted by Mayeres et al. (1996), Maibach et al. (2007), and Santos et al. (2010), and Litman (2009) provided a review of the relevant literature. An external benefit from increased transit supply is a reduction in waiting and access times for transit riders (Mohring 1972). These external costs and benefits need to be considered to estimate the true marginal social cost of transit supply.

3. SURVEY OF SMALL URBAN TRANSIT SYSTEMS

The issue of optimal transit fares and subsidies is important now given recent changes in funding levels and actions transit agencies have made regarding fares and service levels. Transit agencies across the country have been faced with the dilemma of having to either increase fares or reduce service due to tightening budget constraints. The American Public Transportation Association (APTA) conducted surveys of transit systems recently and found that many have experienced reductions in revenue, because of the recession or higher costs, particularly fuel costs (APTA 2008, 2009, 2010). As a result, APTA found that a large majority of transit agencies have reduced service or increased fares or were considering either of these actions for the future. These actions have occurred at a time when ridership nationwide has been at its highest level in several decades. The resulting impacts of these changes on system users and social welfare can be considerable.

To better understand the types of changes being made by transit agencies in small urban areas, a survey similar to those conducted by APTA was used. This survey collected information on recent changes in fares, service levels, and funding. In addition, it also asked about service increases, factors motivating service and fare changes, and the rationale for transit subsidies.

The survey was conducted of urban transit systems receiving section 5307 funding and serving areas with a population below 200,000. It was conducted online, and invitations to participate were sent by email. A list of small urban transit agencies was obtained from the 2008 National Transit Database (NTD). Using the NTD, 394 transit systems were identified. Contact information for these systems was obtained largely through the NTD website and through the APTA member profile information. Of these, contact names and email addresses were found for 318 agencies. However, a few individuals were listed as contacts for multiple systems, leaving 313 actual contacts. Many of these contacts were managers of the transit system, though some were not directly involved in transit operations. Original emails were sent to these 313 contacts. Eight of the emails were returned as undeliverable due to incorrect or outdated addresses. That left 305 transit agencies that received the survey. Two weeks after the original email invitations were sent, a reminder email was sent to those who had not yet taken the survey. A third email was sent a week later to everyone on the list thanking respondents and giving those who had not responded one last chance to complete the survey. The survey was conducted from November 9, 2010, to December 7, 2010.

Responses were received from 141 transit agencies, yielding a response rate of 46%. Transit agencies from all parts of the country were represented, including 21 from northeast or mid-Atlantic states (FTA regions 1-3), 43 from the Midwest (FTA regions 5 and 7), 30 from southern states (FTA regions 4 and 6), and 37 from western states (FTA regions 8-10), with the remainder not identifying their location.

3.1 Changes in Service Levels

3.1.1 Service Reductions

Thirty percent of the transit agencies responding said they have made reductions in service since January 1, 2009, or are in the process of implementing such reductions. Of those that have not made any service cuts, 13% are considering making reductions. Combined, 39% of respondents have made cuts since January 1, 2009, or are considering cuts (Figure 3.1). Furthermore, nearly half (49%) of those that have already made cuts are considering further reductions in service.

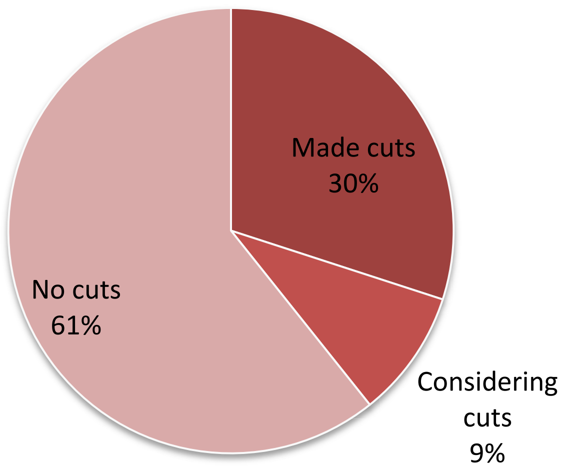

Figure 3.1 Agencies that Have Made Cuts in Service since January 1, 2009, or are Considering Cuts (n=140)

The most common cut made by transit agencies was a reduction of service hours, made by 74% of those that cut service (Figure 3.2). The next most common cut was a reduction in service frequency on existing routes. Other cuts included elimination or reduction of weekend service and reduction in geographic coverage of service, which was less common. Others mentioned eliminating intercity service or reducing non-ADA-required paratransit service.

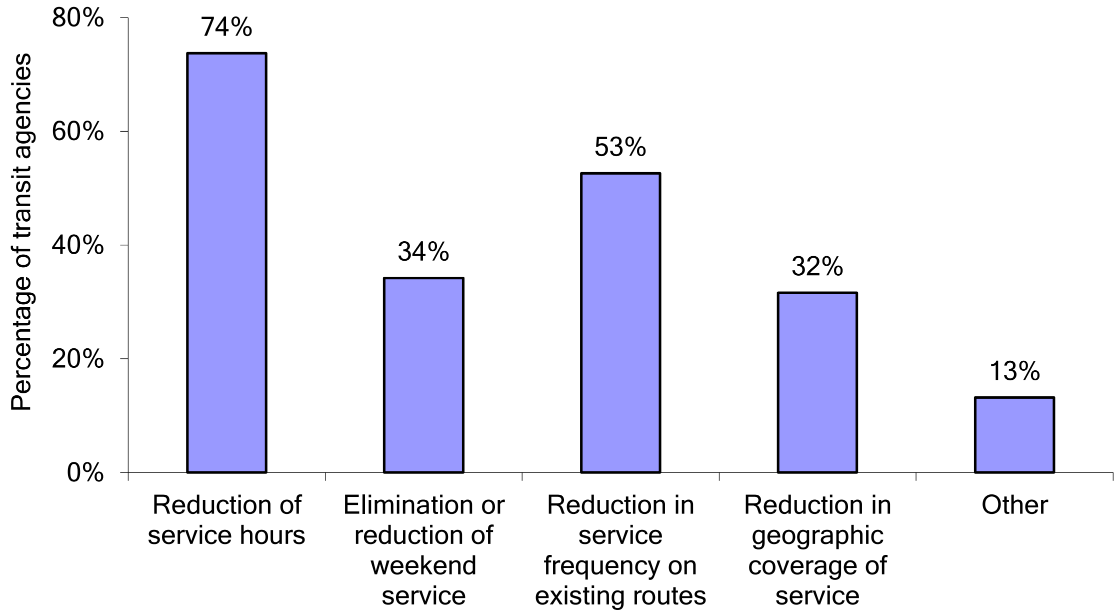

Figure 3.2 Cuts by Transit Agencies that Have Made Service Reductions (n=38)

Transit agencies that have made service reductions have done so largely because of decreases in funding. Smaller percentages of these transit providers said they reduced service because of decreases in other revenues, increases in fuel or other costs, or decreases in service demand (Figure 3.3).

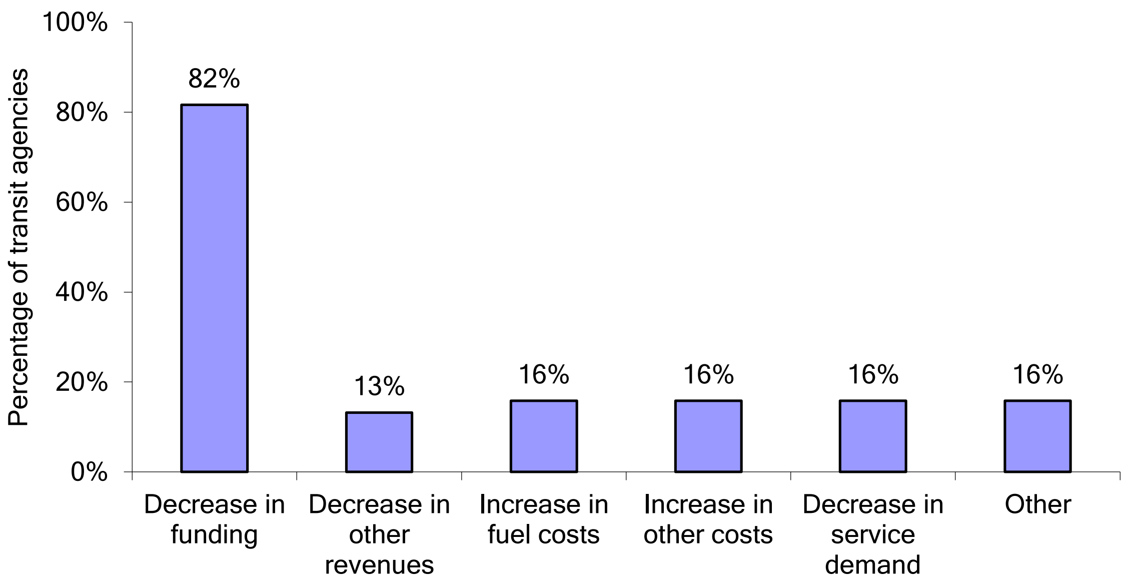

Figure 3.3 Factors that Motivated Decisions to Cut Transit Service (n=38)

Most of the service reductions were due to decreases in revenues or increases in costs, while few were actually due to a decrease in demand. About 60% of those that have made cuts thought the reductions would be enough to resolve the problem (i.e., reduced revenue or increased cost), while 40% indicated that the problems persist. Mostly due to decreases in funding, about half of the transit agencies that have reduced service are considering further reductions. Cuts under consideration are largely similar to those already made, with reductions in service hours being the most common.

3.1.2 Service Increases

Fortunately, while several transit agencies have struggled with the need to cut service, many have also added new service. In fact, half the agencies responding have made increases in service levels since January 1, 2009, or are in the process of implementing such increases (Figure 3.4). Of those that have not increased service, 19% are considering doing so.

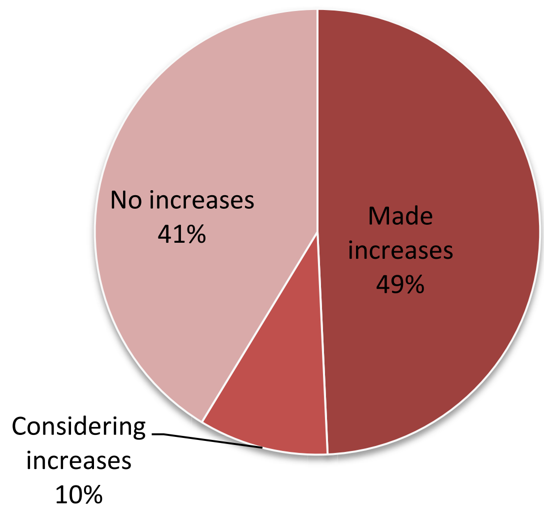

Figure 3.4 Transit Agencies that Have Added Service since January 1, 2009, or are Considering Increases (n=138)

While the service cuts were most commonly a reduction in service hours, the types of services added were more widely distributed, including increases in geographic coverage of service (54%), increases in service hours (42%), increases in service frequency on existing routes (37%), and the introduction or increase of weekend service (22%) (Figure 3.5).

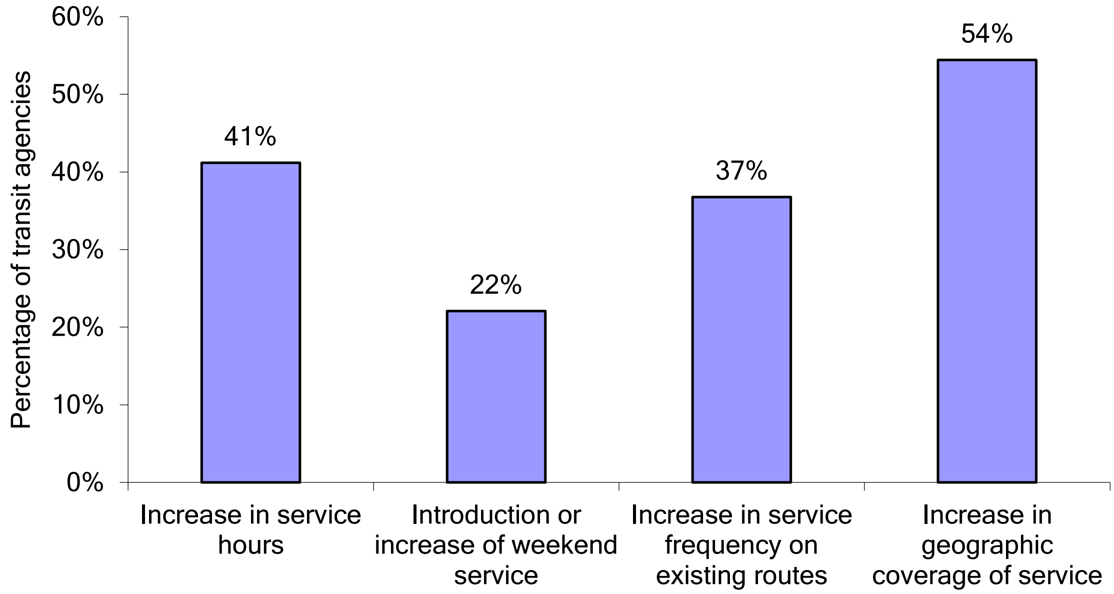

Figure 3.5 Types of Services Added by Transit Agencies that Have Made Service Increases (n=68)

Unlike service cuts, which were motivated primarily by funding decreases or higher costs, service additions were influenced partly by changes in funding but more so by changes in demand. Forty-one percent of those that added service said it was motivated by increased funding, while 66% said the service was added because of increased demand (some agencies cited both as factors). Other motivating factors noted by transit providers included fuel costs being subsidized to more realistic levels (the survey was conducted prior to the rise in fuel prices in 2011), a desire to improve consistency and ease of understanding the system, or issues with running time; a few mentioned that services were added to alleviate issues created with the reduction of other services. An increase in demand for service is the primary reason why some agencies are considering further service additions, while some also noted increased funding.

3.2 Fare Changes

3.2.1 Fare Increases

In response to reduced revenues and higher costs, transit agencies may be forced to choose between the options of cutting service or increasing fares, or both. The survey found that the percentage of transit agencies that chose to increase fares is roughly equal to the percentage that reduced service. About 33% of transit providers said they have increased fares since January 1, 2009, or are in the process of increasing fares (Figure 3.6). Of those that have not increased fares, 18% are considering a fare increase. Agencies are slightly more likely to increase fares rather than reduce service, but the difference is small. The most common fare increase was $0.25 per ride for the base fare.

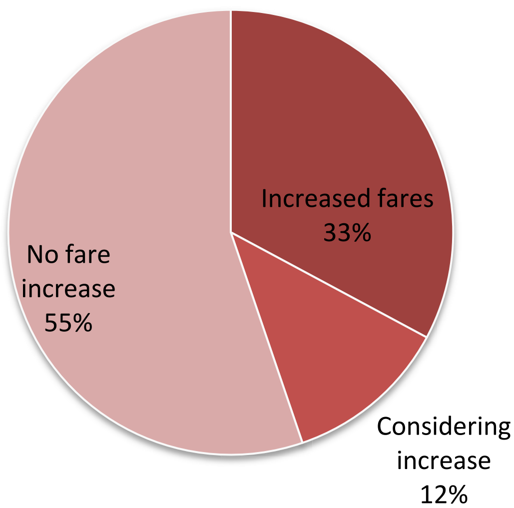

Figure 3.6 Percentage of Transit Agencies that Have Increased Fares since January 1, 2009, or are considering Fare Increases (n=134)

Transit agencies gave a number of reasons for increasing fares. Of those that increased fares, half said they did so because of decreased funding, while some also cited higher fuel costs (41%), increases in other costs (36%), or decreases in other revenues (18%) (Figure 3.7). Some transit agencies may have increased fares so they could maintain their level of service. One provider said that passengers requested that the city council increase fares to retain weekend service, and another said they increased fares to allow for increased service on evenings and weekends.

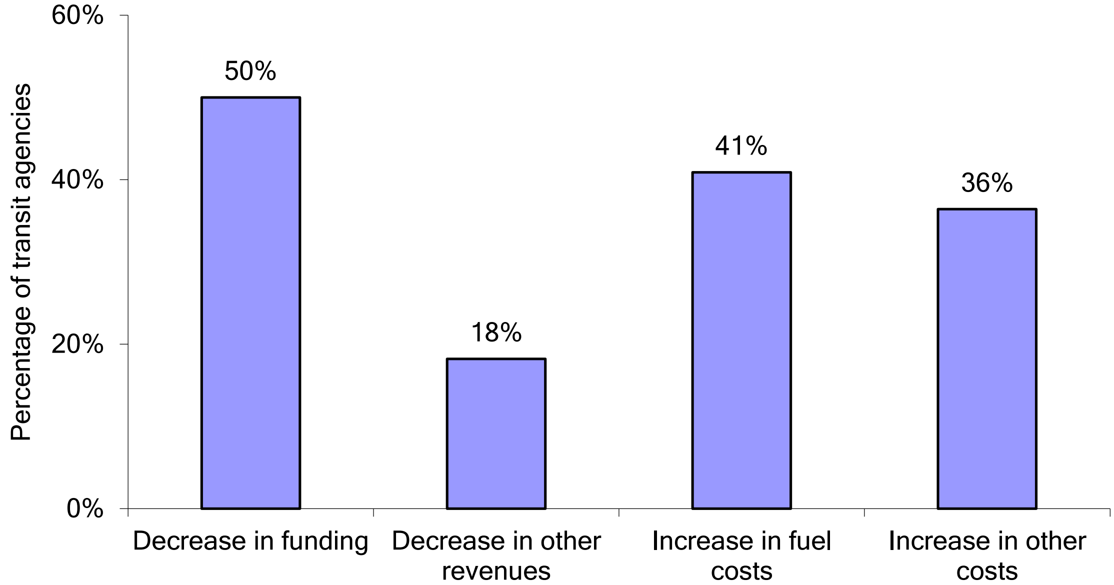

Figure 3.7 Motivations for Fare Increases (n=44)

Sixty-one percent of the transit agencies that increased fares thought the higher fare would be enough to resolve the problems precipitating the increase. Of those with a persisting problem, some are considering further fare increases. Fifteen percent of agencies that have increased fares are considering further increases.

One potential consequence of fare increases is a loss in ridership because some users either cannot afford the higher cost or no longer think it is economical to ride. Judging if a system has lost riders due to fare increases can be difficult, especially when a number of other factors influence ridership. When asked if they thought their system had lost riders because of their fair increase, 36% of respondents said yes, 46% thought they had not lost riders, and 18% answered that they did not know. Of those that estimated they had lost ridership, most speculated the decrease to be around 1% to 10%, while some mentioned greater reductions. A couple respondents noted that ridership was down because of both fare increases and service reductions. One respondent also said that ridership is down because the recession has led to fewer work-related trips, so it is difficult to estimate the impact of the fare increase.

3.2.2 Fare Decreases

A small number of transit agencies indicated they have made some reductions in fares. Seven percent of the transit systems surveyed said they had decreased fares since January 1, 2009, or are in the process of making a reduction. The types of reductions mentioned include adding free rides for veterans with disabilities, providing lower fares for seniors or people with disabilities, introducing monthly passes that could save users money, decreasing the cost of monthly passes, providing half fares on Saturdays, and reducing evening fares.

3.3 Combined Actions Taken

Many transit agencies, of course, have taken more than one type of action. Of those agencies that made service reductions, half of them also increased fares, and 38% countered the service cuts by increasing service elsewhere (Table 3.1). Of those that increased fares, 64% also made increases in service, while 45% cut some service.

Table 3.1 Other Actions Taken by Agencies that Have Cut Service or Increased Fares

Other Actions	Agencies that have: Cut Service	Increased Fares
Cut Service		45%
Increased Service	38%	64%
Increased Fares	51%	
Decreased Fares	5%	11%

As shown in Table 3.2, 47% of transit agencies surveyed have either increased fares or reduced service, and 14% have done both. Sixty-one percent have implemented or are considering either a fare increase or a service cut. While these percentages are high, they are lower than those found in APTA's (2010) survey, suggesting smaller transit agencies have not been influenced as severely by budget constraints.

Table 3.2 Service or Fare Actions Taken or Being Considered

	Implemented Since January 1, 2009, or Approved	Considering Future Action	Implemented AND Considering additional Future Action	Implemented OR Considering Future Action
Service Cuts	30%	23%	14%	39%
Service Increase	50%	28%	18%	59%
Fare Increase	33%	17%	5%	45%
Fare Increase AND Service Cuts	14%	7%	3%	19%
Fare Increase OR Service Cuts	47%	33%	18%	61%

3.4 Ridership Changes and Demand for Service

Transit ridership nationwide peaked in 2008 at its highest level in over 50 years. Total ridership has since declined some, possibly because fewer trips are being made because of the recession and the attractiveness of transit declining somewhat as gas prices decreased in 2009 and 2010. Service cuts and fare increases could be playing a role as well. However, the decline in bus ridership in small urban areas in 2009 was small, according to APTA data, and ridership in areas with population below 100,000 was actually up nearly 4% during the first three quarters of 2010.

Respondents to the survey were asked to identify how much ridership has changed on their system since 2008.[1] Responses covered a wide spectrum (Figure 3.8). Thirty percent said ridership had decreased, including 12% who indicated a loss of more than 10%; 9% said there has been no change; and 61% answered that ridership has increased, including 25% who said their ridership is up more than 10%. On average, these agencies reported increased ridership, though there is some variation in response.

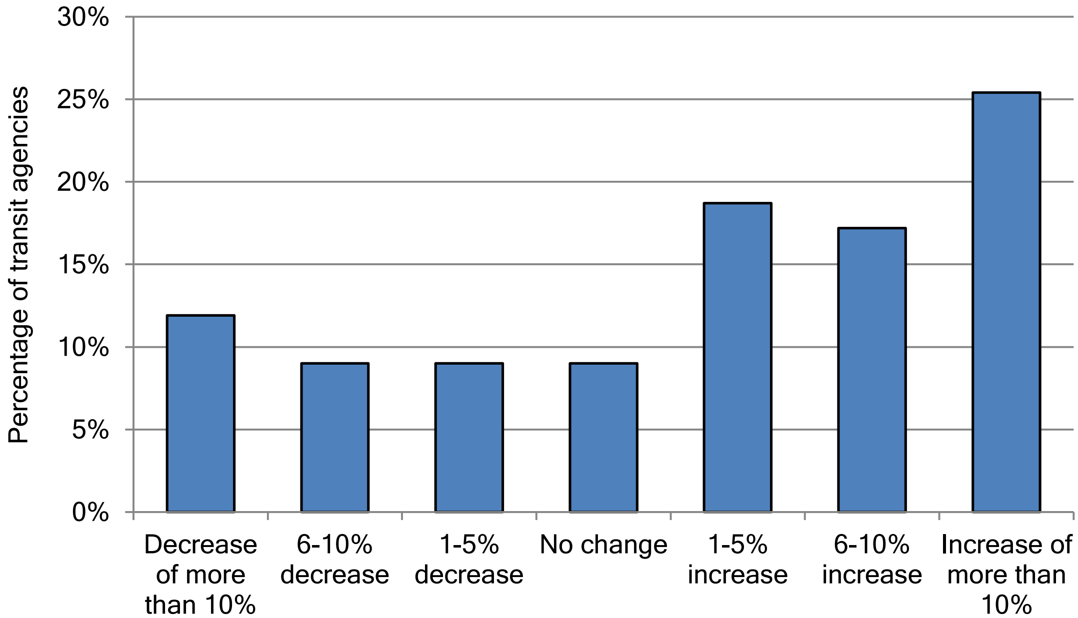

Figure 3.8 Change in Ridership Reported since 2008 (n=134)

Related to ridership is the concept of demand. Demand refers to the amount of service that would be used or quantity of products that would be consumed by individuals at a given price. Ridership could change because of changes in fares, but an actual change in demand would indicate a greater number of people in the service area who would use the service at a given price. Demand for transit service could increase because of population growth in the area or shifts in demographics, where there are greater numbers of individuals more likely to use transit, such as older adults, people with disabilities, immigrants, or low-income individuals. There could also be a number of other factors causing an increase in demand for transit.

[1] To facilitate ease of survey completion, respondents were given ranges of possible ridership changes rather than being asked to identify the exact change in ridership.

Two-thirds of transit agencies responding to this survey said that demand for service in their community is increasing; 28% answered that demand is staying about the same, while just 4% said demand is decreasing. If these perceptions about demand are correct, it would indicate that most of the decrease in ridership experienced by some agencies would be due to service cuts or higher fares and not actual decreases in demand for the service.

Of those who said that demand is increasing in their community, most (94%) said their agency is facing limitations in its ability to add service to meet this demand.

3.5 Changes in Funding

The primary reason given for reducing service or increasing fares was a decrease in funding. Survey results show that decreases in operational funding over the last year were more common than increases, although transit providers most commonly said funding had remained the same, and a few reported increases (Figure 3.9). Funding decreases were more likely at the local, regional, and state levels, while federal funding mostly remained the same.

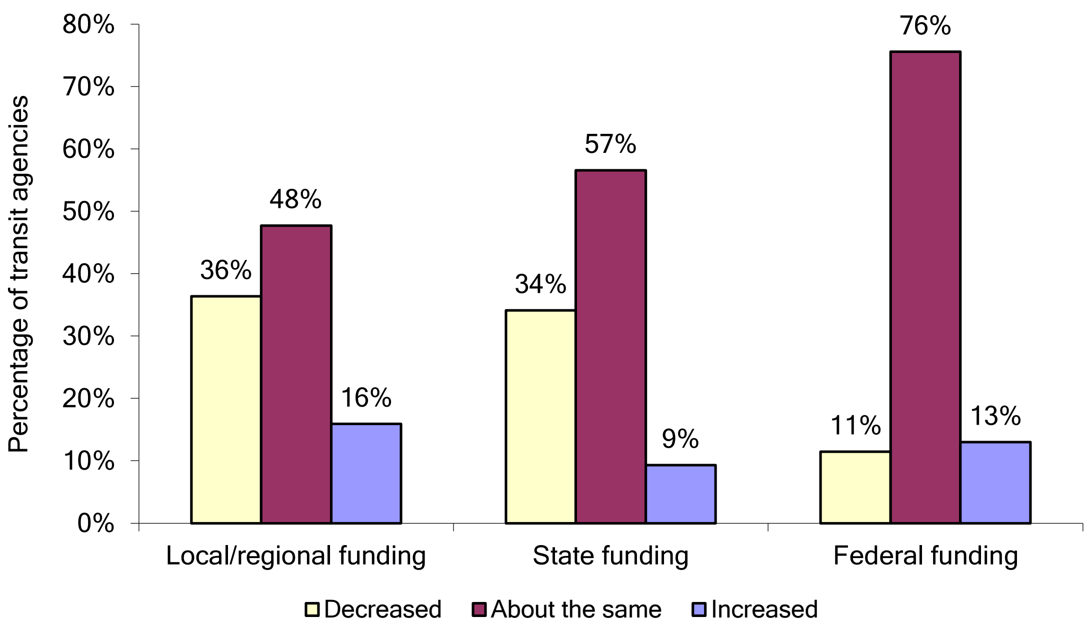

Figure 3.9 Changes in Operational Funding over the Last Year (n=132)

3.6 Marketing and Rationale for Subsidies

The survey asked transit agencies whether or not they view each of the following as a rationale for transit subsidies: to enhance mobility for the underprivileged, to offset social costs of automobile travel (such as pollution, greenhouse gas emissions, and congestion), and to take advantage of economies of scale (that is, the ability to be more cost effective). Ninety-one percent said that enhancing mobility for the underprivileged was a reason for subsidies, 76% thought offsetting social costs of automobile travel provided justification for subsidies, and 63% said the same for taking advantage of economies of scale (Table 3.3).

Table 3.3 What Do You View as the Rationale for Transit Subsidies? (check all that apply)

Answer Options	Number	Percentage
To enhance mobility for the underprivileged	119	91%
To offset social costs of automobile travel, such as pollution, greenhouse gas emissions, and congestion	100	76%
To take advantage of economies of scale (that is, the ability to be more cost-effective)	83	63%

Other responses

Livability

- Enhance mobility to all segments of the population
- Enhance quality of life, promote livable communities
- Maintain an independent lifestyle for seniors
- Mobility enhancement for many groups - not just the underprivileged

Automobile subsidies

- All transportation is subsidized including roads/highways
- To compete vs. the auto, which is also subsidized
- Other modes are subsidized
- Roads are subsidized as well.
- To balance the last 70 years of road subsidy.

Providing alternatives

- Cheaper than building new roads.
- Address auto oriented land use
- Demonstrate to students that transit is a viable travel mode choice.
- Provide choice to auto dependent society
- Provide transportation choice to "choice" riders
- Options, safety, convenience
- Reduce student parking difficulty and cost
- Transit is part of the transportation infrastructure. As infrastructure requirements of an aging population change, the funding for those infrastructure components must also change.
- Urban area growth has increased demands on transit - more riders, more stops, more traffic congestion all contribute to the need for more transit.

Economic development

- Transit provides economic viability, connectivity, job growth, and development.
- Economic- attracting employers, ride to work, ride to college/community college
- Economic development and providing a connection between affordable housing and jobs
- Used as an economic development tool and providing access to jobs.
- To encourage economic growth and business development.
- Increase economic activity among those unable or unwilling to use an auto

Transit agencies also gave a number of other reasons for justifying subsidies, which are shown in Table 3.3. Some noted that transit is needed to enhance quality of life, promote livable communities, and enhance mobility for all segments of the population, not just the underprivileged. Others noted that transit subsidies are justified because other modes, including automobile travel, are subsidized as well. This rationale is completely in line with what was previously discussed, though the survey did not specifically include it as an option. Several respondents commented that subsidies are needed because it is important to provide alternatives to automobiles. One respondent specifically argued that transit is part of the transportation infrastructure, and that as the population changes, the funding for those infrastructure components must also change. A number of respondents also said that transit provides economic viability and is used to encourage economic growth. Future surveys of transit agencies should include these additional categories as potential rationale for transit subsidies.

Regarding the social costs, or consequences, of automobile travel, the survey asked transit providers if they refer to any of them when trying to obtain funding. The most commonly referred to was air pollution, which 65% of transit agencies said they mention when seeking funding (Figure 3.10). Fifty-five percent refer to congestion, and just over half mention greenhouse gas emissions. Smaller percentages refer to the other costs, while 27% said they do not refer to any of the ones listed.

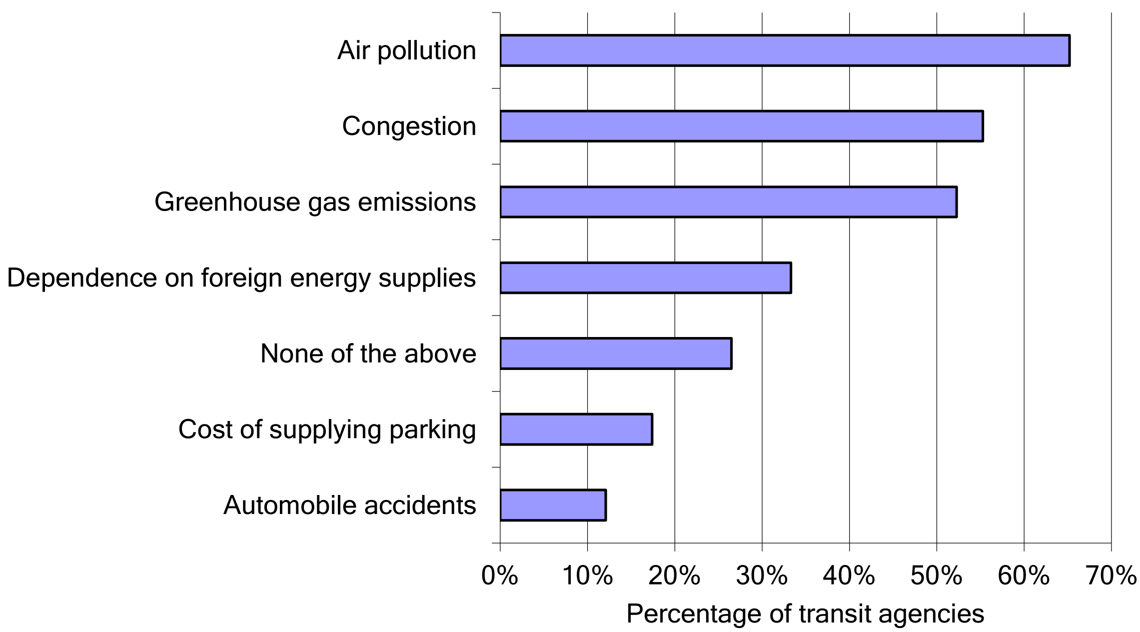

Figure 3.10 Percentage of Transit Agencies that Refer to Any of the Following Consequences of Automobile Travel when Trying to Obtain Funding (n=132)

Transit agencies were similarly asked if they refer to any of these factors when marketing their services, with similar results (Figure 3.11). Respondents commonly mentioned that they also refer to other factors when marketing their services, such as the cost savings to riders and the convenience of not driving. The cost advantage of using transit versus the expense for owning and operating a personal vehicle was frequently mentioned. These factors were not included as options in the survey since we were specifically examining how transit agencies take into consideration the social costs, or negative externalities, of automobile travel when marketing their services and obtaining funding.

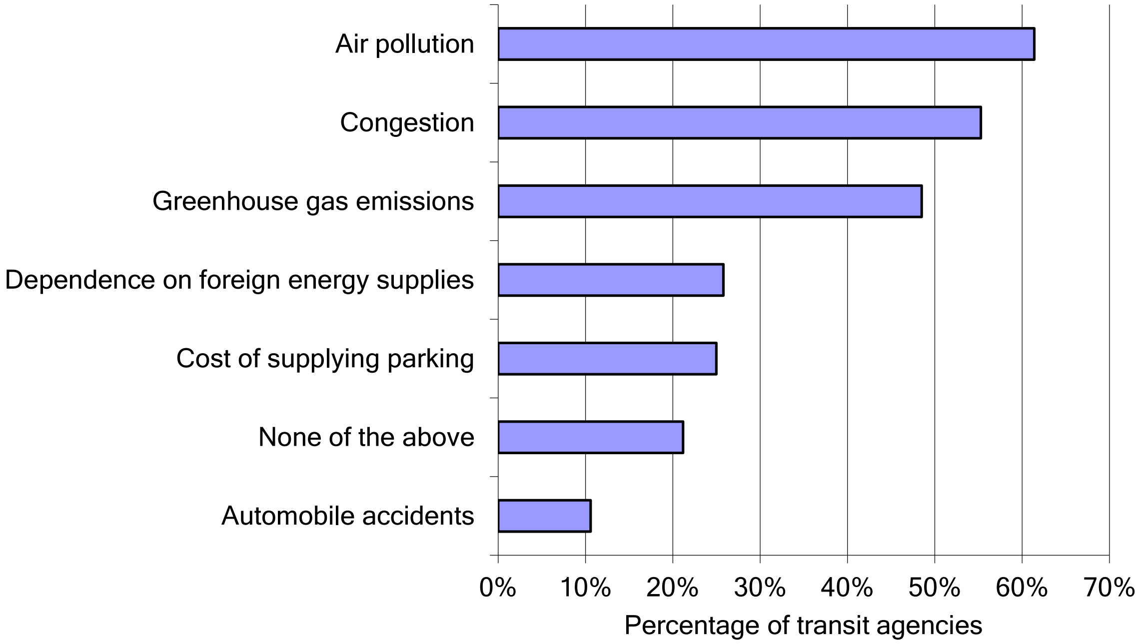

Figure 3.11 Percentage of Transit Agencies that Refer to Any of the Following Consequences of Automobile Travel when Marketing Their Service (n=132)

4. LONG-RUN COST MODEL

This study is primarily concerned with economies of scale as a rationale for transit subsidies, taking into consideration external costs and benefits. We hypothesize that transit agencies serving small urban communities experience increasing returns to scale and density.

A long-run cost function is fit using seemingly unrelated regression (SUR) to determine the economic structure of transit agencies serving small urban communities. SUR allows for the estimation of a system of equations where error terms are considered to be correlated across equations. This readily accommodates modeling of long-run cost functions where share equations are used.
The empirical long-run small urban transit model is represented as a translog function which serves as a quadratic approximation of the true cost function.

Here total cost, *TC*, is a function of output, *Y*; network size, *N*; input prices, P_i; and environmental variables, *Z*. Each variable is evaluated at the variable mean. Consequently, each parameter estimate may be interpreted as an elasticity. Network variables used in transportation cost functions include service area or route length. Environmental variables commonly used include stage length and average load factor. The empirical function is presented in Equation (1).

$$\ln(TC) = \alpha_0 + \alpha_Y \ln(Y) + \alpha_N \ln(N) + \sum_{i=1}^{n} \alpha_i \ln(P_i) + \sum_{k=1}^{m} \alpha_k \ln(Z_k) + \alpha_{YY} \ln(Y) \ln(Y) + \alpha_{NN} \ln(N) \ln(N) + \alpha_{NY} \ln(N) \ln(Y) + \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \ln(P_i) \ln(P_j) + \sum_{i=1}^{n} \alpha_{iY} \ln(P_i) \ln(Y) + \sum_{i=1}^{n} \alpha_{iN} \ln(P_i) \ln(N) \quad (1)$$

Share equations for n-1 inputs are included. These equations are conditional factor demands obtained as the first derivative of the cost function with respect to the corresponding factor price. Homogeneity of degree one in input prices is imposed (that is, a 1% increase in all prices results in a 1% increase in total costs). Symmetry is imposed on cross-price coefficients, which follows from Young's Theorem.

Parameter estimates from the empirical model can be used to calculate returns to density and scale following Caves et al. (1984). Returns to density are the proportional increase in output resulting from a proportional increase in all inputs with network size held fixed. Returns to density can be calculated using Equation (2).

$$RTD = \frac{1}{\varepsilon_Y} \quad (2)$$

Returns to scale are the proportional increase in output and network size resulting from an increase in all inputs. Returns to scale can be calculated using Equation (3).

$$RTS = \frac{1}{\varepsilon_Y + \varepsilon_N} \quad (3)$$

Marginal cost is calculated using Equation (4).

$$\text{MC} = \frac{\partial C}{\partial Y} = \frac{\partial lnC}{\partial lnY} \frac{C}{Y} = \varepsilon_Y \frac{C}{Y} \quad (4)$$

With marginal cost pricing, the required subsidy equals average cost minus marginal cost.

4.1 Full Cost Model

A full cost model is estimated that includes the addition of external costs and benefits. External costs include transit's contribution to congestion, pollution, greenhouse gas emissions, vehicle crashes, and roadway facility costs. Cost estimates are based on those found in previous studies, following Litman (2009). The external benefit of additional transit supply includes reduced waiting and access times for passengers.

Litman (2009) estimated congestion cost for transit buses (in 2007 U.S. dollars) at $0.27 per vehicle mile in urban peak conditions and $0.04 per vehicle mile in urban non-peak conditions, with no cost in rural areas. Most of the cost occurs in urban areas in peak periods. Litman (2009) noted that congestion is largely internal to road users as a group and are borne by individuals in terms of travel time and vehicle operating costs, so to avoid double-counting, his framework netted out congestion costs after accounting for travel time and operating costs. For small urban areas, the congestion costs would be much smaller since there is less congestion and shorter peak periods. Therefore, congestion costs are not included in the model for this study.

Air pollution is commonly recognized as an external cost of motor vehicle travel. Emissions of pollutants such as ozone, particulate matter, carbon monoxide, nitrogen oxides, and sulfur dioxide have significant effects on human health. These emissions vary based on fuel type, vehicle type and condition, and driving style and conditions. In addition, from these human health effects from air pollution, vehicle emissions of carbon dioxide can contribute to global climate change. Calculating a cost for greenhouse gas (GHG) emissions is much more difficult due to greater uncertainties regarding the damage and how to value it. Litman (2009) reviewed a number of studies and estimated average air pollution costs per vehicle mile for transit buses to be $0.185 for urban peak buses, $0.160 for urban off-peak buses, and $0.013 for rural buses, with an overall average of $0.129. For GHG emissions, the estimated costs per vehicle mile are $0.094 for urban peak buses, $0.086 for urban off-peak buses, and $0.077 for rural buses, with an overall average of $0.086. However, there is significant variability in these estimates.

Other external costs included in this study are crash costs and roadway facilities costs. Crash costs refer to the economic value of damages caused by vehicle crashes. External crash costs are those that are not covered by risk-oriented insurance premiums. These can include pain and suffering, lost quality of life, and uncompensated grief to crash victims' friends and family. These costs can be difficult to quantify, but Litman (2009) reviewed the literature and estimated an external crash cost of $0.264 per vehicle mile for transit buses.

Roadway facility costs include public expenditures to build and maintain roadway facilities. Internal roadway costs are those borne by users through fuel taxes and user fees. Expenditures not funded through this manner are external costs people must pay regardless of whether they use the roadway. Litman (2009) estimated an average roadway facility external cost of $0.048 per vehicle mile in urban areas and $0.029 per vehicle mile in rural areas, with an overall average of $0.038 per vehicle mile.

There is also an external benefit of increased transit supply resulting from reduced waiting times following an increase in service frequency. The marginal external benefit associated with additional transit supply equals the monetary value of the decrease in waiting time for all transit riders. The procedure used to estimate this benefit is similar to that used by De Borger and Wouters (1998), and it requires an estimate of the decrease in waiting time, the number of transit passengers, and the value of waiting time. Following a number of previous studies (De Borger and Wouters 1998, Mohring 1972), we assume average waiting time (*WT*) is proportional to the inverse of frequency (*Freq*):

$$WT \propto \frac{1}{Freq} \quad (5)$$

An indicator of frequency is calculated by dividing the number of vehicle miles of service (Q) provided in a given period by the network length (NL).

$$Freq = \frac{Q}{NL} \quad (6)$$

Calculating average wait time for passengers at bus stops is a complicated issue, especially for small urban systems with longer headways. The inverse of service frequency is the average headway. If riders arrived randomly at a bus stop, then the average wait time would be equal to half the headway. Many previous studies have assumed this to be the case, especially for shorter headways. However, with longer headways, riders are more likely to use the transit schedule and arrive closer to the arrival time (Luethi et al. 2007). Small urban bus systems often have headways of 30 minutes or longer. In such a case, passengers are likely to plan their arrival to be a certain number of minutes before the bus is scheduled to arrive, though there may be some passengers unaware of the schedule who arrive randomly. Once headways surpass a certain length, it could be assumed that average wait time is constant as riders arrive according to the schedule. However, this ignores the likelihood that with longer headways, passengers have to adjust their schedules to coincide with the bus schedule, so they may effectively be waiting elsewhere, not making productive use of their time, until it is time to go to the bus stop. Therefore, it may still be appropriate to assume that wait time is proportional to the inverse of frequency, even for longer headways. Furthermore, if service reliability is poor, waiting time for routes with long headways can become very long. Fan and Machemehl (2002) developed mathematical models to predict bus passenger waiting times and found of linear model WT = 2.0 minutes + 0.3*headway was reasonable and efficient for passenger wait time. The same method is used in this study.

The marginal external waiting time benefit (*MEWB*) associated with extra transit supply can be written as

$$MEWB = -\frac{\delta WT}{\delta Q} * X * VOWT \quad (7)$$

where *X* is the number of passengers per hour and *VOWT* is the value of waiting time in dollars per hour. Service frequency is measured in trips per hour, so headway and wait time is measured in hours. Previous studies suggest the value of time range from about one-half to two-thirds the wage rate (Hess et al. 2004). Since bus riders in small urban areas tend to be of lower income, $10 per hour is used for value of time, and sensitivity analyses are conducted with different values. The value of waiting time, however, is likely to vary significantly among different riders.

4.2 Data

Panel data for 168 agencies over a four-year period are used. As Karlaftis and McCarthy (2002) argued, the use of pooled data has several advantages over cross-section or time-series data. For one, pooling the data provides a greater number of observations, improving efficiency of the parameter estimates. The data used in this study were obtained from the NTD for the years 2006-2009. The NTD collects information from transit agencies that receive Section 5307 funds to provide service to metropolitan areas.

As suggested by previous studies (Karlaftis and McCarthy 2002, Harmatuck 2005, Iseki 2008), we consider a somewhat homogenous group of transit agencies by limiting our investigation to those transit agencies serving small urban communities that directly operate fixed-route service. Agencies that purchase fixed-route service are not included as they are not required to report detailed cost information that is required for fitting an economic cost model, and they may have a different cost structure. We removed agencies that also serve areas with populations greater than 200,000. This includes large regional transit systems that serve major metropolitan areas as well as small urban communities. This was done as these agencies are considered fundamentally different than those that serve small urban communities alone. After removing these agencies, there were 168 agencies with data available.

Vehicle revenue miles are considered the single output of small urban transit agencies. Vehicle revenue miles is used as opposed to passenger revenue miles as the latter is impacted by travel demand characteristics, many of which are outside the control of the transit agency.

Data were inflation-adjusted to 2009 constant dollars. Transit agency wage is calculated as total salary and benefits divided by the number of employee hours worked. The price of fuel is calculated as total fuel cost divided by the number of gallons of gasoline and diesel used. Maintenance costs are calculated as the total maintenance cost divided by the number of vehicles in the agency's fleet.

Capital cost per vehicle, *r*, is calculated using Equation (8). Here r_k is the weighted average price of a new transit vehicle, *z* is the weighted average fleet age, *R* is the average prime rate, and *d* is the straight line rate of depreciation assuming a useful life of 20 years. Total capital cost is calculated by multiplying capital cost per vehicle, *r*, time, the agency's fleet size, *K*.

$$r=r_K(R+d)e^{-d(z)} \quad (8)$$

5. DESCRIPTIVE STATISTICS

The mean and standard deviation for the variables used to estimate the long-run small urban transit agency cost function are presented in Table 5.1. There is considerable variation in the size of agencies as measured by their output, fleet size, and costs.

Table 5.1 Descriptive Statistics

	Mean	St. Dev
Population Density (per sq. mile)	1,990	628
Area (sq. miles)	58	30
Wage ($ per hour)	23.95	8.12
Fuel Price ($ per gallon)	2.79	0.42
Maintenance Cost ($ per vehicle)	7,831	4,893
Capital Cost ($ per vehicle)	7,693	767
Labor Cost ($)	2,934,169	3,262,575
Fuel Cost ($)	495,714	442,348
Maintenance Cost ($)	255,104	271,433
Capital Cost ($)	229,428	158,470
Total Cost ($)	3,914,416	4,021,933
Vehicle Revenue Miles	1,525,181	2,161,787
Passenger Miles	3,682,530	6,025,243
Average Length Trip (miles)	4.35	3.58
Seats per Vehicle	27.8	8.9
Fleet Size	30	22
Average Age (years)	8.9	3.5
Labor Share	72%	
Fuel Share	14%	
Maintenance Share	7%	
Capital Share	7%	

To illustrate the degree to which output measures vary and how the statistics vary based on the size of the operation, the transit agencies were classified into six groups according to the vehicle miles of service provided. As Table 5 shows, the smallest 10% averaged 232,000 vehicle revenue miles of service per agency, and the next 20% averaged 459,000 miles, while the largest 10% averaged 6.3 million miles. The largest 10% provide substantially more service than the other agencies, skewing the averages presented in Table 5.1.

Table 5.2 shows how annual passenger miles, average trip length, fleet size, cost shares, and average cost vary among these six groups of transit agencies. Fleet size ranges from 11 vehicles for the smallest agencies to 54 vehicles for the largest. There are some notable differences in the cost data between agencies of different size. Wage rates tend to be higher for the larger transit systems. For all groups, labor accounts for the largest share of total cost, averaging 72%, but this cost share tends to increase with size, ranging from 68% for the smallest agencies to 77% for the largest. Most have a labor cost share of 70% to 74%. While labor cost shares increase with size, cost shares for fuel and capital decrease. The share of total cost accounted for by fuel decreases from 15% amongst the smallest agencies to 11% amongst the largest, while capital shares decrease from 11% to 5%. Meanwhile, the average cost per vehicle mile is found to steadily decrease with increases in vehicle miles provided.

Table 5.2 Data for Transit Agencies by Size

Percentile	Vehicle Revenue Miles (thousand miles)	Passenger Miles (thousand miles)	Average Trip Length (miles)	Fleet size	Wage rate ($/hr)	Labor share	Fuel share	Maintenance share	Capital share	Average cost (per vehicle mile)
1-10	232	573	5.9	11	22.08	68%	15%	6%	11%	4.59
11-30	459	1,180	4.5	19	22.79	70%	14%	7%	9%	4.02
31-50	726	2,332	4.0	25	22.16	71%	14%	7%	8%	3.96
51-70	1,112	3,037	3.9	32	24.47	73%	14%	7%	7%	3.52
71-90	2,077	6,178	4.3	43	24.80	74%	13%	6%	6%	3.02
>90	6,315	10,906	4.2	54	29.00	77%	11%	6%	5%	1.51

Data from the NTD were also used for calculating Equations (6) and (7). The median value for vehicle revenue miles for these agencies is about 875,000. Annual vehicle miles was converted to hourly vehicle miles assuming the transit operators provided 12 hours of service per day. According to 2009 NTD data, the average small urban transit system provided service for 14.1 hours on an average weekday, 10.7 hours on Saturday, and 3.2 hours on Sunday, or 12.1 hours overall. An agency with 875,000 vehicle miles per year operating for 12 hours per day would provide 198 vehicle miles per hour, which is used for calculating service frequency and marginal external waiting benefit. Some of these agencies reported route miles, or network length, in the NTD. The median value reported in 2009 for the small urban agencies was 102 miles. Dividing vehicle miles by network length yields a service frequency of 1.9 per hour, which results in a headway of 0.51 hours.

The average number of passengers per hour used in Equation (7) was calculated by dividing the total number of trips provided by the total number of vehicle hours of service, which results in 23.5 riders per vehicle hour.

6. RESULTS

The long-run small urban transit agency cost function was fit using SAS Version 9.2. The results are presented in Table 6.1. The model had an R^2 value of .904 and F-value of 104.66, indicating a good fit. Results show that small urban transit providers experience economies of scale and density. Marginal cost is found to be less than average cost for all but the largest providers studied, providing justification for subsidies to achieve marginal cost pricing and maximize social welfare.

Table 6.1 Parameter Estimates

	Estimate	t-value
Intercept	0.337	11.13
Wage	0.721	145.30
Fuel	0.137	40.00
Maintenance	0.070	36.63
Capital	0.073	11.86
Wage*Wage	0.081	11.89
Wage*Fuel	-0.016	-5.60
Wage*Maintenance	-0.026	-12.48
Wage*Capital	-0.039	-5.33
Fuel*Fuel	-0.016	1.07
Fuel*Maintenance	0.002	4.10
Fuel*Capital	0.008	2.26
Maintenance*Maintenance	0.038	26.53
Maintenance*Capital	-0.017	-6.33
Capital*Capital	-0.797	-5.59
Output	0.908	33.85
Output*Output	0.160	6.41
Output*Wage	0.052	11.57
Output*Fuel	-0.009	-3.30
Output*Maintenance	-0.013	-8.33
Output*Capital	-0.027	-5.03
Area	0.005	0.14
Area*Area	0.184	2.40
Area*Wage	-0.025	-3.99
Area*Fuel	0.016	3.92
Area*Maintenance	0.006	2.73
Area*Capital	0.002	0.36
Area*Output	-0.120	-3.41
Seats/Vehicle	0.006	8.51
Average Length Trip	-0.010	-3.80

Parameter estimates have the expected sign, and most are statistically significant. The parameters for first-order input prices align with their market share. The parameter for area is positive, but not statistically significant. The parameter estimate for average vehicle size is positive, meaning that agencies with large vehicles typically have slightly higher costs (this is intuitive as these vehicles have slightly worse fuel economy than smaller vehicles). Agencies with longer trips tend to have lower costs, which is due to fewer starts and stops, which slow travel and reduce fuel economy.

Parameter estimates from the estimated long-run cost function are used to calculate economies of density and scale. The results are presented in Table 6.2. With values greater than 1, small urban transit agencies experience economies of density and scale. This provides justification for government intervention with small urban transit providers.

Table 6.2 Estimated Economies of Density and Scale

	Mean
Density	1.101
Scale	1.095

With increasing returns to scale and density, marginal cost is less than average cost and a subsidy is required to maximize social welfare. Estimates of average cost, marginal cost, and required subsidy at the sample mean are presented in Table 6.3. Marginal cost is estimated to be $2.33 per vehicle mile, and the required subsidy is $0.24 per vehicle mile.

Table 6.3 Estimated Marginal Cost and Required Subsidy

	Mean
Average Cost	2.57
Marginal Cost	2.33
Required Subsidy	0.24

Most transit agencies, however, have costs and output that deviate from the sample mean. A majority has an average cost above the sample mean, and there is variation in marginal costs. Because of a small number of larger agencies skewing the data, the measures calculated in Tables 6.2 and 6.3 are actually not representative of most small urban transit agencies. Therefore, these measures were calculated away from the sample mean using second order parameter estimates and descriptive statistics from the sample. Average returns to density, marginal cost, and required subsidies were estimated for six groups of transit agencies categorized by size, as previously shown (Table 6.4).

Table 6.4 Returns to Density, Marginal Cost, and Required Subsidy by Size of Agency

Output Percentile	Returns to Density	Average cost	Marginal cost	Required subsidy
		---------------Per vehicle mile---------------		
1-10	1.65	4.59	2.78	1.80
11-30	1.40	4.02	2.88	1.14
31-50	1.27	3.96	3.12	0.83
51-70	1.17	3.52	3.02	0.50
71-90	1.04	3.02	2.89	0.13
>90	0.88	1.51	1.71	-0.20

Results show that middle-sized transit systems in this sample have returns to density of approximately 1.17 to 1.27. Returns to density is higher for the smaller systems and is above 1.00, indicating increasing returns to density, for all but the largest 10% of systems in the sample. Most small urban transit systems are found to exhibit increasing returns to density, and the results align with those from previous studies that have shown increasing returns to scale for smaller agencies, constant returns to scale for mid-sized ones, and decreasing returns for larger agencies.

Marginal cost averages $2.78 to $3.12 per vehicle mile for all but the largest systems in the sample. Given increasing returns to density, marginal cost pricing requires a subsidy for all but the largest agencies studied. The required subsidy is about $0.50 to $0.83 per vehicle mile for medium-sized agencies and is as high as $1.80 per vehicle mile for the smallest agencies.

6.1 Full Cost Model

Based on the estimates reported by Litman (2009), and after adjusting for inflation to 2009 dollars, marginal external costs per vehicle mile are assumed to be $0.13 for pollution, $0.09 for greenhouse gas emissions, $0.04 for roadway facilities, and $0.27 for crash costs. The total marginal external cost is $0.53 per vehicle mile.

The marginal external benefit from increased transit supply, resulting from decreased waiting time, is estimated to be $0.18 per vehicle mile, following equation 7. There is significant variation in this value, however, as it is positively related to value of waiting time and number of passengers, and it assumes an average headway of about 30 minutes. The benefit would be higher for systems with longer headways, and it would also be greater for smaller systems where an additional mile of service would have a greater impact.

Sensitivity analyses were conducted and reported in Table 6.5 to show how changes in those variables would influence the marginal benefit. In each case, one variable is changed and all other variables are the same as in the base case. VOWT 5 and VOWT 15 are scenarios where the value of waiting time is changed to $5 per hour and $15 per hour, respectively. Ridership per hour is decreased 50% and increased 50%, respectively, in the Riders -50% and Riders +50% scenarios. The next two scenarios change headway to 15 minutes or 1 hour, holding total miles of service constant and changing network length. The last two scenarios change annual vehicle miles provided to 500,000 and 1,500,000, respectively, changing network length and holding headway constant at 30 minutes. The results vary from $0.09 per vehicle mile to $0.35 per vehicle mile. However, if multiple variables are simultaneously altered, greater variation can be observed.

Table 6.5 Estimates for Marginal External Waiting Benefit

Scenario	Estimate ($ per vehicle mile)
Base Case	0.18
VOWT 5	0.09
VOWT 15	0.27
Riders -50%	0.09
Riders +50%	0.27
Headway 15 min	0.09
Headway 1 hour	0.35
Q 500	0.31
Q 1500	0.10

Using a marginal external cost of $0.53 per vehicle mile and a marginal external benefit of $0.18 would increase marginal cost by $0.35 above what was calculated in Tables 6.3 and 6.4. Most small urban transit agencies, however, would still be operating with average cost above marginal social cost, justifying a need for subsidies to obtain marginal social cost pricing.

Fifty-eight of the transit agencies in the dataset had all of the data available for 2009, including data for network length, hours of service per day, passenger trips, vehicle miles, and vehicle hours, to estimate specific numbers with the full cost model. Table 6.6 shows estimates for 12 example systems and averages for the 58 systems. These 58 systems differ somewhat from the full sample as they tend to be a bit smaller, with average annual vehicle miles of 490,000 and an average headway just over 1 hour. The average returns to density for these systems was 1.45, and it was greater than 1.0 for all systems, indicating increasing returns to density. Average cost was $4.39 per vehicle mile, estimated average internal marginal cost was $3.11 per vehicle mile, the external marginal cost was assumed to be $0.53 per vehicle mile as before, and the average marginal external waiting benefit was estimated to be $0.63 per vehicle mile. The waiting benefit was larger than those calculated in Table 10 due to these systems being smaller in size and having longer headways. Total social marginal cost from the full cost model was then estimated to be $3.01 per vehicle mile and the required subsidy is $1.39 per vehicle mile. As Table 11 shows, these estimates vary between agencies. The larger agencies tend to have smaller required subsidies, though that is not always the case. The largest agency in this group had a social marginal cost above its average cost, so it did not require a subsidy, but this was the only agency among these 58 that did not require a subsidy.

The implications of these results and limitations of the research will be discussed further in the next section.

Table 6.6 Estimates for Example Systems and Sample Average

Transit Agency	City, State	Route miles	Average headway	Unlinked passenger trips	Vehicle miles	Total cost	Returns to Density	Average cost	Internal Marginal Cost	Marginal external waiting benefit	External marginal cost	Total social marginal cost	Required subsidy
			(hours)	------------thousands------------				------------------------------$ per vehicle mile------------------------------					
Fond du Lac Area Transit	Fond du Lac, WI	60	1.17	129	160	956	1.83	5.94	3.25	0.77	0.53	3.01	2.93
City of Middletown - Middletown Transit System	Middletown, OH	59	1.02	190	205	719	1.70	3.48	2.04	0.72	0.53	1.85	1.63
The City of Cheyenne Transit Program	Cheyenne, WY	107	1.10	255	367	937	1.47	2.54	1.73	0.35	0.53	1.91	0.63
Cities Area Transit	Grand Forks, ND	80	1.08	272	382	1,504	1.46	3.91	2.69	0.46	0.53	2.75	1.16
City of Rome Transit Department	Rome, GA	328	2.28	691	451	2,315	1.40	5.11	3.64	0.82	0.53	3.36	1.75
Billings Metropolitan Transit	Billings, MT	181	1.17	675	555	2,992	1.34	5.37	4.00	0.41	0.53	4.13	1.24
Metropolitan Transit Authority of Black Hawk County	Waterloo, IA	118	0.81	468	580	2,273	1.33	3.90	2.94	0.22	0.53	3.25	0.65
Unitrans - City of Davis/ASUCD	Davis, CA	81	0.59	3,424	719	3,861	1.27	5.35	4.21	0.62	0.53	4.12	1.23
Su Tran LLC dba: Sioux Area Metro	Sioux Falls, SD	195	1.24	927	719	3,357	1.27	4.64	3.66	0.41	0.53	3.78	0.87
Midland-Odessa Urban Transit District	Odessa, TX	203	1.13	399	721	2,142	1.27	2.95	2.33	0.16	0.53	2.70	0.26
Santa Fe Trails - City of Santa Fe	Santa Fe, NM	124	0.73	790	942	3,795	1.20	4.01	3.33	0.13	0.53	3.73	0.28
Cape Fear Public Transportation Authority	Wilmington, NC	138	0.49	1,424	1,443	4,709	1.11	3.24	2.92	0.08	0.53	3.37	-0.12
58-system Average		117	1.05	667	490	2,179	1.45	4.39	3.11	0.63	0.53	3.01	1.39

7. DISCUSSION AND CONCLUSIONS

7.1 KEY FINDINGS

There are a number of possible justifications for providing subsidies for public transportation, including providing mobility for the underprivileged who cannot drive or access other forms of transportation, the existence of subsidies to other modes of travel, or the possibility that transit operates under conditions of economies of scale. Small urban transit agencies surveyed for this study also commented that transit subsidies are justified to enhance quality of life, promote livable communities, and enhance mobility for all segments of the population, not just the underprivileged.

This study analyzed economies of scale and density as a rationale for subsidizing transit agencies in small urban areas. A long-run cost model was developed and estimated using data for 168 agencies that directly operated fixed-route bus service in small urban areas (population 50,000 to 200,000) over a four-year period from 2006 to 2009. The model uses vehicle revenue miles as transit output.

Key findings are as follows:

- Small urban transit agencies experience economies of density and scale. This provides justification for government intervention.
- With increasing returns to scale and density, marginal cost is less than average cost and a subsidy is required to maximize social welfare for all but the largest agencies studied.
- The results align with those from previous studies that have shown increasing returns to scale for smaller bus systems, constant returns to scale for mid-sized ones, and decreasing returns for larger transit agencies.
- After accounting for external costs and benefits, a majority of small urban transit agencies still operate with marginal costs below average cost, justifying a need for subsidies to obtain marginal social cost pricing.

To maximize social welfare, a subsidy equal to the difference between average cost and marginal cost is required. For many transit agencies, this would require a subsidy of about $0.50 to $0.83 per vehicle mile to allow fares to be set to marginal cost, while greater subsidies are required for smaller agencies.

In addition, there are external costs and benefits of transit service that need to be considered. External costs are those costs caused by the existence of transit but not paid for by the transit agency or its users. These costs include air pollution, greenhouse gas emissions, roadway facilities costs, and costs from bus crashes. Congestion is another potential external cost but is not considered in this analysis of small urban areas, since it is not a major problem in these areas. These external costs are assumed to average $0.53 per vehicle mile based on results from previous studies, but there is much uncertainty and variation associated with this result.

External benefits from additional transit supply also result when transit agencies increase service frequencies and reduce headways, thereby reducing waiting times for passengers. The marginal external benefit of transit supply is estimated to average $0.18 per vehicle mile but varies depending on the value of waiting time, number of passengers, headway, and size of agency. After accounting for external costs and benefits, a majority of small urban transit agencies still operate with marginal costs below average cost, providing justification for subsidies. Estimates from a sample of 58 systems found a marginal external waiting benefit of $0.63 per vehicle mile and a required subsidy of $1.39 per vehicle mile.

7.2 Limitations and Future Research

Marginal cost pricing could be used to obtain optimal fares and subsidy levels. A number of other factors, however, need to also be taken into consideration, including other possible justifications for subsidies. A limitation of this study is that it is not a multi-modal study and does not take into consideration the external costs of automobile travel. As the survey showed, 76% of small urban transit agencies believe that offsetting the social costs of automobile travel, such as pollution, greenhouse gas emissions, and congestion, provide justification for subsidies. This follows the concept of second-best pricing. If automobile travel is being priced below the marginal social cost, then there may be justification to price transit below its social marginal cost, requiring even greater subsidies. With lower fares, more motorists may switch to transit, reducing the negative externalities associated with single-occupancy automobile travel. However, a few issues need to be considered if justifying subsidies based on second-best pricing and negative externalities of automobile travel in small urban areas. First, congestion is not as great a problem in these areas, and second, because of lower bus-occupancy rates in small urban areas, the impact that transit has in reducing pollution and greenhouse gas emissions may be limited. Finally, reducing fares may have only a small impact on automobile travel due to a small cross-price elasticity of demand.

Enhancing mobility for the underprivileged is the most commonly cited rationale for subsidies by small urban transit providers. A significant benefit of transit service results from the creation of new trips that would otherwise not have been made. As transit provides access to work, health care, education, shopping, etc., additional trips will be made for these purposes, resulting in increased earnings, improved health, involvement in social activities, and additional spending in the local community. Furthermore, the service reduces the likelihood of transportation-disadvantaged individuals experiencing isolation and depression. Previous studies have attempted to estimate these benefits in rural and small urban areas and have found benefit-to-cost ratios greater than 1.0 (Burkhardt 1999, Southworth et al. 2005, HLB Decision Economics Inc. 2003). Estimation of these benefits may provide greater justification for subsidies but is beyond the scope of this study. Further research could take into consideration the external costs of automobile travel and the economic benefits of improving mobility, as well as the potential distortionary effects of subsidies.

7.3 Policy Implications

The findings of economies of density and economies of scale indicate that adding new service, through increasing route density, service frequencies, or service coverage, will result in lower average costs per vehicle mile and will reduce waiting and access costs for riders.

The policy implication is important at a time when many agencies have experienced recent reductions in operational funding. The survey found that close to half of transit agencies in small urban areas have either reduced service or increased fares over the last two years, and the main reason for these actions has been a decrease in funding. Most transit agencies reporting increased demand said they are facing limitations in their ability to add service to meet that demand.

Another policy implication regards how subsidies are provided. This study presents costs and required subsidies in terms of dollars per vehicle mile, as transit output is measured in vehicle miles of service provided. A per-mile subsidy may provide the best mechanism for government intervention. Agencies of different output levels require different subsidy levels on a per-mile basis.

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