

**PAYING FOR PUBLIC TRANSPORTATION:
THE OPTIMAL, THE ACTUAL, AND THE POSSIBLE**

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B.A. in Urban Studies and Classics
Brown University, 2003

Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degree of

Master in City Planning
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2007

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Massachusetts Institute of Technology
May 2007

Abstract

Passenger transportation poses challenges to American cities in the form of air pollution, traffic congestion, auto collisions, and barriers to mobility. Public transit has the potential to be part of a solution to these urban problems, yet transit agencies across the country clamor for more resources. Transit finance in the U.S. is heterogeneous, and rarely approached with a comprehensive view of transit's social benefits.

This thesis suggests a framework for a more rational magnitude and incidence of public transit funding based on a more comprehensive view of transit's social benefits. I take up the case of the Chicago metropolitan region and quantify the transit system's major emissions, safety, congestion, and mobility benefits. Next, I survey and highlight current practices in transit finance from other cities in North America and Western Europe. Finally, I assess the size, structure, and distribution of burden of Chicago's current transit funding status quo against theoretical and practical principles of transit funding and offer a range of financing alternatives to solve the current fiscal crisis in Chicago.

I find evidence that the social benefits of public transportation in Chicago outweigh its costs, suggesting that preserving transit services there is justifiable. Transit's benefits accrue to a variety of jurisdictions in diverse and measurable ways which the current funding structure does not approximate. I find evidence that of the multiple beneficiaries of transit in the region, the subsidy structure in Chicago disproportionately benefits auto drivers who receive significantly more congestion benefits than they pay for. Last, I propose several policy options to increase public subsidy to transit in Chicago, and suggest that one particularly theoretically appealing alternative may be to establish tolls on existing roadways.

Thesis Supervisor: P. Christopher Zegras
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Thesis Reader: Frederick P. Salvucci,
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Acknowledgements

"I wake up each morning torn between the desire to save the world and to enjoy the world. This makes it hard to plan the day." -E.B. White

Although the document you're reading bears my name, it would be inaccurate and even arrogant for me to claim the ability to have written it without the help of many others. I am deeply indebted to a number of advisors and colleagues who provided me with inspiration, methodological and philosophical support, and technical review. Despite the help I received along the way, I am responsible for any and all errors, omissions, and weaknesses in this analysis. This research was sponsored in part by the support of the U.S. Department of Transportation's Eisenhower Graduate Research Fellowship.

To the Department and Urban Studies and Planning, my home base, thank you for your consistent optimism, resources, and optimism to "make a difference in the world." From scavenger hunts to proms, urban golf to karaoke, the community and camaraderie of my fellow MCPs has been a highlight of the past two years that I will sorely miss.

To Nigel Wilson, John Attanucci, and others in the transit research group, thank you for including me in an academy of achievement. Preparing to present to those Friday morning meetings was terrifying, but established a level of clarity and rigor of which I am proud. The opportunities to live and work in London and Chicago, and to make my research relevant to an outside party were truly an honor.

Thank you to Natalie Gemmell, Jason Lee, Karl Peet, Ellen Partridge, Jeff Busby, Heather Ferguson and others at the Chicago Transit Authority for showing me the ropes, responding to my chapter drafts, and providing information from 1,000 miles away. To Tom Amenta and my former fellow financiers at Transport for London, thank you for welcoming me and opening my eyes to a different world of transit finance. The exposure and guidance I received as an intern at both the Chicago Transit Authority and Transport for London helped inspire this research.

To Tejus Kothari, Giorgia Favero, Hazem Zureiqat, and Mikel Murga, it has been a pleasure to work so closely with you in the past two years. Thank you for enduring interminable iterations of the "the matrix," and for creating an intellectual space to spin hypotheses and clarify my thoughts. Thanks also to Mikel, whose congestion modeling work provided the basis for my incidence estimates in sections 5.10 and 7.3. Special thanks to Tejus, whom I could always count on to read my work and sum up my rambling with a few choice sentences, no matter how far we were from Cambridge. Tejus was the inspiration behind the congestion functions in Chapter 5.

I owe a great deal to my advisor, Chris Zegras, whose consistent support of me and others in all things transportation in DUSP has been a valuable asset. Chris's careful review of my work here has brought greater discipline, brevity, and accuracy. Thank you for always reminding me of the flip side of every argument, and of my theoretical foundations.

To Ginny Siggia: you are the glue that binds together the transit research group, and your tireless efforts deserve a world of praise.

To Fred Salvucci, my mentor: I will not soon forget the time, thought, and care you have generously shared with me over the past two years. Between listening to lectures, setting up for class, sipping countless cups of coffee, and discussing policy every week, I have quickly come to admire and respect your pragmatism and judgment. Through your gentle wisdom and deep convictions, you have shaped the knowledge and values I will take with me from this institution. Thank you for showing me the kind of vision and achievement to which I can only aspire.

To Mom, Dad, and Sarah, thank you for your unswerving and unconditional love and support. Your generosity, educational values, and high standards have prepared me for where I am today.

To my fiancée Katherine: I couldn't have done it without you. Wherever the next adventures in life take us, I'm thrilled to face them with you by my side.

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1 Introduction

This thesis suggests a framework for paying for public transportation operations with a more rational view of transit's social benefits. I take up the case of the Chicago metropolitan region and quantify the transit system's primary emissions, safety, congestion, and mobility benefits. Next, I survey and highlight best practices in transit finance from other cities in North America and Western Europe. I assess the size, structure, and distribution of burden of Chicago's current transit funding status quo against theoretical and practical principles of transit funding, and I finish by offering a range of financing alternatives to solve the current fiscal crisis in Chicago.

1.1 *Research Objectives*

The purpose of this thesis is to develop a way to think about determining the optimal incidence and magnitude of public funding for public transportation, illustrated by the case of Chicago. To do so, I aim to achieve the following objectives:

- Understand the nature of public transit's social benefits in the context of an individual city.
- Develop and apply methodologies to quantify the size of public transportation's social benefits, and identify its primary beneficiaries;
- Highlight best practices and pitfalls in transit funding from other large transit systems in North America and Western Europe;
- Give public transit policymakers in Chicago and the Illinois Legislature a number of options to pay for transit in the Chicago metropolitan area.

1.2 *Research Motivation*

The passenger transportation sector poses great challenges to U.S. cities and indeed the world: greenhouse gas and local pollutant emissions, petroleum use, and traffic congestion, accidents, and high costs of mobility. The rise of the automobile coincided with post-World War II urban developments and dispersed land use patterns, and aggravated problems of urban poverty and segregation (Squires, 2002).

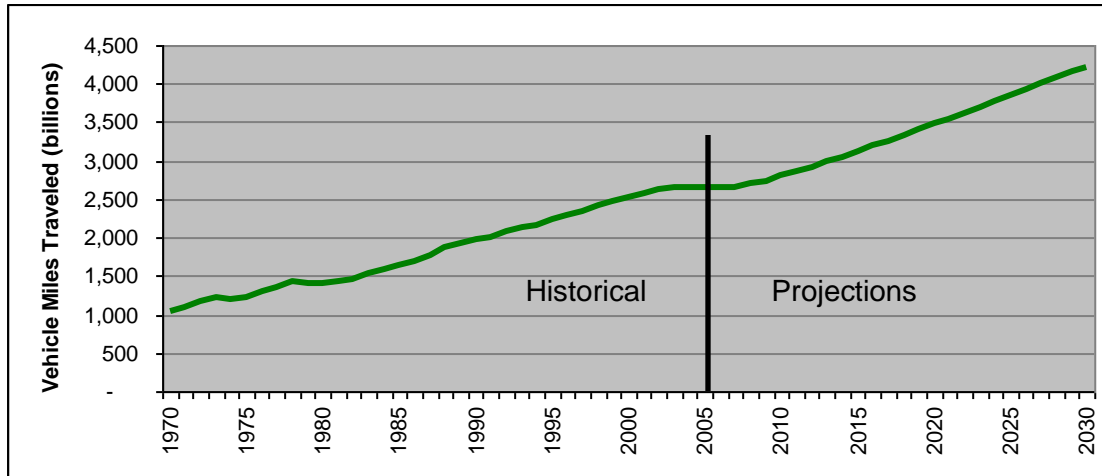
1.2.1 *The Challenge of the Automobile*

In the past half-century, automobile use has grown dramatically. Demographic trends, public policies, and urban development patterns since World War II have resulted in large increases in travel demand, particularly via private automobile. A growing population, women entering the workforce, smaller households, declining relative costs of car ownership, falling auto occupancies, and other factors have caused vehicle-miles traveled (VMT) to increase steadily in recent decades, as shown in Figure 1. In 1950, Americans owned just under 300 cars per thousand people. In 2004, the same figure is around 800 cars per thousand people (Davis and Diegel, 2006, 3.1).

Land development patterns have compounded the challenge. Sprawling growth patterns have resulted in dispersed origins and destinations, diluting the effectiveness of alternative modes such as public transit, as Figure 2 demonstrates. Between 1969 and 2001, average household

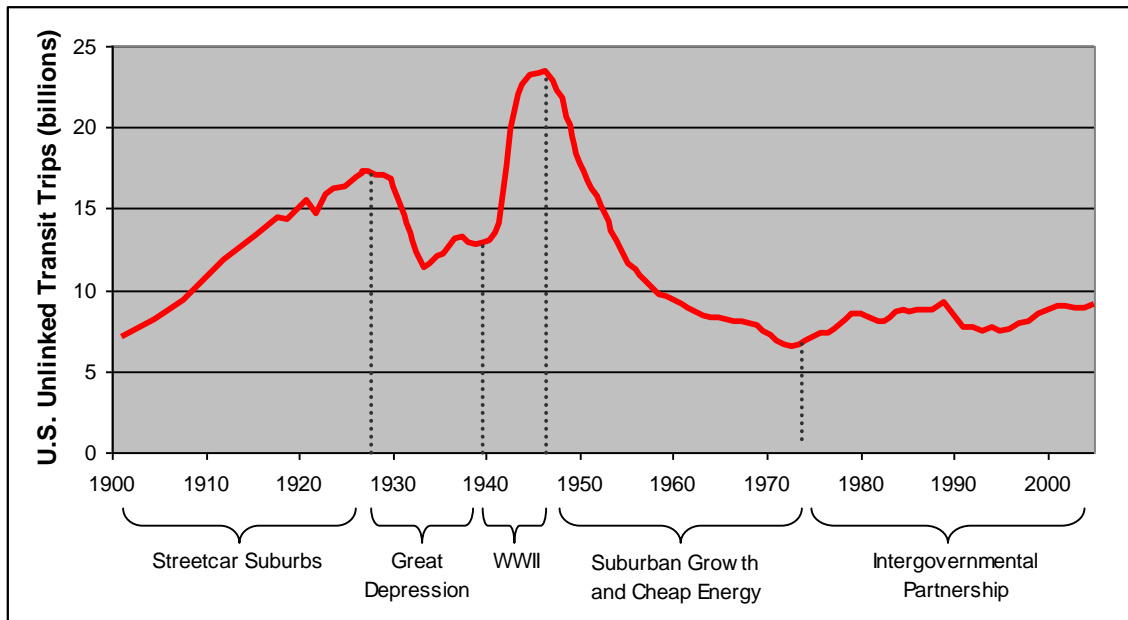
VMT has risen from 34 to 58 miles per day (NHTS, 2004). Although transit ridership has stabilized since 1980, the growth in auto use has meant that transit's market share has dwindled to around 2% of all trips in the U.S. (NHTS, 2004).

Figure 1. Trends in Vehicle Miles Traveled in the U.S.



Source: 1970-2005 historical data from Davis and Diegel (2006); 2005-2030 projections from U.S. DOE, Annual Energy Outlook (2007)

Figure 2. Trends in Public Transit Ridership in the U.S.



Source: adapted from Gordon, 1991 and NTD, 2005.

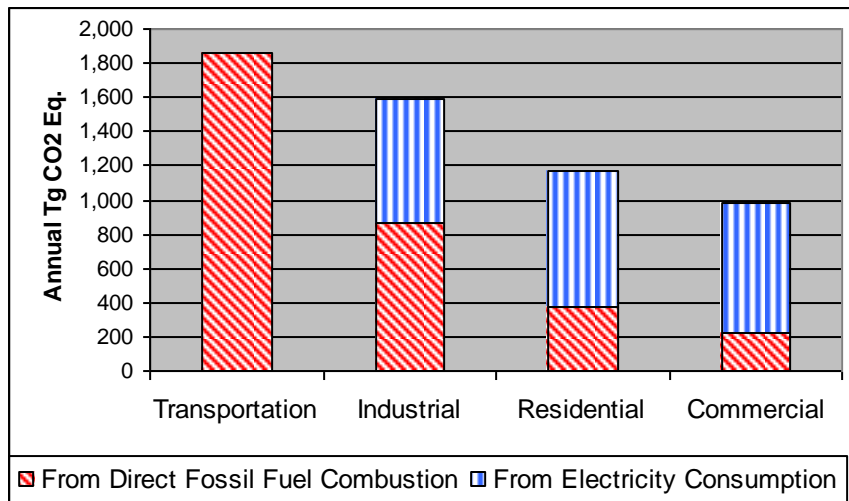
The growth in travel by private automobile has been accompanied by a number of social problems: increased congestion, automobile dependence, and environmental degradation.

Because all VMT growth since 1980 has occurred on a fairly static roadway system, traffic congestion has grown rapidly. Between 1980 and 2000, VMT doubled while lane-miles of road capacity grew by only 4% (FHWA, 2003), causing the cost of urban congestion (measured in

excess time and gasoline spent in traffic) to quintuple since 1982 (TTI, 2005). Because they made up over 90% of total vehicle miles traveled in 2003 (BTS, 2006), automobiles are the primary drivers of rising congestion. According to the Texas Transportation Institute (2005), congestion now makes average peak travel times 50% longer than off-peak times in large cities.

Today, the transportation sector produces 28% of U.S. greenhouse gas emissions, the fastest-growing emissions source (EPA, 2004, 2-25), and automobiles make up around two-thirds of the sector's emissions (EPA, 2006, 2-2). Global warming poses the potential for significant harm (Stern, 2006; IPCC, 2007). Ground-level air pollution is a public health threat to the 146 million Americans who live in urban areas exceeding federal air quality standards for ozone and particulate matter (EPA, 2003, 2-1), and automobiles are responsible for around half of ozone precursors (see Table 5). The growth in overall auto travel has tended to undermine the net environmental gains from cleaner, more efficient vehicles. Despite improvements in automotive technology to increase fuel economy and decrease emissions, these gains have been offset by increased driving and investment in larger and more powerful vehicles (Howitt and Altshuler, 1999).

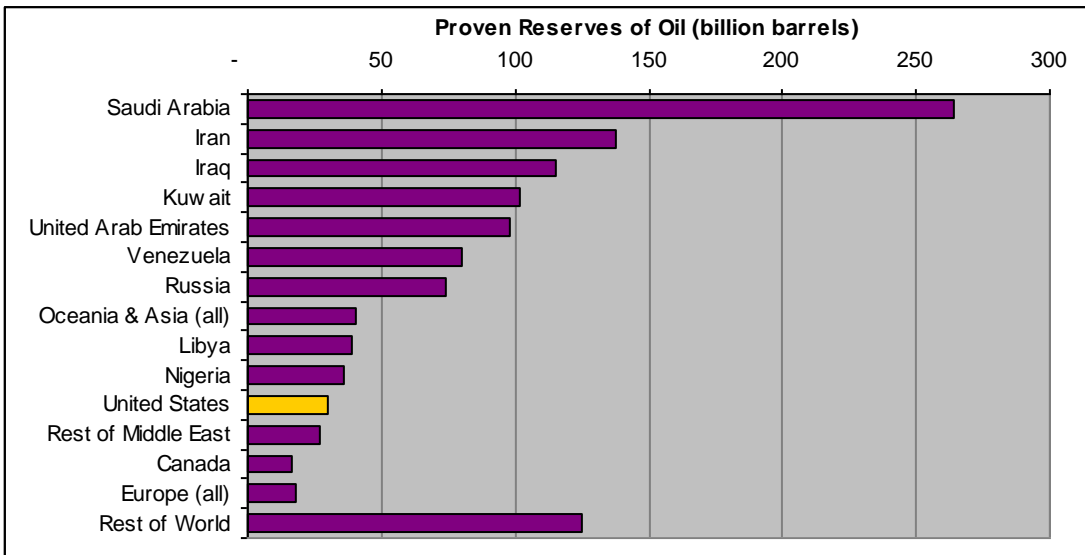
Figure 3. U.S. Greenhouse Gas Emissions by Source



Source: U.S. EPA, 2004, 2-10

Transportation consumes 67% of all U.S. petroleum products (EIA, 2005, 5-3), and the sector uses fossil fuels for 99% of its energy (EPA, 2006, 4). America's reliance on imported oil, the remaining sources of which are concentrated in a small number of countries, continues to cause price instabilities and geopolitical concerns.

Figure 4. Proven World Oil Reserves, 2005



Source: EIA, 2007, quoting BP Statistical Review of World Energy (June 2006)

1.3 The Promise of Public Transportation

Public transit has the potential to be a part of the solution to these challenges. In economic terms, motorists impose external costs in the form of air pollution, accidents, noise, and congestion, and thus the implied underpricing of car travel results in its overconsumption. Since it is difficult to tax these external costs efficiently and make prices equal marginal costs, a “second-best” way to correct these externalities is to “subsidize its substitute” (Wijkander, 1985), i.e. public transportation. Most transit systems in the United States do not make enough money in fares to cover their operating and capital expenditures, so the gap between fares collected and operating expenses incurred is arguably bridged with public funds to compensate for transit’s implied social benefits, outlined below.

1.3.1 Environmental Sustainability

Transit has the potential to provide important environmental benefits.

- Energy consumption and emissions on a per-passenger-mile basis is lower than that of automobiles (Shapiro, Hassett, & Arnold, 2002).
- Transit investments, particularly rail, may be a requirement for more compact, “smarter” urban development, which can be served by a variety of transportation modes, including walking, biking, and mass transit.
- Because public transportation concentrates the means of propulsion into more centralized places such as power plants and bus fleets, it may be more easily adapted to new, cleaner technologies.

1.3.2 Congestion Relief

The availability of a grade-separated alternative to the automobile may tend to mitigate the severity of roadway congestion in cities. By allowing travelers a means to bypass traffic, the city may potentially achieve higher levels of mobility for transit riders and auto drivers alike.

1.3.3 Safety Benefits

As a relatively safe mode of travel per passenger-mile traveled, public transit may avoid a great deal of the public and private costs of traffic accidents, including collisions, injuries and fatalities, and downstream costs such as emergency response and health care.

1.3.4 Scale Economies

In economic terms, transit's increasing returns to scale may mean that the market will naturally result in a monopoly producer. If marginal costs are lower than average costs, marginal cost prices will not cover total production costs. According to theory, a subsidy is required to avoid the monopolist under-producing and overcharging for its services. Transit exhibits signs of scale and density economies (Mohring, 1972), although the precise nature of this phenomenon is debated (Berechman and Giuliano, 1985), especially if passenger time is excluded. At the least, because transit often operates under capacity outside of the peak of the peak, the marginal cost of a passenger is often extremely low (the vehicle would be operating anyways), so fares should be held low.

Theoretically, a transit agency could achieve scale economies in its unit costs, either by allocating common assets like wayside equipment across more passengers ("economies of density" (Braeutigam, 1999)), or by increasing vehicle size to save labor costs (Frankena, 1979). However, as Kennedy and Elgar (2005) point out, larger vehicle size may offset gains from increased frequencies.

1.3.5 Scalable Capacity and Agglomeration

In dense, rapidly congesting urban areas, the high capacity and economies of density of public transport, especially rail corridors, may be the only way to maintain adequate mobility to help cities grow. In the face of growing passenger demand, public transit tends to experience several natural synergies. And if history is any guide, individual travel demand will likely continue to rise (see Figure 1). As passenger demand increases:

- In the short term, transit tends to become more efficient through higher load factors, whereas auto transport tends to become less efficient through congestion effects.
- In the medium term, capacity on a transit line can be increased with investments like new signal control systems, expanded vehicles, or dedicated busways, whereas widening roads, especially in dense cities, can be less financially and politically feasible.
- In the long term, a growing transit system may exhibit economies of scale to the rider (Small, 1992, 58-60). Larger passenger flows can trigger higher frequencies, shorter waiting times, and perhaps more extensive service, so the passenger will have access to more services and opportunities per fare paid. In this sense, an individual's choice to take public transit may confer positive external benefits to other riders.

Furthermore, a body of economic literature (e.g., SACTRA, 1999) points to economies of agglomeration in the core of cities – i.e., that firms are more productive simply because of their proximity to other firms and a labor pool within a dense urban environment, and public transit may be an essential ingredient of this recipe (Graham, 2005). Empirical evidence for this positive externality from transport investment suggests that its effects are real but small, and must be tied to transit-supportive land use policies (Banister and Berechman, 2001).

1.3.6 Equity and Low-Cost Mobility

The cost of car ownership is a significant barrier to accessing opportunity in a modern economy for many households, especially the poor. In 2005, transportation costs consumed over 17% of a typical household's budget,¹ and over 25% for the poorest households. The American Automobile Association estimates the full cost of owning and operating a typical mid-size sedan is around \$7,800 per year (AAA, 2007), three-quarters of which are fixed costs. The large fixed outlays involved in owning a car form a formidable barrier to mobility.

By contrast, the cost of public transit is low and variable with use, thereby enabling low-cost mobility for the car-less who might not otherwise be able to travel. Interestingly, Lewis and Williams (1999, 146) note that to the extent these "captive" riders travel off-peak, they pay the greatest fares relative to the marginal costs of services they consume. Low-cost access is intertwined with an equity argument, as well: public transport allows everyone, including those unable to use a car for any reason – age, low income, physical disability, etc. – a baseline of mobility to access the goods and services necessary to be a contributing member of society.

1.3.7 National Policy Goals

Finally, transit may help achieve policy objectives to reduce consumption of energy, particularly petroleum imports. Transit is less reliant on petroleum fuels than autos, and transit use might mitigate demand. Delucchi and Murphy (2006) estimate that the cost of military expenditures to protect oil resources for U.S. interests is on the order of \$3-33 billion each year. An American Public Transportation Association study estimated that if transit's mode share were to double, the U.S. would save approximately 1.4 billion gallons of petroleum per year (ICF, 2007). Greene and Ahmad (2005) estimate the cost of U.S. oil dependence at \$150-\$250 billion per year. While such economic benefits are difficult to quantify for an individual transit system, national leaders may see an advantage in subsidizing transit to achieve these geopolitical goals.

1.3.8 Summary of Potential Transit Benefits

In summary, transit provides a variety of potential benefits.

- Reducing the air pollution and other environmental costs of autos;
- Bypassing and mitigating roadway congestion;
- Encouraging smart growth that reduces travel demand;
- Reducing auto collisions and safety costs;
- Providing mobility to the poor, elderly, and disabled who are unable to drive;
- Supporting the density needed for urban agglomeration economies;
- Counteracting monopolist prices;
- Easing the burden of auto ownership and providing equitable mobility; and
- Achieving national policy objectives such as reducing foreign oil consumption.

These possible benefits argue for transit subsidies. The ideal size of such subsidies will vary from setting to setting, depending on transit demand, the level of automobile externalities, and the particulars of the city itself.

¹ U.S. BLS Consumer Expenditure Survey, 2005, TR00 item, middle quintile of pre-tax income

1.4 Transit Finance as Urban Policy

Despite public transit's potential to be a major part of a solution to many of the difficulties posed by the transportation sector, the way we pay for public transit operations, I argue, is often disconnected from these potential benefits. Rationales to publicly fund mass transit abound, and public subsidies to transit have persisted despite declining mode share. Yet transit agencies across the country clamor for more funding, threatening fare increases or service cuts, and seem to lack the financial operating resources they need to be more a more effective solution to urban problems. What then is the problem?

Part of the answer lies in the way we provide public funds for transit operations. There is no consistent or singular urban transit finance policy in the U.S., and passenger fares rarely cover more than half of operating expenditures. As a result, major cities pay for their transit systems in very different ways, from sales taxes to toll bridges, in a variety of political and institutional contexts. Furthermore, the way we pay for transit today often bears little rational connection to the needs, benefits, or envisioned role of public transportation in a metropolitan area.

At their core, public transportation finance mechanisms represent large allocations of tax dollars in urban areas, yet their opacity may tend to shield them from critical public attention. These mechanisms often fail to keep pace with rising costs, and are usually established in ad hoc, politically pragmatic means rooted in the political context of a particular time. Because altering such arrangements requires public action, these arrangements often remain in place for years, until a deep enough financial crisis creates enough political will to change. Transit finance arrangements are infrequently crafted with a comprehensive view of the benefits that transit provides. Opportunities to change transit funding structures are as powerful as they are rare. As a large source of public expenditure, much of which affects central cities, transit finance mechanisms are more accurately viewed as significant pieces of U.S. urban policy.

The explanation is partly historical. The first major federal funding program, the Urban Mass Transportation Act of 1964, was passed in part because between 1954 and 1963, 194 transit companies went out of business, leaving governments with the responsibility to continue providing service to its citizens (Wachs, 1989, 3).

The explanation is also partly institutional. Metropolitan Planning Organizations (MPOs) and other agencies often conduct regional planning processes to coordinate land use and transportation planning under a shared vision of a future transportation network, but these organizations rarely control operating funds. And when they do, their role is limited to federal capital dollars. While building new lines may be important, operating funds are equally necessary to maintain reasonable service frequency and extent.

In a vacuum of federal policy, and with little impetus for thoughtful change outside of perceived crises, urban public transit financial policy in America has been cobbled together with little regard for what an optimal subsidy amount might be, or how it should be structured.

1.5 Thesis Question and Outline

I examine this question of optimal transit finance through the case of public transportation in Chicago, where the current funding structure is being challenged. Transit in Chicago appears

to be at a crucial window of political opportunity to change the way it is funded. Frustrated with what they perceive as an inadequate and outdated financial arrangement, transit providers and policymakers are currently making the case to overhaul the amount and distribution of public subsidy. Chapter 2 introduces the Chicago case.

1.5.1 The Ideal

Because transit funding in the U.S. is the heterogeneous product of incrementalism, Chicagoans have little to go on as they search for a new public transportation finance mechanism. To help fill the void, this thesis attempts to step back from stopgap measures and first poses the question: *Ideally, how should public transit be paid for? Who should pay, and how much?*

I propose a conceptual framework for a way to pay for public transportation that tries to more closely match the magnitude and incidence of transit’s key social benefits to its payment structure. The structure I propose takes the beneficiary principle as its core: those who receive benefits from public transportation should more closely bear its costs. In theory, public transportation is subsidized because it provides a host of social benefits to a variety of groups. Historically, tax sources have often been rooted in a pragmatic mix of geographic area of service and some measure of ability to pay. But if current levels of subsidy are inadequate to maintain services, how should this gap be covered? An ideal subsidy mechanism, I argue, would pay for public transit operations with revenues derived from actors and jurisdictions according to the benefits received, as illustrated in Table 1.

Table 1. Proposed Theoretical Basis for Transit Subsidy

Quantifiable Benefit (\$m)	Beneficiary			
	<i>Auto Drivers</i>	<i>Directly Served Communities</i>	<i>General Metropolitan Area</i>	<i>State or World</i>
<i>Congestion</i>	Less time and gas spent in congestion	Less local pollution from congestion	Less ground-level pollution from congestion	Less GHGs from avoided congestion
<i>Economic</i>	---	Mobility benefits to riders	Agglomeration Economies	---
<i>Safety</i>	Fewer accidents with other autos	Increased safety costs of transit	---	Lower medical + emergency costs
<i>Emissions</i>	---	Less local pollution	Different/Less ground-level pollution	Less GHGs from efficiency
Total:				

In such an arrangement, the social benefits of public transportation are quantified and divided amongst four categories of beneficiaries. Revenues are generated so as to align the magnitude and incidence of transit’s burdens with its beneficiaries, and the public subsidy is equal to or less than the sum of benefits.

To suggest an answer to the question of ideal funding in the context of Chicago, I deconstruct and quantify the primary social benefits of transit services in the region in Chapters 3, 4, and 5.

While some transit benefits are varied and difficult to quantify, I focus on several for which existing literature is strong, and for which there is good data for Chicago. [Chapter 3](#) quantifies transit's air pollution benefits to Chicago, [Chapter 4](#) measures the degree to which transit avoids costs associated with auto accidents, and [Chapter 5](#) evaluates transit's contribution to congestion relief, as well as its value to passengers as an alternative to driving.

1.5.2 The Actual

Second, this research examines the operability of theoretically ideal finance instruments in a real-world context by asking: *How do other cities pay for public transit? What lessons from others can be applied to Chicago?* I explore the feasible ways that financial mechanisms can be designed so as to capture the social benefits as public revenues for transit. [Chapter 6](#) describes the role of fares in transit finance, surveys the operating revenues of 15 large urban transit systems in North America and Western Europe, and highlights patterns and best practices in funding.

1.5.3 The Possible

Third and finally, [Chapter 7](#) combines the results of the preceding sections to make specific recommendations to Chicago transit policymakers. Given that transit funding in Chicago is probably inadequate to maintain existing services, *how could Chicago pay for its transit?*

In the real-world setting of Chicago, the immediate question is, who should pay? Because transit is funded from different of sources, sponsor jurisdictions in Chicago seem to find themselves in a game of chicken, where no one wants to pay, and each group is using the others' inaction as an excuse for their own, yet current operating revenues are insufficient to maintain services. Therefore, I compare the incidence of transit's benefits with the current RTA funding structure to identify constituencies who may be receiving more benefits than they are paying.

After assessing the theoretical results, and drawing on the lessons learned from other cities, I offer a range of specific policy recommendations for Chicago to expand and shift the burden of transit funding.

1.6 Research Methodology and Sources

The purpose of this thesis is to suggest a framework for policymaking. As such, it is rooted heavily in existing literature on transportation economics, finance, and policy, and finds most data from publicly-available documents. The case study on Chicago introduced in [Chapter 2](#) draws in part from my experience at the Chicago Transit Authority in the summer of 2006, but also relies on a number of past MIT theses on similar topics (Kirschbaum, 2004; Schofield, 2004; Misiak, 2005).

In the quantification of benefits in [Chapters 3, 4, and 5](#), I draw heavily from an economic literature focused on measuring the "full" social costs and benefits of transportation (e.g., Small, 1999; Greene, Jones, and Delucchi, 1997; Litman, 2005). The benefits of transit are often cast as avoided costs of the automobile system. In some cases, I formulate my own methodologies for quantifying social benefits and costs for transit in Chicago, such as extrapolating historical trends to predict congestion effects. Like much of the literature, I often confront the problem of the appropriate counterfactual – costs and benefits *compared to what?* For the most part, I

attempt to measure how much would Chicago stand to lose in a hypothetical no-transit scenario after reaching a medium-term equilibrium. I find specific data and statistics for the Chicago region from a variety of publicly-available documents such as the U.S. EPA, the Illinois Department of Transportation, the National Transit Database, and the Texas Transportation Institute.

The survey of transit finance in other cities in Chapter 6 relies on mine and others' previous research completed for Transport for London (Antos, 2005; Favero, 2006). Finally, the ideas presented in the conclusion are largely my own, except where noted.

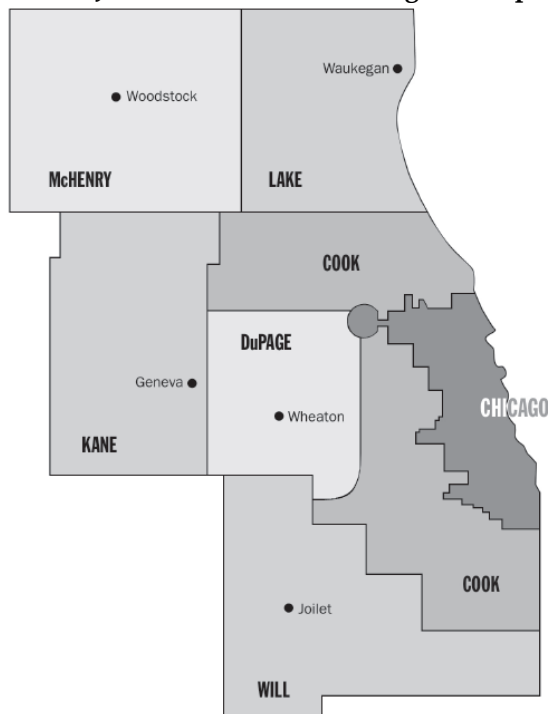
2 Transit Finance in Chicago

To explore the question of optimal transit finance, I take up the case of public transport in Chicago, where the adequacy of transit funding is currently being challenged. Transit in Chicago appears to be at a political window of opportunity to change its transit funding arrangements, providing a useful lens for me to examine how a city can and should pay for transit services.

2.1 *The Chicago Metropolis*

The greater Chicago metropolitan area in northeastern Illinois is home to around 8.4 million people, centered on downtown Chicago where the Chicago River meets Lake Michigan. Although the metropolis includes some parts of southern Wisconsin and northwestern Indiana, the most common spatial definition of the region includes the six Illinois counties of Cook, Lake, McHenry, Kane, DuPage, and Will counties. Cook County, which encompasses the City of Chicago and 128 other local governments, is the most populous and urban of the six-county region. Unusually for American cities, the jurisdiction of the City of Chicago more or less approximates the urban form of the city, including most land areas within five miles of the central business district (CBD, also called “the Loop”). The portion of Cook County that is not the City of Chicago is referred to as “Suburban Cook County,” while the five surrounding counties are called the “collar counties.” As shorthand, I refer to “Chicago” to denote the entire six-county region, while the “City of Chicago” indicates the central city.

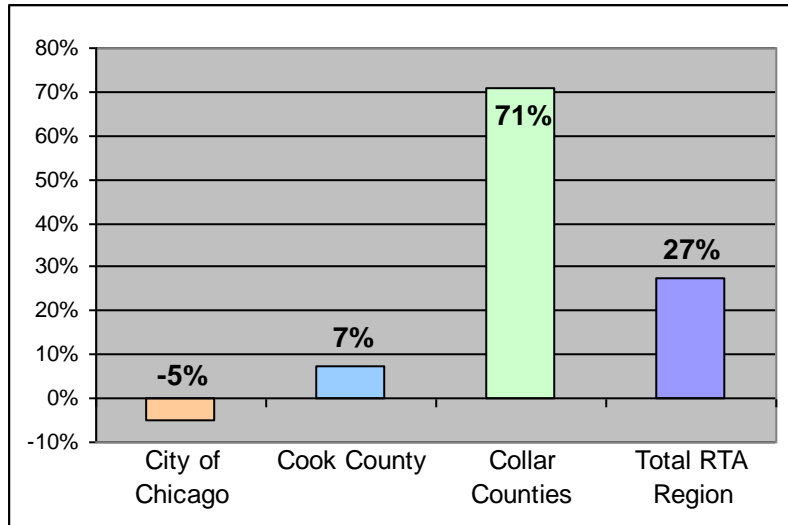
Figure 5. Political Jurisdictions in the Chicago Metropolitan Area



Source: RTA, 2007a

Similar to other mature U.S. cities, the growth of the Chicago metropolitan area in recent decades has been characterized by a stabilizing population and economy in the central city, and much stronger population and income growth in the suburbs (see Figure 6). Since 1990, the six-county region's population has grown at about 1% per year, but the majority of this growth has come from the suburban collar counties as the central city remains stable. For example, in the decade between 1990 and 2000, the population of Cook County grew by 5%, while suburban McHenry County grew by 40%. Balancing this unbalanced growth, however, is the magnitude of Cook County: in 2000, it accounted for 67% of the region's population (RTA, 2007a).

Figure 6. Growth in Sales Tax Base in the RTA Region, 1985-2003



Source: Extrapolated from Kirschbaum, 2004, figure 3-4

The suburban collar counties have traditionally been faster-growing and more wealthy than the urban core. Unemployment rates in 2005 were 5.7% for Cook County, and between 3.7-4.6% in the collar counties (RTA, 2007a, ex. 8-9). Jobs in Chicago have been decentralizing: despite a growing absolute number of jobs since 1980, Cook County's proportion of regional jobs has declined from 79% to 67% (RTA, 2007a, 8-10). In 2005, median household income in the City of Chicago was \$41,015, Cook County's was \$48,950, and the same indicator in the collar counties ranged from \$68,000 and above.

As the Chicago metropolitan area has been growing most strongly in its suburbs, its overall urbanized area population density has fallen as well. From 1970 to 1990, Chicago's urbanized area land mass grew 24% from 1,277 to 1,585 square miles, while its population grew only 1%. The result has been an 18% drop in urbanized area density from 1970 to 1990 (Orfield, 1997, 3-6). Population density is higher in the center city where some areas reach over 20,000 inhabitants per square mile, while areas of the collar counties can be under 100 people per square mile (NIPC, 2002).

2.2 Transit Institutions in Chicago

In 1974, the Illinois General Assembly created the Regional Transportation Authority (RTA) to consolidate all public transit services in the six counties in the greater Chicago metropolitan area (thereby known as the RTA Region). The RTA, as a special-purpose unit of government

and a municipal corporation of Illinois, provides financial oversight over the major transit operators in the metropolitan area, or “service boards:”

- The Chicago Transit Authority (CTA) operates core city buses and heavy rail rapid transit (“the El” for “elevated”). The bus network operates around 2,000 buses per day, while 1,190 vehicles serve eight routes and 222 miles of track on the rapid transit system.
- Metra operates 11 separate radial commuter rail lines which terminate in the CBD and primarily serve stations outside the City of Chicago. The commuter rail network runs a fleet of 1,100 vehicles (Metra, 2007, 6) to 230 stations, some of which are as far as 50-60 miles from the CBD.
- Pace, a suburban bus company operating primarily in suburban Cook County and the collar counties, operates a fleet of around 360 buses, and vans. In summer 2005, Pace took control of the regional paratransit service, a demand-responsive system of vans and taxis for those with disabilities.

Table 2. Transit Service Consumption by Service Board, 2005

	Passenger Miles (mill.)	%	Passenger Trips (mill.)	%	Average Trip Length (miles)
CTA	1,918	51%	490	82%	3.9
Metra	1,548	41%	69	12%	22.5
Pace	273	7%	37	6%	7.4
Total	3,740		596		

Source: NTD, 2005

2.3 The Structure of Transit Finance in Chicago

In 1983, the Illinois legislature passed the RTA Act, which continues to define operating funding and governance of public transit services in Chicago today.

2.3.1 Operating Revenue Generation

Under the RTA Act, the RTA receives an increment added to the statewide 6.25% sales tax collected in the six-county region: 0.75% in Cook County, which includes the City of Chicago, and 0.25% in the five suburban collar counties. That is, for every \$100.00 of taxable goods sold in the region, the state collects an additional \$7.00 in Cook County and \$6.50 in the collar counties, of which \$1.00 for transactions in Cook County or \$0.25 in the collar counties is dedicated to the RTA. In addition, for every \$4.00 raised for the RTA this way, the state provides a \$1.00 match in the form of the Public Transportation Fund. In 2005, this generated a total of \$876 million, or around 80% of all public subsidies to transit operations. The remaining 20% comes largely from discretionary funds from the state, including appropriations from general funds, partial reimbursement of reduced fares, and other assistance (RTA, 2007a). In 2005, all public subsidies to RTA transit services totaled \$1,096 million.

In addition, the 1983 RTA Act requires that the three service boards collectively meet a 50% “recovery ratio,” similar to a farebox recovery ratio but which includes all system-generated revenues and excludes some expenditures.

2.3.2 Operating Revenue Distribution

The RTA Act distributes 85% of these revenues among the three service boards by formula, based on where the sales tax was generated, as follows:

Table 3. Distribution of Non-Discretionary RTA Sales Tax and Matching Revenues

		Origin of Sales Tax		
		City of Chicago	Suburban Cook County	Collar Counties
Destination of Sales Tax	CTA	100%	30%	0%
	Metra	0%	55%	70%
	Pace	0%	15%	30%

The RTA allocates the remaining 15% of funds by its own discretion, although for much of the RTA’s history, almost all of this has been awarded to the CTA.

2.3.3 Capital Funds

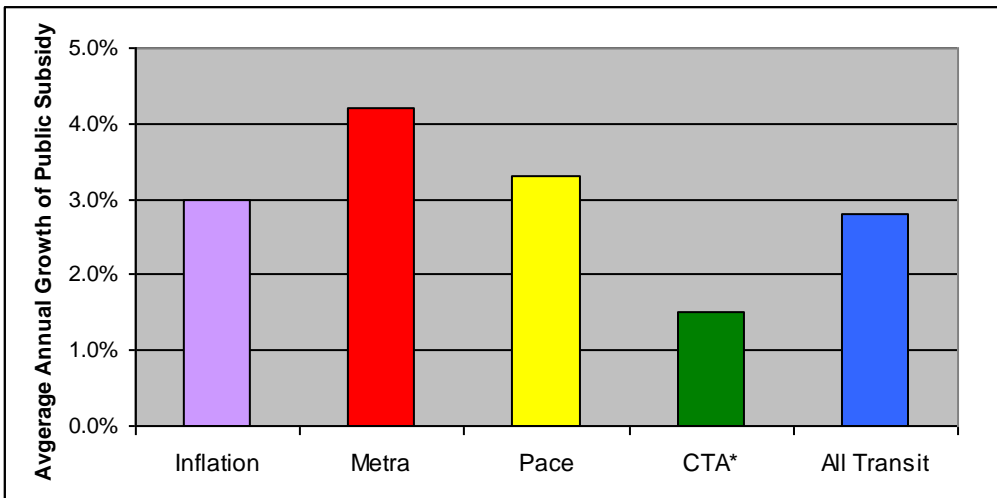
Although I limit my analysis to operating funds, it is important to note that transit in Chicago also received approximately \$450 million in federal capital funds in fiscal year 2007 (CATS, 2006, 3-2). These funds are authorized under several sections of the 2005 spending bill Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), and are primarily backed by the federal gasoline tax. Several other capital sources also backed public transit in Chicago (RTA, 2007a, 1-D).

2.4 Problems with Transit Finance in Chicago

The RTA funding structure has been unchanged since 1983, which has produced several consequences.

Since sales tax revenues are tied to their originating jurisdiction through the service boards as described in Table 3, and because population and economic growth has been focused more strongly at the metropolitan periphery, as shown in Figure 6, funding for the CTA’s core bus and rail services has not kept pace with inflation since 1983. On the other hand, revenues for Pace and Metra’s primarily suburban services has risen faster than inflation, as shown in (CTA, 2005). The distribution of revenues has favored suburban services, particularly commuter rail, because even as sales tax receipts have been growing fastest in the suburbs, the ridership and infrastructure needs of the central city have remained strong.

Figure 7. Annual Growth of Public Transit Subsidy in Chicago 1985-2005



Source: CTA, 2005. *Note: excludes paratransit funds.

The practical extent of transit services since 1983 has changed beyond the structure established in the RTA Act. For instance, residents outside the City of Chicago and even Cook County regularly use the CTA (CTA, 2005), the metropolitan statistical area of Chicago has expanded to include counties beyond the RTA region, and operators often bear the operating costs of services outside the jurisdiction from which they derive funding. In addition, the mandated 50% fare recovery ratio for all service boards does not account for capital investments, which has arguably worked in favor of capital-intensive rail and against operations-heavy bus services.

Perhaps correlated with this financial emphasis on suburban services, fares on the CTA have risen above inflation and ridership has fallen, while Pace and Metra's fares have remained below inflation since 1985, and Metra ridership has risen (CTA, 2005).

2.5 *The Politics of Subsidy in Chicago*

Frustrated with what they perceive as an inadequate amount and distribution of public subsidy, transit providers under the Regional Transportation Authority are making the case to alter and augment its funding structure. Under a political campaign labeled "Moving Beyond Congestion" (MBC), the three transit agencies in Chicago have requested approximately \$700 million in additional funds over three years from the Illinois Legislature (RTA, 2007a).

Transit supporters have worked hard to make the case for increased public funding, yet few sources seem willing to come forward with the money. In 2004, the Chicago Transit Authority claimed that revenues were insufficient to continue existing services, and passed two versions of its 2005 budget called "gridlock" and "mobility" to call attention to its financial needs (CTA, 2004). But the CTA's call apparently fell on deaf ears, and the agency in response raised fares, shed responsibility for paratransit, and borrowed capital debt to pay operating expenses for two years. In 2006, all three operators agreed to repeat the call for funding under the leadership of the Regional Transit Authority. This campaign has produced a host of materials in hopes of convincing legislators and voters to increase transit subsidies (RTA, 2007b).

Echoing the earlier conclusions of scholars that transit in Chicago faces a “structural deficit” which cannot be solved with fare increases (Anderson, 2004), a March 2007 audit by the Illinois General Auditor found that “RTA revenues are insufficient to pay the continuing cost of programs or funding new services” (Holland, 2007, 4). Releasing his report, the Auditor commented that “even if you double the fares, it's not enough to solve the problem” of inadequate funding (McKinney, 2007).

Yet so far, public transportation needs in Chicago seem to be getting little support. In June 2006, the Illinois Legislature told Chicago that it would not bail out mass transit in the following year. In February 2007, Illinois Governor Blagojevich proposed a budget to the Illinois Legislature that did not include new funds for public transportation in Chicago (Illinois OMB, 2007).

In a move of brinkmanship, transit operators in Chicago have passed a consolidated operating budget for 2007 that is based on \$140 million of revenues that do not yet exist, in hopes of securing more funds from the Illinois Legislature (RTA, 2007a). The Regional Transit Authority has declared that its current operations cannot continue without increased public subsidy. As this thesis goes to press, the RTA continues to operate as if it had a full year of revenues, and it is unclear what may happen in the final months of the year if supplemental funds are not identified.

2.6 How This Thesis Fits

The purpose of this research is not to criticize the RTA statute. Indeed, many others have shown that the 1983 RTA Act suffers from distortions (Kirschbaum, 2004; Anderson, 2004; Schofield, 2004; CTA, 2005; Misiak, 2005; Hamos, 2005). Instead, I emphasize not *why* the RTA's funding structure should be changed, but *how* it should be changed. Because transit funding policy in the U.S. is the heterogeneous product of incrementalism, Chicagoans have little to go on. They have no ideal against which to compare themselves. The Moving Beyond Congestion campaign has not explicitly justified its funding request against any concrete reference point of need or optimal subsidy. Instead, the RTA's operating budget shows the funds needed to maintain current services, and the MBC final report includes a “wish list” of capital projects. The campaign lays out a vision for transit's role within the city, and describes a menu of financing options for how to pay for it, but stops short of choosing one option and implicitly identifying who should bear the burden. In this thesis, I attempt to provide some more rational framework for transit funding against which to compare the current funding arrangements.

3 Measuring the Energy and Air Emissions Benefits of Transit

With a view to a funding structure based on social benefits, the purpose of this chapter is to verify and quantify the air pollution and energy benefits of public transportation in Chicago. Indeed, one oft-cited justification for transit subsidy is the relatively low energy consumption and air emissions of public transportation compared to private automobiles. Transportation is the largest domestic source of greenhouse gases, depends almost entirely on fossil fuels, and is a major contributor to the urban air pollution that currently exceeds federal standards in Chicago. Public transportation in particular is often touted as a potential solution to these problems, and is claimed to provide a number of air quality benefits to the region it serves. As a building block for a funding mechanism, it is important to verify and quantify these benefits.

However, modal comparisons of energy and environmental performance are complex. Urban transport modes rely on different fuels and propulsion technologies, each of which affect air quality in different ways, and road congestion alters the energy consumption of private cars. To account for these complexities, I perform a top-down comparison of the energy and environmental performance of public and private passenger transportation in the Chicago metropolitan region. My analysis integrates a variety of data sources to build an emissions inventory, models the interaction between mode choice and emissions through auto congestion, and comments on the relative advantages and disadvantages of public transit in the future.

3.1 Current Air Quality in Chicago

Broadly speaking, passenger transport in Chicago contributes to two categories of air emissions: ground-level pollutants that pose public health costs, and stratospheric greenhouse gases that contribute to global climate change.

Table 4. Classification of Transportation-Related Air Pollutants

Effect	Pollutant	Range
Climate Change	Carbon Dioxide (CO ₂)	Global
	Non-CO ₂ Greenhouse Gases	Global
Public Health	Nitrogen Oxides (NO _x)	Metropolitan
	Particulate Matter (PM)	Metropolitan
	Volatile Organic Compounds / Hydrocarbons (VOC)	Metropolitan
	Carbon Monoxide (CO)	Local

3.1.1 Current Ground-Level Pollution in Chicago

Ground-level “criteria” pollutants, so named because they are regulated directly by the Clean Air Act, include oxides of nitrogen (NO_x) and sulfur (SO_x), carbon monoxide (CO), volatile organic compounds (VOCs, approximate to hydrocarbons), and particulate matter (PM). These contribute to ground-level pollution such as ozone, causing human health concerns at a local and regional scale.

Ground-level ozone and particulate matter pose health risks to the Chicago region. The metropolitan area currently exceeds the National Ambient Air Quality Standards (NAAQS) established by the U.S. Environmental Protection Agency (EPA) for both of these pollutants. In 2004 and 2005, the EPA designated the Chicago region as a “moderate non-attainment area” for both ozone and particulate matter because air quality monitoring stations around the city exceeded certain threshold levels (CATS, 2005). Breathing ground-level ozone may only induce coughing or chest pains, but prolonged or repeated exposure reduces lung functions, and may cause asthma and scar lung tissue. The Illinois EPA estimated that the Chicago region accounted for over 85% of the air quality warnings it issued statewide in 2005 based on an index of pollutants. For roughly half of monitored days in 2005, the Air Quality Index for Chicago-specific sectors was “moderate” and “unhealthy for sensitive groups.”² The American Lung Association (2007, 95) gave Cook County’s air a grade of “F” because of high ozone days between 2003 and 2005.

Concerns over Chicago’s air quality are amplified because a large number of metropolitan inhabitants are exposed to the poorest-quality air in the state, posing a public health risk. In addition, the EPA has recently tightened existing regulations, making the further reduction of pollutants a long-term concern. For example, the EPA strengthened the 1-hour ozone standard to a more stringent 8-hour standard.

Passenger transportation is a significant contributor to air pollution in Chicago. The sector relies on fossil fuel combustion, which produces NO_x, VOCs, and CO. Ground-level ozone, in turn, is formed when NO_x and VOCs react with heat and sunlight. In 2001, EPA inventories show that passenger transportation was responsible for about half of these ozone precursors and over three-quarters of the RTA Region’s carbon monoxide (Table 5). Other economic sectors are responsible for the majority of emissions of PM and SO_x, so these pollutants are excluded from this analysis.

Table 5. Pollutant Emissions in RTA Region (2001) and Nationally (2002)

Emission type (tons)	NO _x	VOC	CO	PM _{2.5}	SO ₂
Transport's Share of Total Chicago Region Emissions	51%	27%	61%	6%	3%
Transport's Share of Total U.S. Emissions	56%	45%	82%	--*	5%

Source: Illinois data from U.S. EPA AirData, Emissions by Category Report. “Passenger Autos” is category 11-(all), “Railroads” is category 12-05, and may include freight rail in addition to commuter rail. National data from EPA, 2003, figs. 2-5, 2-19, 2-36, 2-54.

While the Chicago area has attained the federal standard for carbon monoxide, these emissions are still a localized concern. Carbon monoxide is an odorless, poisonous gas released due to incomplete fuel combustion, but disperses rapidly. If concentrated amounts are inhaled, carbon monoxide restricts oxygen to the brain and other organs, impairing cognitive abilities and can cause brain damage or death. Despite my reliance on a single emissions factor, CO emissions vary based on emissions control technology, vehicle speed, and air temperature. The California Air Resources Board estimates that idling below 10 mph can produce as much as 3-9 times the carbon monoxide as traveling at 30 mph or higher (CARB, 2000, 6.2-3).

² IEPA (2006) p. 17, fig. 9, highlights the Chicago region as home to 91 of 105 Air Quality Index warnings in 2005.

Therefore, CO emissions from transportation are of particular concern after a cold start and when cars idle in traffic, which can create temporarily high concentrations of the gas, or “hotspots.” This analysis relies on regional averages, which may understate the danger of localized hotspots.

3.1.2 Current Greenhouse Gas Emissions in Chicago

Greenhouse gases (GHGs) have very little public health impacts, but instead contribute to the greenhouse effect globally. The International Panel on Climate Change (2007) declared with “very high confidence” that greenhouse gas emissions from human activity are causing global warming. The report states that the warming of the climate is unequivocal, and projects an average global temperature rise of roughly 0.2° C per decade if current trends continue. According to the report, scientists are becoming increasingly certain about predictions of changes in wind patterns, precipitation, sea level rise, melting ice, and extreme weather events.

Because of the worldwide nature of climate change, greenhouse gas emissions are a fundamentally different problem than ground-level pollution. Carbon dioxide poses little immediate health risks to nearby populations, but because the gas eventually joins everyone’s atmosphere, carbon emissions from anywhere are a concern everywhere.

Although many greenhouse gases contribute to global warming, carbon dioxide (CO₂) is the leading anthropogenic greenhouse gas, and its concentration in the atmosphere now “far exceeds” pre-industrial levels (IPCC, 2007). Carbon dioxide made up 85% of the anthropogenic greenhouse effect in the U.S. in 2003 (EPA, 2006, 2.1), and that proportion climbs to over 95% in transportation. Therefore, this analysis focuses on carbon dioxide, but expresses greenhouse gases as “carbon dioxide equivalents” to account for non-CO₂ GHGs as well.

In Illinois, transportation was responsible for 27% of the state’s greenhouse gas emissions in 1998 (DNR, 1998, 7). On a national level, the sector accounts for nearly 30% of all anthropogenic CO₂ emissions in the U.S., the largest single domestic source (EPA, 2006, 3).

3.2 Transportation Consumption in Chicago

Underlying much of transportation’s air emissions is the consumption of passenger transport. In 2005, public transportation in Chicago provided approximately 211 million vehicle miles (NTD, 2005), while autos produced around 55 billion vehicles miles of passenger travel.³ This analysis omits freight, and transit non-revenue service.

³ The Illinois Department of Transportation (IDOT, 2006a, Tables FC-4 and TVT-1) reports 59.8 billion VMT in the six-county region in 2005, but also states that 91% of VMT in urban areas is by 4-tire passenger vehicles, while 9% is by single and multiple unit trucks. Because this analysis compares only passenger transportation, total VMT is estimated at $59.8 \times 0.91 = 54.5$ billion vehicle miles. This 59.8 billion figure is 3.7% lower than the 60.5 billion VMT reported by TTI (2005).

Table 6. Transportation Consumption Statistics in RTA Region, 2005

Mode	Vehicle-Miles	%	Passenger-Miles	%	Passenger Trips	%	Trip Length	Pax per Vehicle
CTA Bus	66,572,049	0.12%	781,977,753	1.1%	303,244,197	3.3%	2.6	11.7
CTA Rail	68,920,555	0.13%	1,136,464,595	1.7%	186,759,524	2.0%	6.1	16.5
Metra Rail	38,260,317	0.07%	1,548,276,634	2.3%	68,950,955	0.7%	22.5	40.5
Pace (All modes)	36,918,305	0.07%	273,384,845	0.4%	36,879,312	0.4%	7.4	7.4
Transit Subtotal	210,671,226	0.39%	3,740,103,827	5.5%	595,833,988	6.5%	6.3	17.8
Cars and Trucks	54,456,495,730	99.61%	64,422,034,449	94.5%	8,616,027,076	93.5%	7.5	1.2
TOTAL	54,667,166,956	100.00%	68,162,138,276	100.0%	9,211,861,064	100.0%		

Source: IDOT, 2006a; NTD, 2005. Auto passenger-miles and passenger-trips calculated as discussed in text.

3.2.1 Average Vehicle Occupancy and Trip Length

Converting automobile vehicle miles to passenger-miles and passenger-trips requires two key auto statistics: average vehicle occupancy and average trip length. The National Transit Database provides equivalent data for transit. The Chicago Area Transportation Study, in its transportation model underpinning the TIP conformity analysis, uses a number of average vehicle occupancies depending on time of day and trip purpose. I find the direct average of these rates by trip purpose, weighted by the traffic volume occurring at those time periods to produce an average of 1.18.⁴ Average trip length for automobiles is found by taking an average trip length from CATS weighted by national travel volume by trip purpose.⁵ By these figures, transit in the six-county Chicago region captures a passenger-mile market share of around 5.5%, but a passenger-trip share of around 6.5%.

3.3 Energy Consumption from Transportation in Chicago

Public transportation in Chicago operates on a number of different fuels. CTA buses run on diesel, while the CTA rail system operates on electricity. Metra commuter rail trains run primarily on diesel fuel, but one line runs on electric power. Pace vehicles operate on diesel fuel and regular gasoline. This analysis omits paratransit and non-revenue fleets.

⁴ CATS, 2005, Appendix B, p. 74-76, Tables 7.2 and 7.5. Occupancy rates range from 1.00 to 1.34. This figure is not out of line with other recent estimates. A 1997 study estimated that the average vehicle occupancy for Chicago was 1.29 ± 0.02 passengers per vehicle using accident data and windshield screen counts in the Chicago MSA for cars, vans, and trucks (FHWA, 1997, 3-8). The 2001 National Household Travel Survey suggests a national occupancy rate of 1.1 passengers per vehicle for work commute trips, and 1.6 passengers for all trips (NHTS, 2001, Table A-14). The Mobility in Cities Database (UITP, 2001) reports Chicago's average vehicle occupancy as 1.1.

⁵ CATS (2005) in their TIP conformity analysis estimates trip lengths based on trip purpose: 10.6 miles for home-to-work, 5.3 miles for home-to-other, and 5.7 miles for other purposes. The NHTS (2001) estimated that nationally, around each of these three categories accounted for around one third of all VMT, so a weighted average for Chicago based on these figures yields an average auto trip length of 7.5 miles.

Table 7. Transportation Energy Consumption Statistics in RTA Region, 2005

Mode	Gallons of Diesel	Gallons of Gasoline	kWh Electricity	Energy consumed in BTUs (000)	%
CTA Bus	24,428,000	-	-	3,590,916,000	0.98%
CTA Rail	-	-	408,603,200	1,394,154,118	0.38%
Metra Rail	24,125,000	-	100,576,936	3,889,543,506	1.07%
Pace (All modes)	5,335,716	707,600	-	872,800,252	0.24%
Transit Subtotal	53,888,716	707,600	509,180,136	9,747,413,876	2.67%
Cars and Trucks	-	2,682,585,997	-	355,442,644,543	97.33%
TOTAL	53,888,716	2,683,293,597	509,180,136	365,190,058,419	100.00%

Source: NTD, 2005, Table 17

I estimate gasoline consumed on Chicago’s road system by applying an average fuel economy (EPA, 2005a) to the total number of vehicle miles traveled in the six-county region. Assuming that the mix of vehicles on the road in Chicago is little different from the rest of the country,⁶ and that all 4-tire passenger vehicles run on gasoline,⁷ cars on Chicago roads in 2005 consumed around 2.7 billion gallons of gasoline. To compare energy usage, all fuel types are converted to common units: British Thermal Units, or BTUs.

3.4 Air Pollution from Transportation in Chicago

To estimate the volume of air pollutants generated by each mode, national average emissions factors are applied to current travel patterns in Chicago. However, data for emissions factors are found in several different sources, and depend on the type of vehicle, the vehicle’s age, fuel consumed, and driving conditions. A comprehensive transportation emissions model using hundreds of emissions factors such as MOBILE6 is beyond the scope of this analysis. Table 8 shows the emissions factors used in this analysis.

Table 8. Modal Emissions Factors Applied

	CO ₂		NO _x		VOC		CO	
	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
<i>grams</i>								
Cars and Trucks (per mile)	382	394	1.43	1.16	0.60	1.56	1.59	16.27
Diesel Buses (per mile)	3,695	---	23.18	---	0.58	---	3.19	---
Diesel Locomotives (per mile)	6,349	---	107.63	---	6.28	---	16.77	---
Electric Power (per MWh)	220,763.41		362.87		12.70		88.90	

Source: discussed in text.

The EPA provides emissions factors for carbon dioxide for all fleets based on fuel usage (EPA, 2005b). Emissions from electricity generation for CO₂ and NO_x are taken specifically from environmental disclosure statements from Chicago’s supplier for railroads, Commonwealth

⁶ NHTS (2001) provides evidence that the Midwest region of the U.S. is little different from the average national fuel efficiency. Compared to the NHTS national average of 20.2 MPG, the “East and West North Central Midwest” regions of the U.S. showed fleet averages of 20.3 and 20.0 MPG, respectively (Table A3, Energy Information Administration / Household Vehicles Energy Use: Latest Trends).

⁷ Diesel-powered passenger cars are a very small component of the U.S. auto fleet. In 2004, 0.4% of new vehicles sold on retail markets were diesel (Davis and Diegel, 2006, 4.5). In 2003, diesel-powered light vehicles consumed 2.2% of all highway transportation energy (Davis and Diegel, 2006, 2.4).

Edison, as filed with the Illinois Commerce Commission (ComEd, 2006). For VOC and CO emissions from electric generation, Illinois statewide figures from a U.S. Department of Energy dataset are used (Leonardo Academy, 2004, Table 3).

Emissions factors for NO_x, VOCs, and CO for autos are from the Bureau of Transportation Statistics, and cars and trucks in the Chicago area are assumed to have the same emissions as the national light-duty gasoline auto fleet nationally (BTS, 2006, Table 4-38). Using the same dataset, diesel transit buses fall into the category of diesel heavy-duty vehicles for emissions of CO and VOCs (HC), and Pace vanpools are treated as gasoline cars and trucks. I calculate Metra's commuter rail diesel locomotives ground-level emissions by separating into them two groups based on the "tier" of emissions with which they comply,⁸ applying EPA's emissions factors (EPA, 1997), and deriving a weighted average.

Nitrogen oxide emissions factors for buses and commuter rail locomotives must be selected with care, since technology and regulations are rapidly decreasing emissions rates. Detailed testing of existing diesel urban transit buses is difficult to find and depends on how frequently the bus starts, stops, and idles. Studies from public health literature use a central estimate of 28.7 grams/mile (Cohen, Hammitt, and Levy, 2003). In 2003, New York City MTA estimated their buses typically emitted around 24.5 grams NO_x/mile (EESI, 2004). However, recent experience from other transit agencies shows that new diesel buses with emission control technologies can achieve NO_x rates of 17.9 grams per mile.⁹ Diesel-electric hybrids with filters may be able to run at 10.0 grams NO_x per mile, or less than half that of conventional buses (EESI, 2004). Since some of the transit buses in Chicago are equipped with these new technologies, I use the last three numbers in a weighted average based on the composition of the CTA's current fleet, for an average of 23.2 grams/mile.

3.4.1 Ground-Level Pollutants from Transportation in Chicago

Table 9 shows the results of applying emissions factors for ground-level pollutants to transportation services consumed.

⁸ Only Metra's MPI MP36PH Locomotive fleet was purchased after 2002 and complies with Tier 1 standards; the rest of the fleet is treated as Tier 0. These 27 locomotives represent 19% of the overall fleet (RTA, 2006, Commuter Rail Locomotive Rolling Stock).

⁹ WMATA measured this performance from an Orion model year 2004 diesel buses equipped with a Series 50 Engine, Exhaust Gas Recirculation, and particulate filters similar to those in use by the CTA (Melendez et al., 2005).

Table 9. Total Ground-Level Pollutants in RTA Region from Transportation

Mode	Lbs. NO _x emitted	%	Lbs. VOC emitted	%	Lbs. CO emitted	%
CTA Bus	3,401,525	2.2%	85,124	0.0%	468,184	0.0%
CTA Rail	326,883	0.2%	11,441	0.0%	80,086	0.0%
Metra Rail	9,158,736	6.0%	843,149	0.4%	1,434,475	0.1%
Pace (All modes)	1,089,593	0.7%	64,394	0.0%	451,847	0.0%
Transit Subtotal	13,976,736	9.1%	1,004,108	0.5%	2,434,592	0.1%
Cars and Trucks	139,188,150	90.9%	187,794,031	99.5%	1,952,718,408	99.9%
TOTAL	153,164,886	100.0%	188,798,139	100.0%	1,955,153,000	100.0%

3.4.2 Greenhouse Gases from Transportation in Chicago

Surface passenger transportation in Chicago generates a significant volume of greenhouse gases. Since carbon dioxide is the leading greenhouse gas in the transportation sector, the EPA advises simply inflating CO₂ calculations by 100/95 to reach estimated CO₂ equivalents from fossil-fuel based transportation (EPA, 2005b), which is followed here for CTA bus, Pace, Metra, and cars and trucks. Following EPA guidelines, I compute CO₂-equivalent emissions by calculating carbon dioxide emissions and then adding a small amount for non-CO₂ GHGs.

Both the CTA and Metra purchase electricity to power their trains from the private supplier Commonwealth Edison (Illinois Commerce Commission, 2005), which in 2005 derived 89% of its electricity from nuclear power, thereby emitting relatively little CO₂ (ComEd, 2006).

Table 10. Total Greenhouse Gas Emissions in RTA Region from Transportation

Mode	Lbs. CO ₂ Emitted (000)		Lbs. CO ₂ Equiv. Emitted (000)	
CTA Bus	341,948	0.6%	359,945	0.6%
CTA Rail	198,867	0.4%	198,867	0.4%
Metra Rail	386,657	0.7%	407,007	0.7%
Pace (All modes)	89,289	0.2%	93,989	0.2%
Transit Subtotal	1,016,761	1.9%	1,070,275	1.9%
Cars and Trucks	52,042,168	98.1%	54,781,230	98.1%
TOTAL	53,058,929	100.0%	55,851,505	100.0%

3.5 Comparing Transportation Modes

A fair comparison between transportation modes will use passenger-mile and passenger-trip figures. Economic theory suggests that transportation is an intermediate good whose demand is derived from the spatial distance between other demanded goods. Travelers, according to this theory, do not consume transportation for transportation's sake, they travel to reach some other good such as a job, shopping, opportunities, and the activities of daily life. Thus what is important to transportation networks is the throughput and distribution of passengers, not vehicles, from place to place.

From a social perspective, a modal comparison based on passenger-miles may underestimate the energy efficiency of public transit because transit trips tend to be shorter. If the true measure of success in transportation provision is accessibility, not mobility, and if travelers derive utility from trips, regardless of mode or length, a comprehensive measure of a

transportation system performance may be the provision of passenger-trips, not passenger-miles. A mile on a train may not be directly comparable to a mile in a car because the automobile system operates in built environments where longer trips are required for comparable levels of accessibility (Holtzclaw, 2007). For instance, a rail passenger might access his job with a 5-mile trip, achieving the same amount of accessibility as someone who drives 10 miles to their job. Transit riders may simply travel shorter distances in motorized vehicles than automobile drivers by living in dense, compact development friendly to automobile substitutes such as walking, bicycling, and transit. Behind each transit passenger-mile may be fewer passenger-miles altogether, and behind each transit passenger-trip may be more walking and biking trips. The Transportation Research Board’s latest modal comparison of energy and emissions assumes that one mile on transit would be the equivalent of four miles in an auto (TCRP, 2003). To keep this analysis conservative, I assume that one passenger-mile on transit is equivalent to one passenger-mile by auto.

3.6 Results: Modal Performance

I measure the performance of passenger transport modes in Chicago on a per passenger-mile and per-trip basis. In this analysis, I use unlinked transit trips.

3.6.1 Results: Ground-Level Pollution

Table 11. Energy and Ground-Level Pollution by Mode, Per Passenger-Mile

Mode	BTUs per pax-mile (000)	Lbs. NO _x per thous. pax-mile	Lbs. VOC per thous. pax-mile	Lbs. CO per thous. pax-mile
CTA Bus	4.6	4.35	0.11	0.60
CTA Rail	1.2	0.29	0.01	0.07
Metra Rail	2.5	5.92	0.54	0.93
Pace (All modes)	3.2	3.99	0.24	1.65
Cars and Trucks	5.2	2.16	2.92	30.31
Transit Average	2.6	3.74	0.27	0.65

Table 12. Energy and Ground-Level Pollution by Mode, Per Passenger-Trip

Mode	BTUs per trip (000)	Lbs. NO _x per thous. trips	Lbs. VOC per thous. trips	Lbs. CO per thous. trips
CTA Bus	11.8	11.2	0.3	1.5
CTA Rail	7.5	1.8	0.1	0.4
Metra Rail	56.4	132.8	12.2	20.8
Pace (All modes)	23.7	29.5	1.7	12.3
Cars and Trucks	38.9	16.2	21.8	226.6
Transit Average	16.4	23.5	1.7	4.1

In sum, transit emits less hydrocarbons and carbon monoxide but more NO_x than cars and trucks. While public transportation produces over 90% fewer VOCs per passenger-mile, and only a fraction of the carbon monoxide as cars, its reliance on diesel fuel for buses and commuter trains results in higher NO_x emissions. Other studies have found similar results (Barth, Younglove, and Tadi, 1996).

Public transport’s various modes have differing environmental performance, depending on the mode’s energy efficiency, as well as the pollution-intensity of the energy it consumes. On

average, RTA services moved passengers around Chicago at half the energy as private cars in 2005, but the propulsion technology determines differing emissions. For example, Metra’s commuter rail operations emit NO_x at a particularly high rate even though it is fairly energy efficient, due in part to the age of the diesel locomotive fleet.

On a per-trip basis, public transit tends to compare more favorably, mostly because transit trips are shorter than automobile trips. For example, buses in Chicago emit roughly twice the NO_x as cars per passenger-mile, but slightly less NO_x than cars per passenger-trip. Since Metra trips tend to be fairly long (22.5 miles on average), commuter rail’s performance worsens on a per-trip basis, especially in NO_x. However, even though Metra trips use more energy per trip, each trip is responsible for fewer emissions of CO and VOCs than an auto trip.

With the exception of NO_x, which a per-trip analysis tends to reduce, public transit in Chicago emits fewer ground-level pollutants than private cars.

3.6.2 Results: Greenhouse Gases

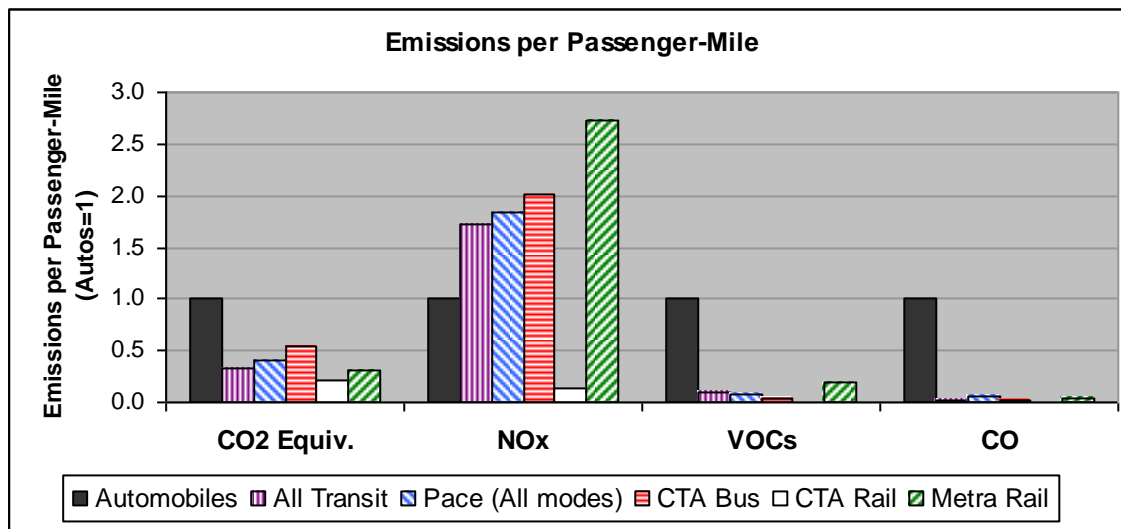
In contrast to ground-level pollution, public transit emits fewer greenhouse gases on nearly all measures. GHG emissions from public transportation are about a third of private autos per passenger-mile, and a typical car trip emits almost four times as much CO₂-eq. as a typical transit trip. Bus modes perform well on a per-trip basis, since bus trips tend to be fairly short.

Table 13. Greenhouse Gases by Mode per Passenger-Mile and per Passenger-Trip

Mode	Lbs. CO ₂ Equiv. per pax-mile	Lbs. CO ₂ Equiv. per trip
CTA Bus	0.46	1.2
CTA Rail	0.17	1.1
Metra Rail	0.26	5.9
Pace (All modes)	0.34	2.5
Cars and Trucks	0.85	6.4
Transit Average	0.27	1.7

CTA rail appears to perform very well on this metric, both because of its baseline efficiency, and because the electricity the trains use is produced by low-carbon sources. If the electric power consumed by rail were produced at the Illinois state average CO₂ emissions rate which relies more heavily on coal (Leonardo Academy, 2004), or roughly triple that of ComEd, transit in Chicago would emit only around 30% more CO₂ overall. This would cut transit’s advantage from third to a half of the emissions per passenger-mile as autos.

Figure 8. Air Emissions by Mode, Per Passenger-Mile



3.7 Quantifying the Air Pollution Benefit of Transit

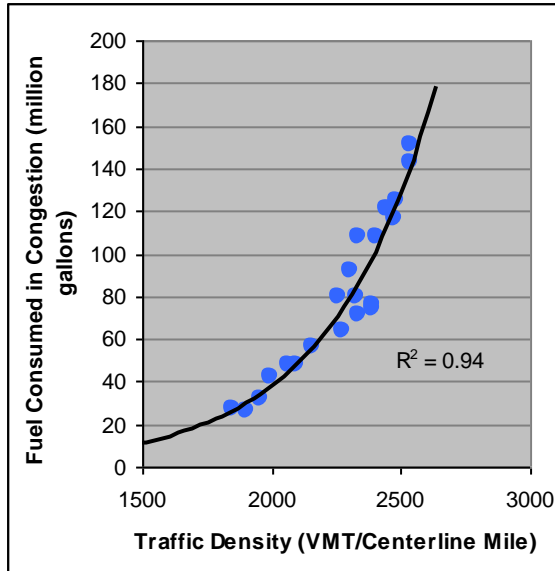
Because public transportation in Chicago emits air pollutants at a lower rate than private transport, transit use avoids a certain amount of regional and global air pollution. To quantify this air quality benefit, I predict the air pollution that would have otherwise occurred in the absence of transit and compare to the current situation. If there were no public transportation in Chicago, I assume that transit riders would drive at the current average vehicle occupancy.

The interaction between mode choice and emissions through traffic congestion complicates the comparison between these modal scenarios. Increased congestion will tend to decrease fuel economy and increase emissions rates per mile, and to the degree that public transportation use reduces congestion, transit produces ancillary air pollution benefits. Thus, quantifying public transport's effect on air pollution in a metropolitan area takes two dimensions: directly avoided emissions through greater efficiency, and indirectly avoided emissions through automobile congestion relief.

To model the air pollution impacts of congestion, I express excess gasoline consumed in traffic (TTI, 2005) as a function of traffic density, measured in auto VMT per road centerline-mile. This indicator controls for historic growth in VMT and roadway capacity, and says intuitively that congestion is a product of how many cars are on a given stretch of road.¹⁰ As Figure 9 shows, fuel consumed in congestion has been historically correlated to traffic density.

Figure 9. Excess Fuel Consumed in Congestion in Chicago

¹⁰ All data are from TTI (2005), and financial figures are inflated by the Bureau of Labor Statistics' Urban Consumer Price Index to 2003 dollars.



Source: TTI, 2005

I make the simplifying assumptions that emissions per gallon are roughly similar between normal and congested speeds, that all modes of transit are not affected by, and do not contribute to congestion, and that VMT is added to the road network with roughly the same spatial and temporal distribution as existing traffic. This is a conservative estimate, since idling probably produces higher emissions levels. Without transit, traffic density and congestion would increase, and excess gasoline consumed from congestion in the no-transit scenario would increase by 44 million gallons.¹¹ By applying the emissions factors in Table 8 to excess fuel, I obtain emissions from congestion.

The overall differences between the current situation and the no-transit scenario are shown in Table 14.

¹¹ To calculate emissions savings with mileage-based emissions factors, 44 million gallons of saved fuel is the equivalent of 44 million gal. × 20.3 miles per gallon = emissions equivalent of 893.2 million “miles.” Congestion does not cause an increase in distance traveled; this figure is used to calculate the emissions equivalents of idling and traveling for longer durations to cover the same distance.

Table 14. Quantity of Emissions Saved by Transit in Chicago, 2005

Efficiency Savings (tons)	NO_x	VOC	CO	CO₂ Equiv.
With Transit	69,474	85,637	886,842	55,851,505
Without Transit	66,800	90,127	937,161	56,770,338
Savings from Transit	(2,674)	4,490	50,318	918,833
from CTA Bus	(777)	995	10,539	138,004
from CTA Rail	965	1,497	15,589	326,226
from Metra	(2,637)	1,665	20,637	391,945
from Pace	(226)	332	3,554	62,658
Congestion Savings (tons)	NO_x	VOC	CO	CO₂ Equiv.
Saved Emissions	1,036	1,397	14,528	407,565
TOTAL (tons)	(1,639)	5,887	64,846	1,326,397

In every pollutant except nitrogen oxides, transit in Chicago is providing a net environmental benefit. Transit saves the region roughly 1.3 million tons of greenhouse gases each year. However, transit's net addition of nitrogen oxide emissions is a serious concern, since ozone is the product of both VOCs and NO_x. Dividing the avoided costs by service board may be unrealistic given the network interdependencies of transit, but it does illustrate how different propulsion technologies have different environmental effects. The CTA has a negligible effect on the region's NO_x emissions as a whole, because its dirtier bus operations are balanced by its cleaner rail operations. Metra, which runs primarily on older diesel locomotives, increases the overall NO_x emissions in Chicago. In fact, these results suggest that if the sole objective were the reduction of NO_x, Chicago's air would be better off if passengers aboard CTA buses and Metra trains drove cars. However, the other effects of transit tend to offset this drawback.

3.7.1 Financial Value of Transit's Emissions Reductions

However, not all reductions of air pollution provide equal benefits. To consider appropriate amounts and sources of transit finance, I place an economic value on the reduced air pollution.

Attaching a dollar figure to the value of improved air quality is difficult, because the connection between tailpipe emissions and human health and economic costs depends on a number of uncertain intervening factors. For example, hydrocarbons and NO_x react with sunlight to produce ozone, but the costs of these emissions depends on weather, time of day, the number of people exposed, and the duration and concentration of exposure. Similarly, the cost of carbon dioxide emissions will hinge on how the planet's ecosystems will respond to warming (AEA, 2005a), and how climate change will effect the global economy. The recent Stern Review of Global Climate Change in Britain predicted costs of global warming between 5-20% of world GDP (Stern, 2006), suggesting that the range of carbon emissions costs could be very large.

Despite these methodological difficulties, researchers have produced estimates of the social cost of air emissions. While a thorough literature review is beyond the scope of this thesis, evaluation methodologies include contingent valuation, hedonic analysis, and stated and revealed preferences. Data comes from a wide variety of disciplines such as insurance costs, epidemiological studies, air circulation and meteorological models, and econometric analysis.

Most analyses model “pathways” between emissions and health and environmental effects, using dose-response models (Krupnick, Rowe, and Lang, 1997). To account for uncertainty in these estimates for my purposes, I select a range of social cost values.

- NO_x. The primary driver behind the cost of nitrogen oxides is costs due to bronchial illnesses and deaths. Litman (2005) estimates a cost of \$15,419 per ton for mortality, and AEA (2005b) estimates €4,400 – €12,000. I use \$6,000 - \$25,000.
- VOCs. Hydrocarbons and other organic compounds are another precursor to ground-level ozone with local and regional effects. One European study (AEA, 2005b) estimated the cost of VOCs between €950-€2800 per tonne. Litman (2005), updating Wang, Santini, and Warinner (1994), cites \$14,419 per ton. Holland and Watkiss (2002) estimated €2100 per tonne in Europe. I use the range of \$1,500 - \$14,419.
- CO. Costs of carbon monoxide include acute CO poisoning, cardiovascular effects from chronic inhalation, and the effects of more than 2,000 deaths per year in the U.S. (Mott, et al., 2002). However, because CO is very local and rapidly disperses, the cost to human health is relatively low. Delucchi and McCubbin (1996) estimate a range of \$10-\$90 per ton, while Litman (2005) updates Wang, Santini, and Warinner (1994) and estimates \$435 per ton. I use the range of \$10-\$435 per ton.
- CO₂. The IPCC (2007) predicts costs between \$20-80 per ton by 2030, and \$30-155 per ton by 2050. A review of academic literature suggested a mean value of \$93 per ton, with a range as high as \$350 per ton (Tol, 2005). To account for this range of uncertainty, I use \$20 and \$350 per ton.

Table 15. High and Low Estimates of Social Costs of Air Emissions

Pollutant	Social Cost per Ton	
	Low	High
Nitrogen Oxides	\$6,000	\$25,000
Volatile Organic Compounds	\$1,000	\$14,419
Carbon Monoxide	\$10	\$435
Carbon Dioxide eq.	\$20	\$350

Source: discussed in text.

Table 16. Quantity and Value of Air Emissions Saved from Transit

Efficiency Savings	Reduced by Transit	Low Estimate		High Estimate	
		Social Cost per Ton	Total Cost	Social Cost per Ton	Total Cost
NOx	(2,674)	\$ 6,000	\$ (16,046,255)	\$ 25,000	\$ (66,859,397)
VOC	4,490	\$ 1,500	\$ 6,734,837	\$ 14,419	\$ 64,739,741
CO	50,318	\$ 10	\$ 503,184	\$ 435	\$ 21,888,484
Ground-Level Subtotal			\$ (8,808,235)		\$ 19,768,827
CO2-Equivalent	918,833	\$ 20	\$ 18,376,656	\$ 350	\$ 321,591,483
Total Efficiency Savings			\$ 9,568,421		\$ 341,360,310
Congestion Savings					
NOx	1,036	\$ 6,000	\$ 6,213,242	\$ 25,000	\$ 25,888,509
VOC	1,397	\$ 1,500	\$ 2,095,742	\$ 14,419	\$ 20,145,669
CO	14,528	\$ 10	\$ 145,280	\$ 435	\$ 6,319,659
Ground-Level Subtotal			\$ 8,454,264		\$ 52,353,837
CO2-Equivalent	407,565	\$ 20	\$ 8,151,294	\$ 350	\$ 142,647,638
Total Congestion Savings			\$ 16,605,557		\$ 195,001,475
TOTAL Savings			\$ 26,173,978		\$ 536,361,785

From a financial perspective, the value of the air pollution avoided by public transit is in the range of \$26-\$536 million per year. The biggest source of variance between these low and high estimates is the social cost of greenhouse gases. This range reflects the considerable uncertainty between tailpipe emissions and economic and public health costs, but suggests that transit’s overall impact on air quality in Chicago is positive.

3.8 Sensitivity Analysis

To test the sensitivity of the calculations in these results, I tested a range of parameters as shown below. The low range of the carbon per megawatt-hour of electricity models the effect of transit consuming average Illinois electricity. Overall, while my results do display some sensitivity, the range tested here does not change the direction or conclusion of the research.

Table 17. Sensitivity Analysis of Emissions Calculations

Parameter	Initial Value	Range Tested		Transit Lbs. CO2 / PMT		Auto Lbs. CO2 / PMT		Transit Lbs. CO2 / Trip		Auto Lbs. CO2 / Trip		Mill. Tons CO _{2-eq.} Saved by Transit	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Initial Values				0.27	0.85	1.70	6.4	1.33					
Lbs. CO2 per MWH Electricity	487	1152	350	0.36	0.25	--	--	2.30	1.60	--	--	1.17	1.36
Average Vehicle Occupancy	1.18	1.60	1.00	--	--	0.63	1.01	--	--	4.7	7.5	0.96	1.58

3.9 Remarks on Results

The results of this analysis lead to several observations.

3.9.1 Damages from Electricity Generation

Because public transit is partially powered from an electrical grid, transit's ground-level air pollution could in fact be even less harmful than that of automobiles depending where the power plants are. Because ozone is only a human health problem if people are exposed, a remote generating power plant could lessen human health impacts. However, ground-level air pollutants also damage ecological systems.

3.9.2 Addressing Previous Research

This analysis provides some insight into the ongoing academic debate over the social desirability of urban public transit. For example, Winston and Maheshri (2006) dismiss the environmental benefits of rail transit by pointing to rail's low load factor, high consumption of electricity which produces pollution, and reliance on heavy fuels, concluding that transit has "at best, an ambiguous effect on the environment." This analysis does account for transit's load factor, pollution produced by electricity generation, and the environmental effects of diesel fuel, and concludes that the net environmental effect of rail transit is measurably positive for the Chicago region.

3.9.3 Including Full Lifecycle Emissions

It can be argued that a true comparison of energy efficiency between modes should include estimates of energy to construct the facilities upstream. Rail operating emissions seem low, for example, but rail requires much heavier initial construction costs and energy than roads. However, the academic literature on "well-to-wheel" lifecycle analyses concludes that the modal difference is small. The U.S. Department of Energy estimates that the total lifecycle cost of fuel production (extraction, refining, etc.) and vehicle production for cars and buses are approximately 1.4 times the direct emissions, while the same proportion for electric rail is about 1.1 (EPA, 2006, 14-1). In a detailed analysis of vehicle lifecycle greenhouse gas emissions, Delucchi et al. (2002) estimated that public transit persistently emits 26-79% less greenhouse gases than typical autos per passenger-mile, even when accounting for fuel, vehicle maintenance and storage, infrastructure construction, and vehicle assembly. Even if transportation does benefit from energy-intensive capital investments, it seems that lifecycle energy costs do not differ substantially across modes.

3.9.4 Technology and NO_x

In the future, public transit's disadvantage relative to autos in NO_x emissions is likely to persist. The CTA and Pace plan to replace older buses with new vehicles which emit as much as 90% less CO and VOCs, but NO_x emissions reductions will be "in the 5 to 15% range" (CTA, 2007, 84). As Metra replaces older diesel locomotives with newer Tier 2 compliant engines with roughly half the emissions as the Tier 0 machinery it primarily operates now, NO_x emissions will fall (EPA, 2007), but the long service life of locomotives will limit the speed of this effect.

However, automobiles will likely achieve comparable emissions reductions at a similar pace. Future technology is projected to dramatically improve NO_x emissions in Chicago more than mode choice. In its MOBILE6 model, the EPA instructs Metropolitan Planning Organizations to use emissions rates for NO_x which drop steeply in future years (EPA, 2001, 1-7). The air quality

conformity analysis for Chicago's TIP shows an 80% reduction of NO_x and a 27% increase in vehicle miles traveled by 2030.¹²

3.9.5 Future Environmental Role of Transit

In the future, ground-level air pollution from passenger transport might conceivably be eliminated nearly entirely. Tighter regulations of propulsion technology, from cleaner fuel combustion to tailpipe emissions capture, might drive criteria pollutants from engines to near zero. Offsetting this trajectory, however, may be rising overall volumes of travel, and growing scientific knowledge that the types and amounts of pollution previously thought safe are indeed unsafe.

While controlling ground-level pollution has been achievable by both increasing overall fuel economy and controlling emissions per gallon, there appears to be no viable analogous technology to the latter for carbon dioxide. Until de-carbonized fuels or carbon sequestration become viable, reducing CO₂ emissions per passenger-mile traveled in transportation may have to come from improved fuel economy, cleanly-generated electricity, or higher passenger loads per vehicle. Ultimately, public transportation's environmental advantage may remain because electrification and high passenger load factors are feasible and realistic.

3.10 Air Emissions: Conclusion

In this chapter, I built an inventory of key air emissions from the surface passenger transportation in Chicago and compared the environmental performance of travel modes within the sector. I found that public transportation provides mobility to passengers with less air pollution than the private automobile. On local pollutants, the results are mixed: transit loses its environmental advantage in NO_x due to its reliance on diesel, but contributes significantly less hydrocarbons and carbon monoxide. On global pollutants, transit's greenhouse gas emissions are roughly a third of private cars per passenger mile. On energy, public transit's energy use is roughly half of cars per passenger mile.

In addition, I quantified the net environmental benefit of public transportation by constructing a hypothetical no-transit scenario and comparing to the current situation, including the results of a simple congestion model. I concluded that without transit, air quality would be affected in two ways: first, accommodating equivalent levels of travel demand with automobiles would decrease NO_x slightly but increase every other type of emission, including the emissions of 1.2 million tons of greenhouse gases per year. Second, the additional vehicles on the road would cause increased congestion, further degrading air quality. I conjecture that public transit's future environmental advantage may stem from its ability to run on relatively clean electric power and achieve high passenger loads, but that technology is likely to improve emissions for all modes.

Finally, I attached a range of financial values to the emissions avoided by public transit, and calculated that the net benefit to air quality in Chicago from transit was between \$26 and \$536

¹² CATS (2005) section 5.2, table 2, p. 24 indicates VMT growth; sections 10.1 and 10.3, tables 8 and 9, pp.89-90 show NO_x and particulate matter reductions.

million per year. This range largely reflects uncertainty around the economic costs of greenhouse gas emissions.

4 Measuring Safety Benefits of Transit

It is often argued that public transportation is a safer mode of transportation than private automobiles. Transit, the theory goes, avoids a great deal of public and private costs from traffic accidents, including external costs that everyone in society pays for above and beyond collision insurance. Because of the relatively high safety costs of auto travel, transit is sometimes touted as a way to avoid some of these costs. This chapter attempts to quantify the safety benefits that public transportation services in Chicago provide to the region.

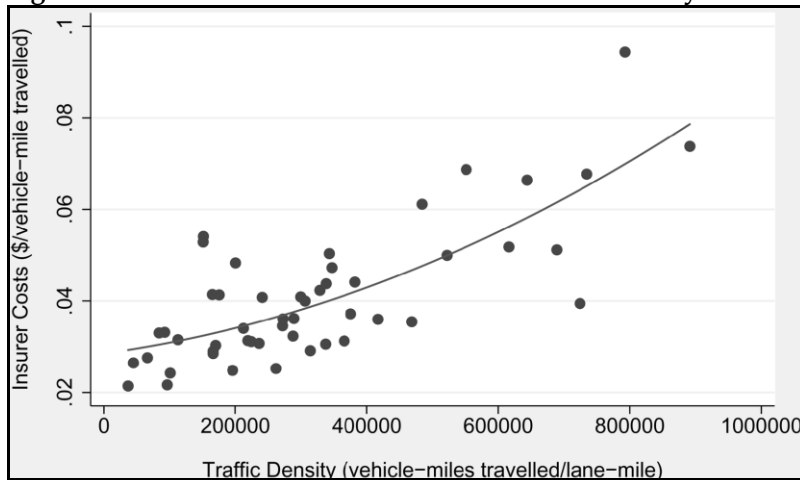
4.1 *The Theory: Why Do We Care?*

Why should the government care about transportation safety? To some extent, drivers know the risks they take when they choose to drive, and mandatory insurance programs make certain that only those who drive pay for each other's medical and collision expenses. However, insurance programs do not internalize all costs of driving – some costs are external and are paid by those who do not drive, or who do not incur the costs. Put another way, auto drivers do not face the full social marginal costs of their actions when they make daily decisions to drive, so their consumption decisions are not economically efficient. Indeed, many recent studies on the external costs of automobiles identify safety as the largest cost component, above air and noise pollution (INFRAS, 2004; Lindberg, 2001).

When a crash happens in the U.S., parties besides the affected drivers and their insurance programs pick up a portion of the costs in a number of ways. Government health care programs pay medical costs for uninsured people, senior citizens (through Medicare), the poor (through Medicaid), and those prevented from working (through Worker's Compensation). States typically pay for emergency roadside assistance programs with revenues from all taxpayers. When an accident causes traffic delays, hundreds or thousands of motorists could be forced to waste time and fuel, and others inconvenienced. Miller calculates that external costs of highway travel reach one-third of total costs (Miller, 1997, 298). Blincoc (1996) estimates that the driver involved in the crash and insurance programs ultimately pick up 76.4% of the costs of accidents, while government and other parties pick up the remaining 23.6%.

Besides these average external costs, there is an increasing marginal cost to driving as well. Simply put, your chance of getting into an accident depends on how many other cars are on the road with you. Newbery (1988) suggested that accident rates will increase as the square of traffic flow, an idea that Steimetz (2004, 36) notes is similar to kinetic gas theory: "the number of collisions between 'particles in a box' is proportional to the square of the number of particles in the box." Like congestion, insurance costs per vehicle mile traveled have been shown to rise as roads become more saturated with vehicles (Edlin and Mandic, 2006) (see Figure 10).

Figure 10. U.S. Automobile Insurance Collision Costs by Traffic Density



Source: Edlin and Mandic, 2006

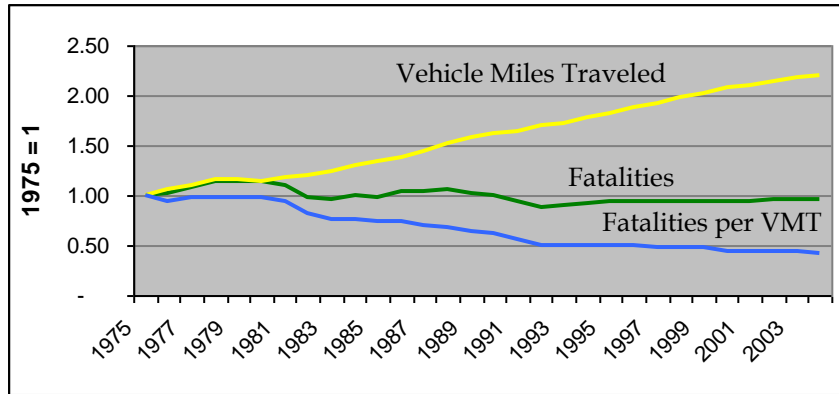
When you decide to drive, you theoretically account for the possibility you might be involved in a crash, but you do not consider that your joining the road will increase the possibility of a crash for everyone else already on it. Because marginal social costs are therefore higher than marginal private costs, there is an economic rationale for government action to raise the price to marginal social costs, or to correct for the external costs in some other way.

Like congestion, accident costs are partly external. From a moral perspective, it may be government's duty to do everything it can to stop all traffic accidents because of the value of human life. From an economic perspective, though, government may not be obliged to eliminate accidents, since the benefits of car travel are worth some risk. But it is government's job to correct the market failure wherein auto drivers do not face the full marginal social cost of their actions, and where one subset of society is imposing external costs on everyone in society. Zero-car households, for example, pay taxes for accident response services they do not use. By reducing the external crash costs of driving automobiles, government can assure a more efficient and equitable outcome.

4.2 National Patterns in Traffic Safety Costs

The magnitude of fatalities, injuries and property damage of automobile crashes are significant on a national scale. In 2004, over 41,000 Americans were killed in vehicular accidents, which equates to over 100 people per day (NHTSA, 2005). In addition, crashes caused over 5.3 million non-fatal injuries, and damaged around 28 million vehicles (Blincoe et al., 2002). Since 1975, the overall number of traffic fatalities has held roughly steady in the U.S. However, vehicle-miles traveled have been rising, so the average fatality rate per vehicle-mile traveled has been on the decline (NHTSA, 2005).

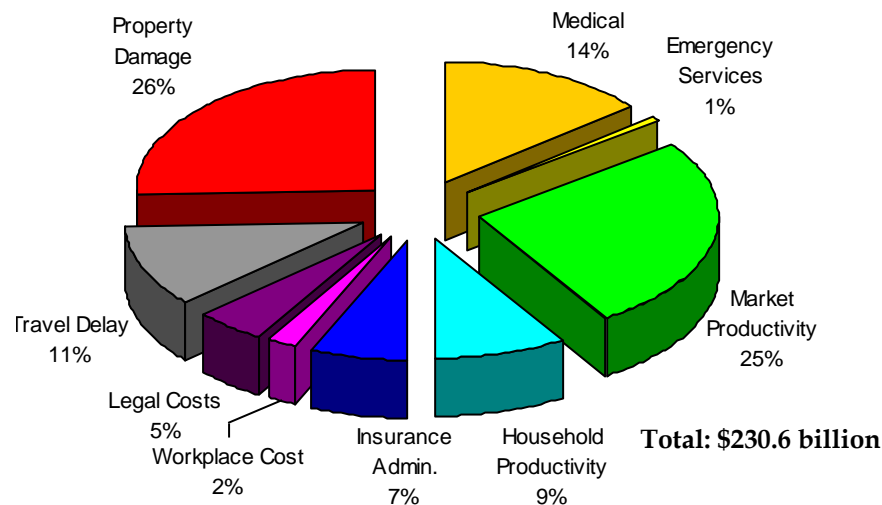
Figure 11. U.S. Automobile Traffic Fatalities and Fatality Rate Since 1975



Source: Data from 1975-2000: NHTSA 2000 Economic Impact of Motor Vehicle Crashes: 2000, Table 5. Data from 2001-2004: NHTSA Traffic Annual Assessments (multiple years).

Traffic accidents result in large economic costs. Miller (1997, 297) estimated that the social costs of automobile accidents totaled \$367.9 billion in 1993. The U.S. Department of Transportation estimates that the economic costs of automobile crashes in 2000 totaled \$230.6 billion, or roughly 2.3% of the total national GDP (Blincoe et al., 2002). Included in this figure are medical costs, lost market productivity, travel delays, and property damages, as shown in Figure 12.

Figure 12. Components of U.S. Automobile Accident Costs, 2000



Source: (Blincoe et al., 2002)

It should be noted that the financial value of a human life used in analyses like these is a statistical construct only. Economists use a variety of valuation techniques to determine this value, most commonly built from the discounted future value of earnings, but also from contingent valuations, juries' values, willingness to pay for risk reduction, and wage-risk studies (Miller, 1997).

4.3 Accident Costs in Chicago

Automobile accidents are costly for Illinois and the Chicago metropolitan region as well. In 2005, a total of 433,000 car crashes on Illinois roads killed 1,363 people and injured 112,000

(IDOT, 2006b). Using an economic value of \$7,500 per crash, \$1,150,000 per statistical life, and approximately¹³ \$45,000 per injury, the Illinois Department of Transportation estimates that crashes cost the state's economy \$9.8 billion in 2005. Blincoe et al. (2002)'s national study estimates Illinois' accident costs at \$9.0 billion in 2000.

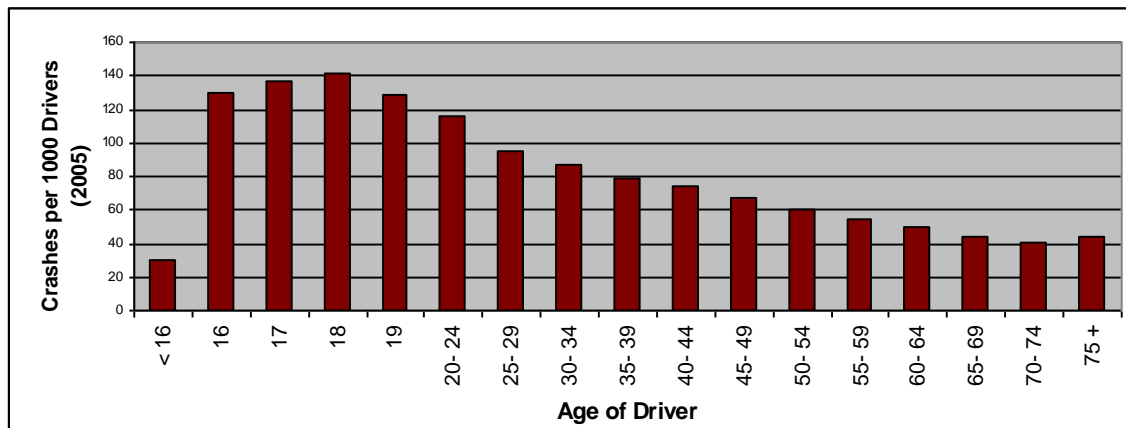
Table 18. Social Costs of Accidents in Chicago

Social Cost Type	2005 Cost
Collision (baseline)	\$ 7,500
Injury (any severity)	\$ 45,000
Fatality	\$ 1,150,000

Source: IDOT, 2006b

The costs of automobile collisions are not distributed evenly across all travel. For example, crash rates in Illinois are highest amongst young drivers, males of all ages, drivers on urban roadways, and drivers with a blood-alcohol level greater than zero (IDOT, 2006b).

Figure 13. Illinois Automobile Crash Rate by Age of Driver, 2005



Source: IDOT, 2006b

Nor was the economic burden of automobile crashes evenly distributed geographically. The Chicago metropolitan region appears to bear a higher proportion of these costs than its magnitude of travel would suggest. The six-county RTA Region, home to 55% of the state's vehicle-miles traveled, suffered 70% of the state's crashes and 64% of the associated costs. Applying Blincoe's (1996) estimate of external costs means that auto drivers in the RTA Region imposed external costs on the order of \$1.2-1.4 billion which they did not pay. Accidents appear to be more frequent in the Chicago metropolitan area relative to the rest of the state, but the accidents tend to result in more injuries and less fatalities for higher economic cost (Table 19 and Table 21).

¹³ IDOT does not report this figure directly; it is interpolated here by subtracting the reported injury and fatality costs from the total cost.

Table 19. Auto Accident Statistics in the RTA Region and Illinois, 2005

	VMT	Population	Crashes	Fatalities	Injuries	Crash Costs
RTA Region	59,842,302,610	8,091,720	295,297	612	74,425	\$ 6,267,652,500
Rest of Illinois	48,017,669,900	4,327,573	126,225	751	37,918	\$ 3,516,647,500
Illinois	107,859,972,510	12,419,293	421,522	1,363	112,343	\$ 9,784,300,000
% RTA	55%	65%	70%	45%	66%	64%

Source: IDOT, 2006b

This pattern persists within the RTA Region as well between Cook County and the Collar Counties. Although 58% of region's vehicle travel occurred in Cook County, the county suffered a higher share of the region's crashes and associated costs.

Table 20. Auto Accident Statistics in the RTA Region and Cook County, 2005

	VMT	Population	Crashes	Fatalities	Injuries	Crash Costs
Cook County	34,756,129,460	5,376,741	209,165	378	49,430	\$ 4,227,787,500
Collar Counties	25,086,173,150	2,714,979	86,132	234	24,995	\$ 2,039,865,000
RTA Region	59,842,302,610	8,091,720	295,297	612	74,425	\$ 6,267,652,500
% Cook County	58%	66%	71%	62%	66%	67%

Source: IDOT, 2006b

Table 21 summarizes these trends by calculating crash rates and per-vehicle-mile crash costs.

Table 21. Auto Accident Rates in Illinois by Proximity to Chicago, 2005

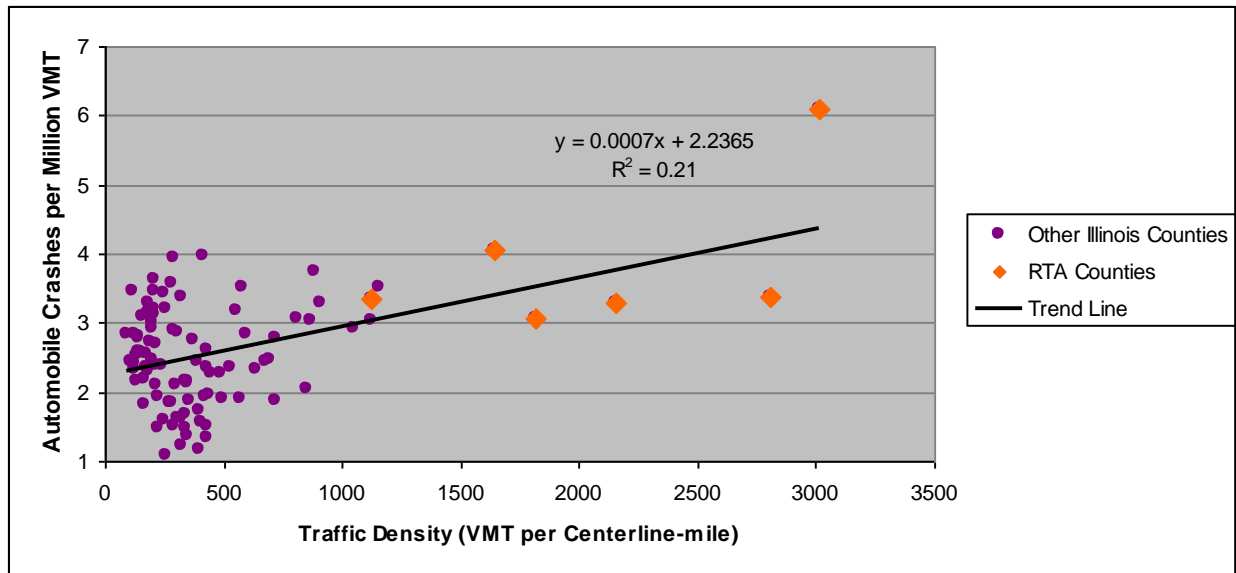
	Crashes per mill. VMT	Fatalities per bill. VMT	Injuries per mill. VMT	Crash Costs per VMT
Cook County	6.02	10.9	1.4	\$ 0.12
Collar Counties	3.43	9.3	1.0	\$ 0.08
RTA Region	4.93	10.2	1.2	\$ 0.10
Rest of Illinois	2.63	15.6	0.8	\$ 0.07

Source: IDOT, 2006b

It seems that more central or urban areas exhibit higher crash rates per VMT and somewhat higher aggregate crash costs per VMT, though accidents in more urban areas tend to result in more injuries and less fatalities.

Similar to Edlin and Mandic's (2006) findings, Illinois roads with higher traffic densities appear to suffer from higher crash rates. After surpassing a certain density, which the RTA Region appears to have done, additional VMT per centerline-mile tends to increase the crash rate.

Figure 14. Automobile Crash Rates by Traffic Density in Illinois

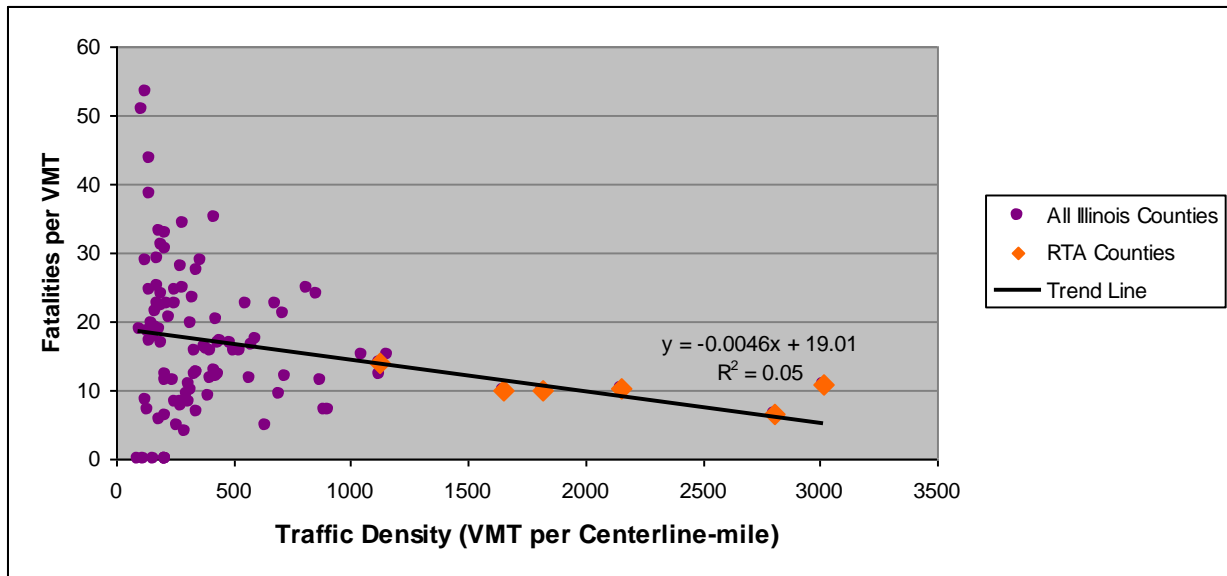


Source: (IDOT, 2006b; IDOT, 2006a)

Remember that these figures categorize VMT and accidents where they occur, not by origin of driver. For example, a Lake County resident involved in a crash in Cook County would be counted towards Cook County. Public health research suggests that urban residents face safer travel choices, mostly because they drive less – either by driving shorter distances, or substituting other modes for automobiles. Ewing et al. (2003) found that for every 1% decrease in sprawl in counties in large U.S. cities (as measured by density and street accessibility), the traffic and pedestrian fatality rate decreased by 1.5%. Lucy (2003) studied the danger of traffic fatalities and homicides in different built environments in 15 U.S. metropolitan areas, and concluded that “the exurbs are the most dangerous parts of metropolitan areas” because of traffic fatalities associated with relatively high car use and high speeds.

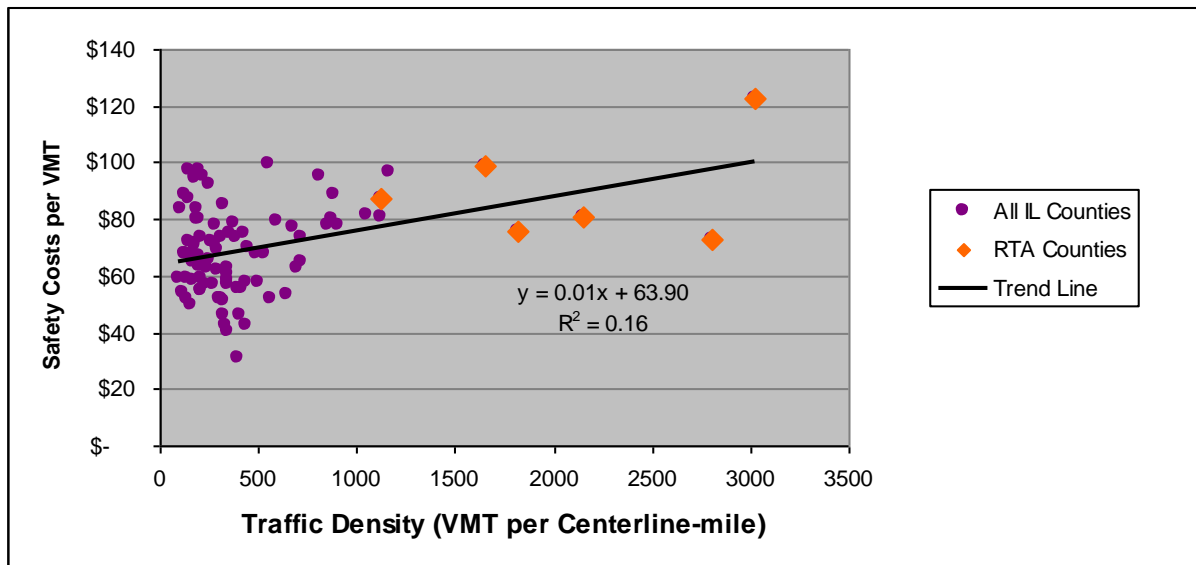
This pattern appears to hold for the RTA Region as well. As traffic density increases, fatalities tend to decrease even as crashes become more frequent. Specifically, crashes tend to be less frequent, but more fatal in the suburban and rural counties. In addition, several counties in Illinois appear to be home to particularly lethal roadways, perhaps “hotspots” or remote areas traversed by regional interstates. However, this correlation is weak.

Figure 15. Automobile Fatality Rates by Traffic Density in Illinois



Source: IDOT, 2006a; IDOT, 2006b

Figure 16. Automobile Safety Costs by Traffic Density in Illinois



4.3.1 Role of Public Transportation in Traffic Safety

If auto travel is dangerous, to what degree can encouraging transit use reduce auto accident costs? Like mobility, safety costs are most appropriately measured on a per-passenger mile basis, since the purpose of a transportation system is to move people and goods, not vehicles.

Public transit has safety risks as well – some of which are difficult to compare to auto travel. U.S. transit agencies reported a total of 248 fatalities and 19,000 injuries in 2004, and there were 135 cases of trains derailing or buses going off the road in 2004 (APTA, 2006, 26). The risk of personal injury, theft, or other crimes by passengers onboard transit vehicles is significant, and private autos arguably pose no analogous concern. Because transit stations and vehicles are

open, public spaces, they are home to criminal activity. Finally, while fatality rates tend to be higher for occupants in cars compared to non-occupants, the opposite is true for public transportation. Transit vehicles pose higher risks to non-occupants than to occupants. Buses and rail vehicles tend to operate in dense urban environments replete with pedestrians, bicyclists, and rail grade crossings, whereas a large portion of roadway travel occurs on grade-separated, exclusively auto roads. While accident rates for autos appear to be a function of the number of autos in a given area of road space, accident rates for transit vehicles may be a function of the number of other moving objects in the operating environment.

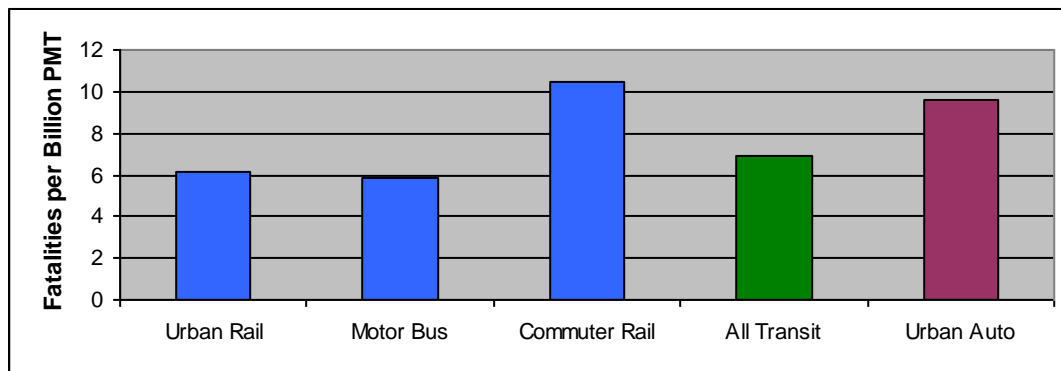
Table 22. U.S. Transportation Fatalities by Mode and Occupant Type, 2000

	--- 2000 Fatalities ---			Occupant %
	Occupant	Non-Occupant	Total	
Automobiles	20,492	7,004	27,496	75%
Light Trucks	11,418	8,877	20,295	56%
Motorcycles	2,862	78	2,940	97%
Transit Buses	19	77	96	20%
Light Rail	5	12	17	29%
Large Trucks	741	4,189	4,930	15%

Source: Semmens, 2003, Table 1

However, a fair modal comparison of safety risks will compare safety impacts per passenger mile traveled. This is the marginal choice facing a passenger when deciding how to travel.

Figure 17. U.S. Transportation Fatality Rate per PMT by Mode, 1995-2000 Average



Source: Semmens, 2003; FTA, 2004

As shown in national figures in Figure 17, there is evidence that on a per-passenger-mile basis, transit causes less passenger injuries and deaths to occupants and non-occupants alike. Commuter rail causes a higher rate of fatalities, primarily to non-occupants; however, the mode's relatively low passenger-miles of travel compared to heavy rail and bus mean that transit's average is only marginally increased.

The U.S. Bureau of Transportation Statistics reports that the fatality rate of transit is nearly 10 times less than automobiles, but these numbers may include non-urban VMT and exclude transit fatalities to non-occupants. Therefore, Figure 17 presents a six-year national average of fatality rates by mode including urban auto travel only. Based on this national data, auto travel

is responsible for roughly 1.5 times more fatalities per passenger mile than transit. Miller (1997) reports that safety costs per passenger-mile are five times less for rail than for private autos.

4.4 Quantifying Transit's Safety Benefit to Chicago

This analysis has presented evidence that safety costs are probably lower on public transportation than in private automobiles. Theoretically, faced with the decision to take transit or drive, a traveler choosing transit might save themselves and the region safety costs.

I estimate the contribution of public transit to transportation safety in the Chicago metropolitan region by imagining the region's safety costs without transit. I extrapolate direct increased safety costs by applying the average per-mile cost to transit travel described in Table 21. I predict indirect safety costs on a per-mile basis based on the trend identified in Figure 16. In addition, I estimate added safety costs of transit by extending average per-passenger-mile costs. To express uncertainty, I use a range of estimates.

$$S_{\text{AUTO}} = f(V)$$

$$S_{\text{TRANSIT}} = f(P)$$

$$E_{\text{AUTO}} = f \left[\frac{V + \frac{P}{O}}{C} - \frac{V}{C} \right] \text{ (based on Figure 16)}$$

$$\text{Transit Safety Benefit} = \left[\frac{P}{O} \times S_{\text{AUTO}} \right] + \left[\left(V + \frac{P}{O} \right) \times E_{\text{AUTO}} \right] - \left[S_{\text{TRANSIT}} \times P \right]$$

Where: S_{AUTO} = safety cost per auto vehicle mile
 S_{TRANSIT} = safety cost per transit passenger mile
 E_{AUTO} = incremental indirect safety cost per auto vehicle mile (based on traffic density)
 V = automobile vehicle-miles traveled
 P = transit passenger-miles traveled
 O = average automobile occupancy
 C = roadway capacity in centerline-miles

The Illinois Department of Transportation estimated that accidents cost the RTA Region \$6.3 billion in 2005, or the equivalent of around 10¢ per vehicle mile. Those costs were higher in Cook County (12¢ per vehicle mile), but were made up of different kinds of accident costs. Although around half of transit passenger miles took place on the CTA in Cook County, many of the passenger miles on Metra and Pace may have occurred in the Collar counties. To reflect this uncertainty, I use Cook County and RTA Region averages for high and low estimates for S_{AUTO} .

Estimating S_{TRANSIT} for the RTA Region is difficult, mostly because the standard reporting system for incidents is incomparable to that of the automobile system. The National Transit Database stopped reporting detailed safety statistics in 2002. Furthermore, fatalities caused by

train collisions at grade crossings are reported as rail fatalities, even though “impacts with vehicles and pedestrians at rail-highway crossings accounted for 92% of passenger train costs” nationally in 1993 (Miller, 1997, 300). On average between 1999 and 2001, however, transit services in the RTA region reported approximately 1750 incidents, 1600 injuries, and 37 deaths per year (NTD, 1999-2001, Tables 22, 23, 24). By assuming that this average rate has not changed in 2005, and by applying the economic costs described in Table 18, I estimate that transit in Chicago incurred safety costs of around \$128 million in 2005. Similar results are obtained by assuming that the differential fatality rates in Figure 17 are proxy for overall safety cost rates. Over two-thirds of transit deaths were reported by Metra (NTD, 1999-2001; Federal Railroad Administration, 2007), many of which may have occurred at grade crossings, so the intrinsic safety of transit may be even greater than what is reported here, and my estimates are probably conservative. To reflect the uncertainty of these assumptions, I use a range of \$100-\$150 million as high and low estimates of S_{TRANSIT} .

To account for the weak correlation shown in Figure 16, I take as a low estimate that the traffic density effect on safety costs is zero, and the trend line as a high estimate. Vehicle-miles traveled V and roadway capacity C are from IDOT (2006a), while transit passenger-miles traveled P is from NTD (2005). Average vehicle occupancy O is taken from section 3.2.1.

Table 23. Estimated Safety Benefits of Transit in the RTA Region, 2005

Savings in \$ Millions	Low	High	Central
Saved Fatalities	32	34	
Saved Injuries	3,875	4,432	
Saved Crashes	15,377	18,753	
Safety Costs Saved Directly	\$ 326	\$ 379	
Safety Costs Saved From Lower Traffic Density	\$ -	\$ 276	
Transit Safety Benefits	\$ 326	\$ 655	491
External to Government	\$ 77	\$ 155	116
Internal to Drivers	\$ 249	\$ 501	375
			-
Transit Safety Costs Incurred	\$ (150)	\$ (100)	(125)
External to Communities Served by Transit	\$ (35)	\$ (24)	(29)
Internal to Transit Service Providers	--	--	--
			-
Net Safety Benefits of Transit	\$ 291	\$ 631	461

I estimate that if all passenger-miles traveled on transit were to occur on roads, adjusted for average vehicle occupancy, the RTA Region would incur between \$326-\$379 million in additional collision costs on its roadways. In addition, traffic densities would rise slightly, but because I found only weak evidence that this would increase the probability of accidents and hence the average costs per mile, I conservatively estimate that this effect would cause between \$0-\$276 million in incremental safety costs. Offsetting these losses would be reduced accidents from transit itself, which I estimate between \$100-\$150 million.

However, some of these costs are internal, while some are external. The RTA service boards carry accident insurance similar to auto drivers. Applying Blincoe’s (1996) estimate that 24% of

the traffic safety benefits (net of transit safety costs) are external, I estimate an external benefit to society of \$77-\$155 million, and an internal benefit to auto drivers of \$249-\$501 million, and I estimate an external cost to communities served by transit of \$24-\$35 million, while the internal costs to the transit service boards are internalized as insurance expenses. In total, I estimate the net safety benefits of public transportation in Chicago between \$291-\$631 million.

Considerable uncertainty is reflected in these approximations, but they provide a rough idea of the magnitude of safety benefits from transit services in Chicago. Broadly, my findings suggest that transit is safer than cars in Chicago, so the safety benefit of choosing transit is measurable and positive. The phenomenon of an accident externality through increased traffic density may be applicable to Chicago, and I have included it as a high estimate, but further research is needed.

Lastly, and perhaps most promisingly for transit, the external costs of automobile accidents appear to be highest where public transportation can best mitigate them by providing an alternate means of mobility- in urban areas.

5 Measuring the Congestion Relief and Mobility Benefits of Transit

Another potential justification for public transportation is that transit is said to relieve congestion on the roads and provide a low-cost alternative means of mobility. In view of a potential new transit funding structure, it is worth quantifying these benefits, and measuring to whom they accrue.

However, quantifying these benefits of transit can be difficult, since the demands for transit and roadway capacity are interrelated. Congestion indicates an equilibrium between alternative modes. To measure the congestion relief provided by transit, I compare the current situation in Chicago to a hypothetical city without transit. Recognizing the difficulties in constructing this counterfactual, I suggest ways to measure congestion costs and mobility benefits without transit based on a medium-term equilibrium.

5.1 Why Congestion Happens

Practically, congestion occurs because human societies organize daily activities so as to capture the value of coinciding periods of work, leisure, and rest (Downs, 1992). We come into the office in the morning because everyone is more productive together in the same building at the same time, so our colleagues can join our meetings and answer our phone calls. We endure chronic traffic slowdowns because it's worth it – whatever is at the end of our trip is more valuable than the congestion we suffer through. To a certain extent, then, some congestion is inevitable and a sign of economic strength. The optimal level of congestion is not zero. Without proper planning and accommodation, however, congestion becomes a real problem that hinders economic growth.

Physically, congestion happens because drivers supply their own time in the production of transportation services on roads, yet the quality of the service provided depends on the rate at which vehicles can pass by a given point, so growing traffic density results in slower speeds (Mohring, 1999).

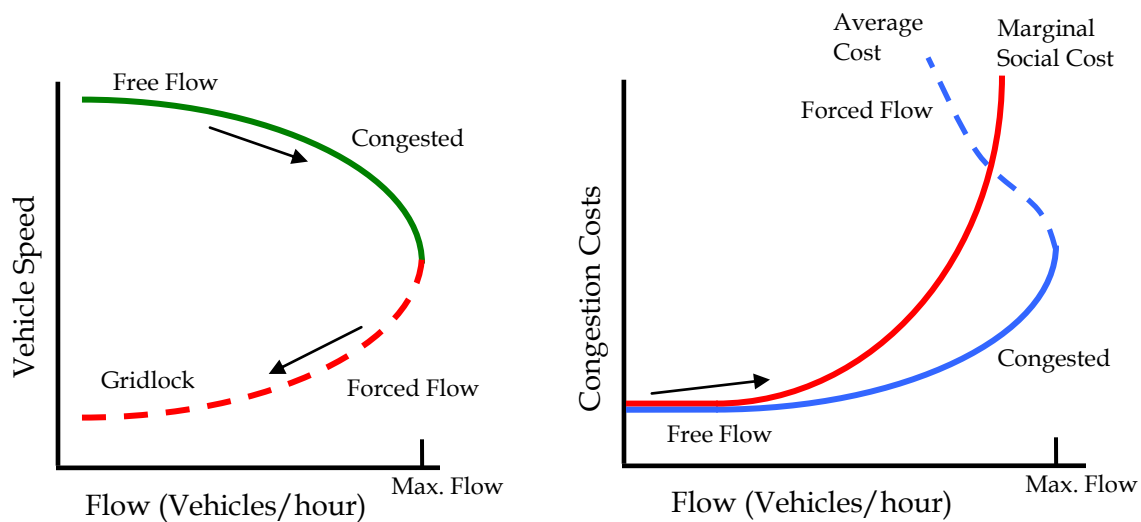
Economically, roadway congestion occurs because road capacity has traditionally been given away without market price signals. Traffic occurs because drivers on the road consider only private, not social costs when deciding to drive. When deciding where and when to travel, a driver only accounts for the traffic she expects to experience, not the contribution her trip will make to overall traffic levels and hence the external cost she will impose on every other driver.

For example, imagine that adding one additional car to a 100-car road at rush hour might slow everyone's travel time by 1 second. This driver, perhaps on a 5 minute trip, will face a *private* cost of 5:01 and decide to drive, ignoring the cumulative effect of the 1-second penalty she imposes on everyone else. Because each car experiences a slowdown, the marginal *social* cost of her decision to drive is her private cost (5:01) plus the public cost (100 cars × 1 second = 100 seconds = 1:40), or 6:41. More drivers, facing similar choices, continue joining the road until congestion becomes intolerable. In economic terms, this is a classic "tragedy of the commons:" because drivers consider only private cost, not the higher marginal social cost of their actions, they overconsume, the common good is degraded, and everyone is worse off (Hardin, 1968).

Each driver acts rationally according to the incentives before him, yet collective inefficiency persists.

Theoretically, this implies that auto driving is underpriced and probably overconsumed, especially in peak periods. All drivers are imposing external costs on another, and no driver pays the true marginal social cost of their actions. Empirical evidence shows that roadway congestion is an exponential function. As more cars join a roadway with finite capacity, marginal costs diverge sharply from average costs past a critical point, and congestion increases rapidly until the road reaches “forced flow:” stop-and-go traffic or even gridlock depending on the design of the street network. Figure 18 illustrates this relationship:

Figure 18. Engineering and Economic Representations of Congestion



Source: Adapted from TRB, 2000; Mohring, 1999

Without a way to charge higher prices for a finite quantity of road space at times of peak demand, demand will always exceed supply, and levels of congestion will always exceed the optimal amount.

5.2 Congestion Pricing's Promise for Congestion Relief

Since the 1950s, transportation economists have been calling for “congestion pricing,” or imposing a variable road toll to make drivers face the true marginal social cost of their decisions (Vickrey, 1963). By this logic, the toll would be the difference between average costs and marginal social costs where motorists’ willingness to pay equaled marginal social costs. While consumers are accustomed to peak pricing in goods like airplane tickets, cell phone calls, and movie theatres, congestion pricing on roads has proven politically and pragmatically difficult. Pricing strategies for road space are fraught with political, informational, and practical problems (King, Manville, and Shoup, 2007).

Perhaps the strongest explanation for policymakers’ reluctance to price road space is policymakers’ perception that mobility is too fundamental to price. Peaking is inherent to

transportation because of the way we organize human activities, and the cost of shifting travel to off-peak times or pricing some trips off the road is perceived to be very expensive, especially where other modes are unavailable.

5.3 Road Construction's Role in Congestion Relief

In the absence of first-best congestion tolls, or regulatory mechanisms such as parking limits or signal priority, one politically acceptable policy alternative to congestion relief in the U.S. has been to build roads. However, this policy is limited by the high cost of road-building in mature networks, and the temporary relief provided by new road capacity.

Increasing urban roadway capacity in the U.S. is becoming increasingly onerous for a variety of reasons. A cascade of environmental legislation, such as the National Environmental Policy Act, internalized many previous external environmental costs of highway construction, making road-building more expensive relative to prior decades. Large-scale demolitions and takings for right-of-ways are increasingly infeasible in dense, built-out cities. Network spillover effects during construction periods and required mitigation costs are high in mature road networks. The financial resources in the Highway Trust Fund are projected to be in deficit by 2009 (Congressional Budget Office, 2007), so the cost of road building may be rising at the same time that available funds are dwindling.

Furthermore, absent congestion charging, building more roads tends to provide only fleeting relief to mature transport networks. More road capacity increases the relative attractiveness of driving and soon attracts even more traffic (sometimes away from transit), and reinforces auto-dependency in land use and car ownership patterns. A growing academic literature points out that road construction will tend to induce traffic demand through feedback mechanisms in trip distribution through land use, and any new roads will quickly fill up to similar levels of congestion as the roads they were meant to relieve. In a literature review of induced demand, Cervero (2002) estimated the long-term elasticity of auto travel with respect to lane-miles of capacity at 0.73, and concluded that "there is no question that road improvements prompt traffic increases". Winston and Langer (2006) concluded that every \$1.00 of federal spending on roadway construction resulted in \$0.11 of congestion relief. As Mogridge (1990) states, traffic expands to meet the available road space. Consensus may be growing in transportation planning that we cannot build our way out of congestion.

5.4 Transit's Role in Congestion Relief

Another politically acceptable alternative to address congestion in the U.S. has been to subsidize alternative modes of transport such as transit.

The appeal of subsidizing transit is that it provides moderate congestion relief without explicitly charging for automobile mobility, and allows additional trip-making irrespective of roadway congestion. Practically, subsidizing one transport mode may be politically easier than taxing another. In a congested city, public transport's role may not be to *relieve* congestion directly, but to *bypass* congestion – which contributes to relief somewhat, but also enables mobility.

5.4.1 Importance of Grade Separation

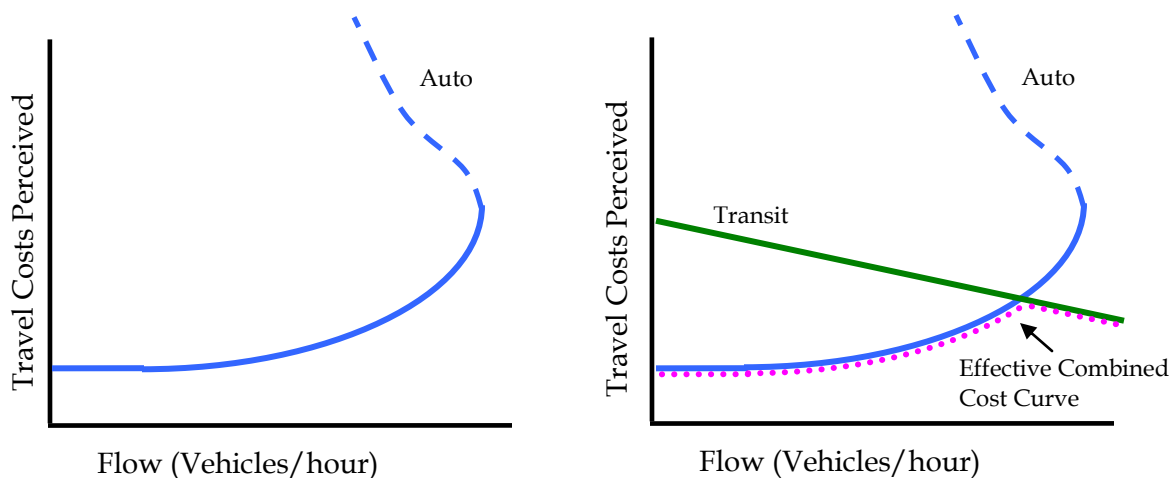
Grade separation for transit is important to this strategy: without it, transit’s potential to relieve congestion is reduced. Urban rail transit operating on its own right-of-way will be independent of roadway congestion. Transit buses contribute to congestion reduction because they take up the equivalent of about two passenger cars of road space yet can carry ten times as many passengers. But buses still get stuck in traffic caused by other cars on the road. This problem often leads to the irrational situation where bus riders, frustrated that the bus is too slow, choose to drive instead. This adds to traffic, reduces fare revenues, and slows the bus further. This encourages even more passengers to abandon the bus, and the cycle repeats until the bus is nearly empty and heavily subsidized, traffic is even slower, and everyone is worse off. Indeed, imposing reserved bus lanes on clogged urban routes would in some cases increase passenger flows, but policymakers face the political conundrum that when the road is lightly trafficked, “buses don’t need it,” and when the road becomes congested, “buses can’t have it” (Wilson, 2006).

5.4.2 Road-Transit Equilibrium in Congested Corridors

In strategic corridors at peak periods, increasing transit capacity may be the best way to alleviate congestion for everyone. There is considerable empirical evidence that grade-separated, parallel alternative modes will tend to reach equilibrium where door-to-door travel times are equal. In theory, some travelers in a given market will be indifferent to everything but travel times on peak, and will switch to whichever mode is fastest. In these situations, roadways may congest only up until travel times equal transit travel times. Transit quality will thus “pace” auto congestion, because transit sets the lowest acceptable travel speed (Suchorzewski, 1973). Lewis and Williams (1999) document this phenomenon in several high demand U.S. corridors, including the Loop-O’Hare and Loop-Midway corridors in Chicago.

If it is mass transit that will determine long-run equilibrium travel speeds on a mature transportation network’s most congested corridors, the only real policy to increase travel speeds to all modes is to improve the performance of the transit system (Lewis and Williams, 1999, 100-103). This is a twist on the saying, “a fleet is only as fast as its slowest ship.”

Figure 19. Representation of Perceived Travel Costs without and with Transit



5.4.3 A Little Bit Can Go a Long Way

Critics of transit subsidy in the name of congestion relief often argue that public transportation accounts for too small a portion of overall travel to have a significant influence on roadway congestion. On a national scale, this is probably true. But national averages tend to mask that congestion is highly concentrated spatially and temporally in dense urban areas where the prospects for transit use are greatest. Furthermore, because congestion costs tend to rise exponentially with increases in travel, luring even small traffic volumes off of busy roads in peak periods may confer disproportionately large benefits to those who remain. Indeed, “a 5-10% reduction in traffic volumes on a congested highway typically causes a 10-30% reduction in congestion delay” (Litman, 2005, 5.5). Three years after London began its congestion charge, an 8-17% reduction in vehicles has resulted in a 26-30% reduction in congestion measured in vehicle-hours of delay (Transport for London, 2006a). Viewed another way, if all public transit riders were to drive instead, they would impose large congestion penalties on all existing drivers.

5.4.4 The “Backfill” Phenomenon

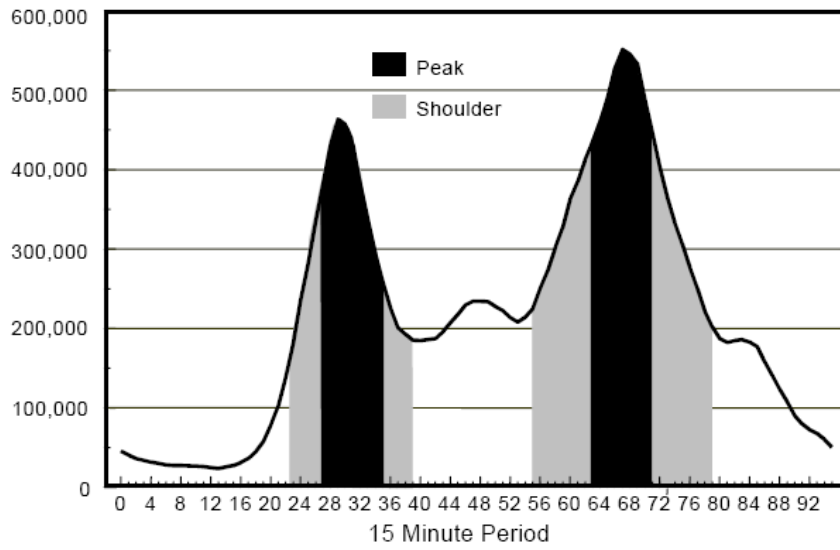
Just as induced auto demand tends to offset the congestion relief provided by new road capacity, the same phenomenon may also offset much of the relief provided by transit capacity. Because demand for automobile travel appears to be so elastic, most urban road capacity freed up by transit riders may be quickly “backfilled.” Economists have described the idea of “latent demand,” that is, demand that is inhibited or shifted off-peak because of the cost of congestion alone (Small, Winston, and Evans, 1989). In the context of severe road congestion, congestion costs alone may be the primary determinant of travel demand, all other things being equal, so any measures to augment capacity or divert demand may have only moderate effects on congestion (Small, 1992, 113). If a policy removes cars from the road, congestion costs decrease, and elastic auto drivers who had been just on the margins are encouraged to travel once again, or shift their travel to the peak.

Several studies have attempted to quantify this backfill phenomenon vis-à-vis public transportation. In the months following the inauguration of BART service between Oakland and San Francisco, an evaluation found that the line diverted 8,750 automobile trips from the parallel San Francisco Bay Bridge, but that these trips were soon replaced with 7,000 new automobile trips (Sherret, 1980). That is, 80% of the road capacity freed by transit use was backfilled by more cars. Although the growing literature on induced demand focuses on backfill from new highway, not transit capacity, the conclusions are broadly consistent. While the backfill phenomenon does partially undermine transit’s ability to reduce congestion, it does point to transit’s potential to increase total mobility without increasing congestion. This phenomenon also indicates the elasticity of demand for auto travel with respect to congestion costs.

5.5 Congestion in Chicago

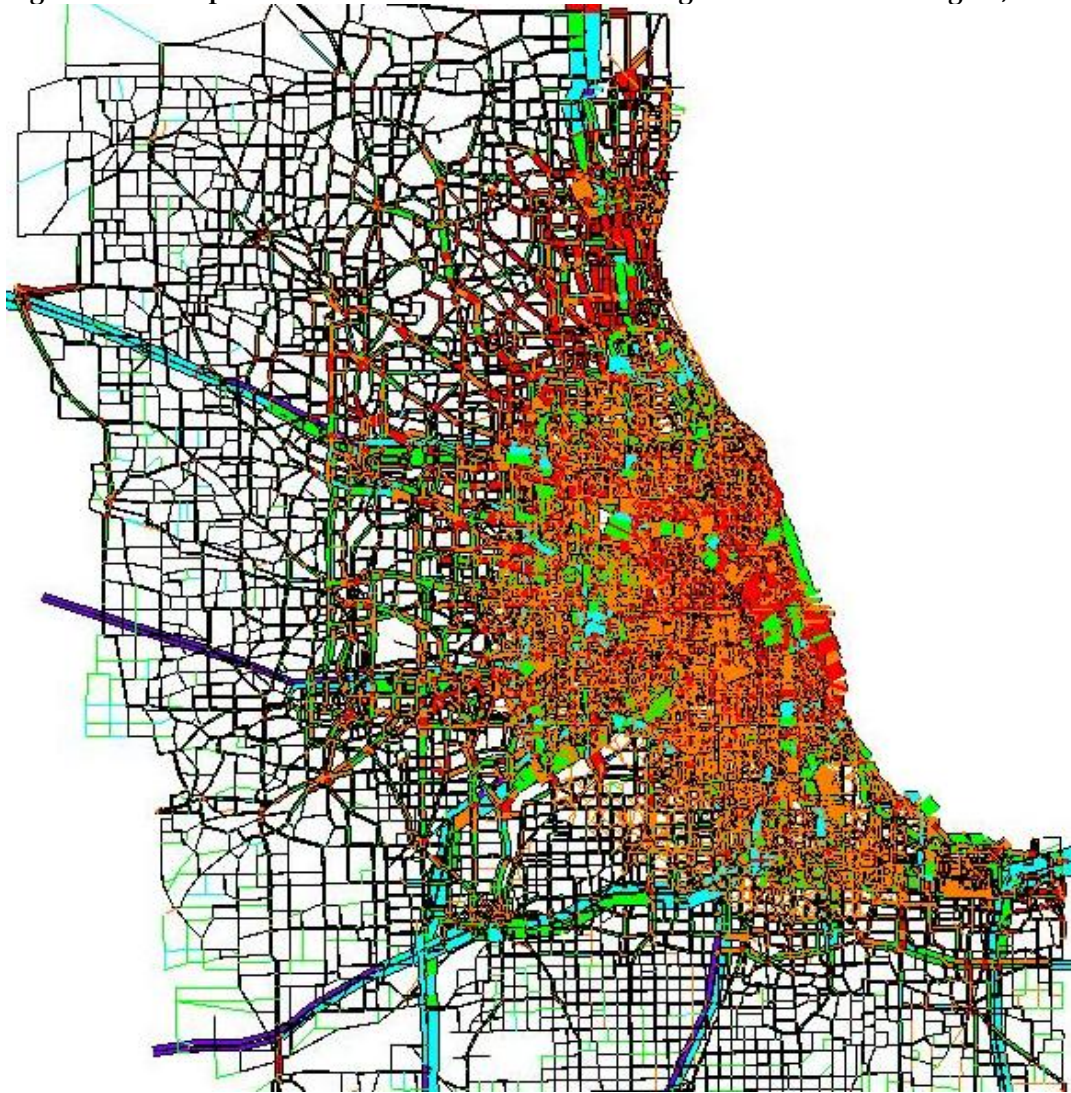
Automobile congestion in Chicago is relatively severe and is the primary way proponents in Chicago seek to justify government support for transit services. Between 1982 and 2003, as the metropolitan region’s population grew by 13%, VMT increased by 73% on a road network which only grew by 26% (TTI, 2005). Underlying this situation is the spatially and temporally peaked nature of travel demand, as shown in Figure 20 and Figure 21.

Figure 20. The Temporal Distribution of Trips in Chicago



Source: CATS, 2005, 7.2

Figure 21. The Spatial Distribution of Automobile Congestion in the RTA Region, AM Peak



Source: Murga, 2007

Chicago is among the top ten major U.S. cities in most indicators that the Texas Transportation Institute uses to measure congestion. Chicago was the third worst congested American city in 2003 measured by overall costs (a combination of lost time and excess fuel consumption), behind New York City and Los Angeles. Chicago is second only to Los Angeles measured by the travel time index, an indicator of how much more on-peak travel costs relative to off-peak.

However, these indicators represent only costs to automobile travelers, and are an incomplete measure of how much congestion affects most people's daily lives (Litman, 2006). Drivers in New York City, for example, may face the nation's second highest congestion costs, but a substantial proportion of New Yorkers do not drive automobiles on a daily basis. Measured in delay *per traveler*, New York City ranks 18th in the country. Chicago ranks 7th in delay per traveler.

Supporters of public transportation in Chicago argue that transit's ability to reduce congestion is a primary rationale for continued government funding. Indeed, the congestion argument may be a powerful one in a political calculus where only 8% of motorized trips in the region are served by transit, yet some funding for transit is needed from the other 92%. Getting the majority to commit resources to a service used by a minority requires powerful arguments that the service provides communal benefits to all. The promise of congestion relief may be a good way to convince people who aren't riding transit that they benefit from it.

5.6 Modeling Transit's Role in Congestion Relief in Chicago

Because of the interactions between transit and the automobile, congestion in a given metropolitan region is the result of an equilibrium between travel demand and costs, including the quality and availability of alternatives. To quantify the value of public transit's congestion relief, I compare the current situation to a hypothetical no-transit city, but the no-transit counterfactual can be difficult to predict. Here, I develop a methodology to imagine medium-term congestion levels in the absence of transit.

5.6.1 The Elasticity of Travel Demand

Some argue that public transport does nothing to reduce congestion – that without a transit system, few passengers would otherwise be driving (Cox and O'Toole, 2004). These arguments implicitly assume that demand for auto travel with respect to congestion is perfectly elastic. Given that transportation is primarily an intermediate good to access other activities, and that many transit passengers have access to automobiles, the idea that transit riders would simply avoid or shift travel in the absence of transit is unlikely.

Others argue that public transport does a lot to reduce congestion - that without a transit system, all transit riders can and will drive the exact same trips. The Texas Transportation Institute (2005) reports “congestion savings from public transportation,” by forcing all public transit travel onto the road networks at its current distributions, recalculating travel costs, and taking the difference. This calculation assumes that demand for auto travel with respect to congestion costs is perfectly inelastic. This TTI figure is, I believe, an upper bound of the short-term congestion savings from transit.

A third view, more conservative than the TTI figure, is that travel demand is somewhere in between. If transit were eliminated, former riders would respond in a variety of ways, with several demand elasticities depending on the timeframe.

- In the immediate term, many transit riders may drive, causing congestion to spike exponentially. Some transit riders' mobility may be restricted simply because they do not own a car. However, the limited parking supply in central areas would likely become a more severe constraint to mobility than congestion.
- In the medium term, car ownership could increase, travel patterns would readjust, and many travelers may be forced to peak-shift or be deterred from driving because of congestion costs alone.
- In the long term, the land use system will adjust to the new road demand and capacity, perhaps by sprawling. In this situation, some economic growth may simply shift to another metropolitan area.

To make this analysis conservative, I predict transit's value by modeling the medium-term condition of a city without transit by assuming a mid-range elasticity of demand with respect to congestion costs.

To estimate the slope of this demand function, I turn to the backfill rate introduced in section 5.4.4 and assume a backfill rate of 75% based roughly on Sherret (1980) and Cervero (2002). In theory, if 75% of the roadway capacity liberated by new transit capacity is backfilled by elastic auto demand, I assume the inverse is also true. That is, eliminating transit capacity will only add 25% of existing transit demand onto the roads in the same spatial and temporal patterns. In a no-transit scenario, the remaining three-quarters of transit riders would peak-shift, at some expense.

5.6.2 The Cost of Peak Shifting

As traffic grows in severity, costs rise sharply enough that travelers either a) shift to an off-peak time, b) spill over to alternate routes, c) carpool, or d) decide not to travel. The cost of these compensatory measures is probably more than zero, but less than the private average travel costs in the congested conditions – otherwise, you would choose to endure the trip. To keep this estimate conservative, I omit these costs to form a lower bound. However, recognizing that transit ridership may be concentrated in peak hours, these omitted costs are likely to be high, lending some credibility to the TTI estimate of avoided congestion costs.

5.6.3 The Nature of Congestion Costs

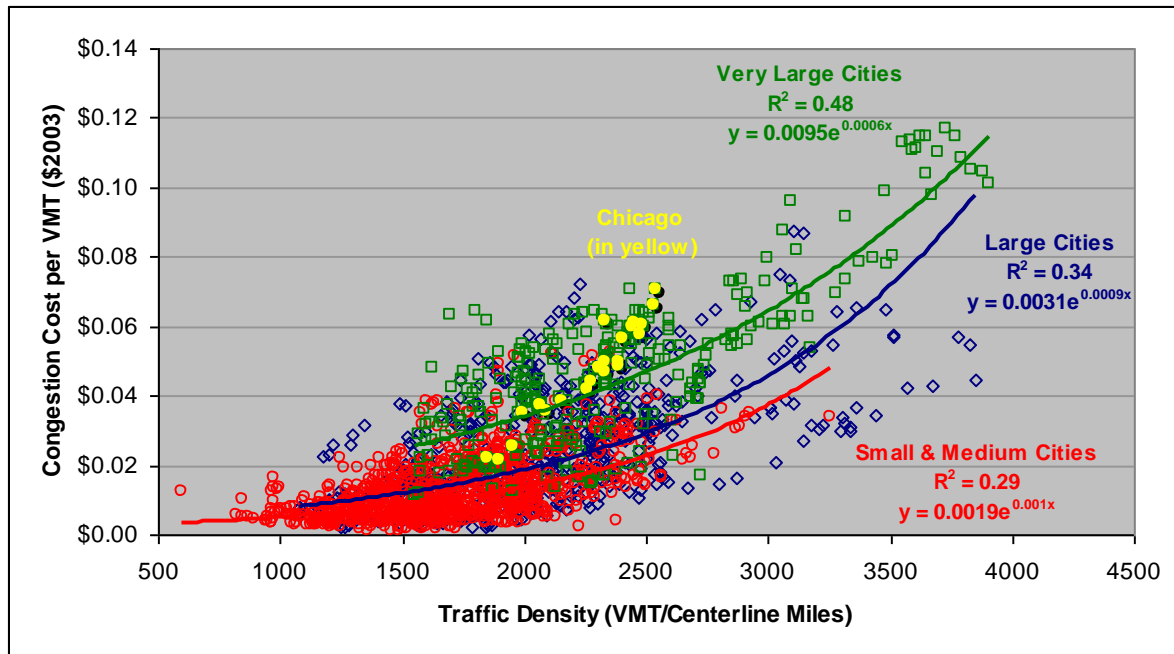
In addition, I assume that congestion costs are the only determinant of automobile travel in Chicago that differs between the with-transit and no-transit scenarios.¹⁴ Although Mohring (1999) and others (Small, 1992, 69, 87) model congestion as a function of the volume/capacity ratio or vehicle flows on one specific road segment, this kind of analysis is difficult to adapt to an entire metropolitan region. Therefore, I express congestion costs published by the Texas Transportation Institute as a function of traffic density, measured in auto VMT per road centerline-mile. This function controls for historic growth in VMT and roadway capacity, and implies intuitively that congestion is a product of how many cars are on a given stretch of roadway.¹⁵

On a national level, the relationship between traffic density and congestion appears to hold broadly across many different city types, but the pattern is strongest among large cities where the streets are likely close to capacity already. The historical data for Chicago specifically appear to be no different, and in fact may even be approaching its limits faster than other large cities.

¹⁴ Since congestion costs are the only component of travel costs that change between the two scenarios, I use congestion costs and travel costs interchangeably in this chapter.

¹⁵ All data are from TTI, 2005, and financial figures are inflated by the Bureau of Labor Statistics' Urban Consumer Price Index to 2003 dollars.

Figure 22. Congestion Costs in 85 U.S. Cities, 1982-2003



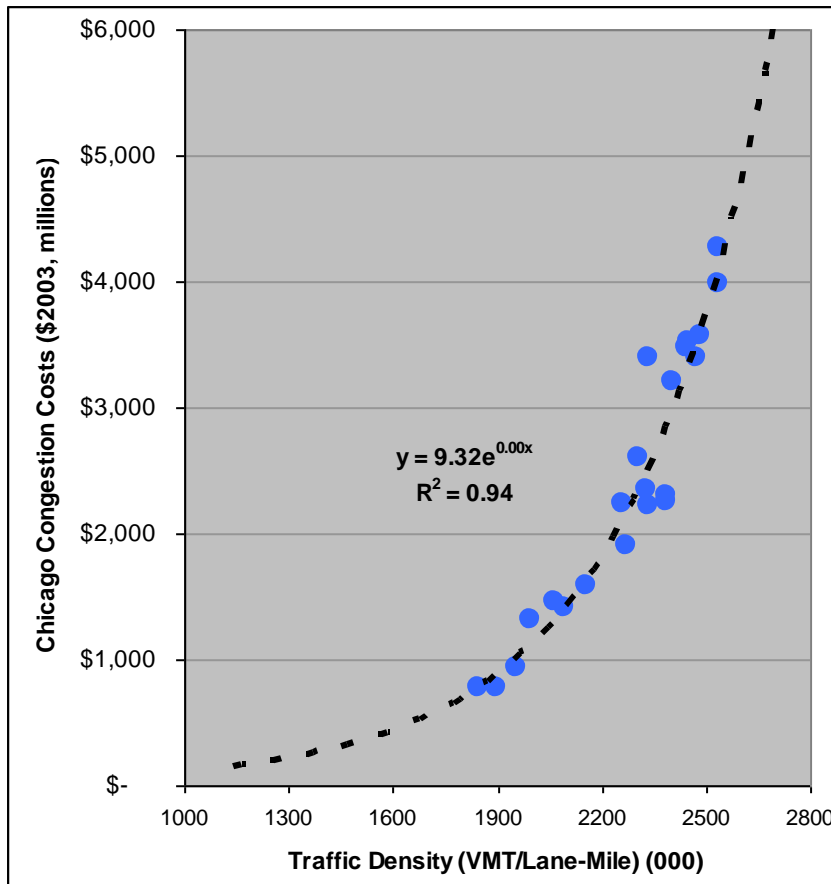
Source: TTI, 2005

5.7 Results: Transit's Congestion Relief in Chicago

Traffic density is a good predictor of congestion costs in the six-county Chicago region, and in accordance with theory, the relationship appears to be exponential. Similar to gasoline consumed, congestion costs in Chicago can be expressed as a function of VMT divided by the capacity of the roadway network, i.e. traffic density.

The Texas Transportation Institute's Urban Mobility Report calculates congestion by establishing free-flow speeds for each road link depending on road type and direction, estimating congested speeds based on daily vehicles per lane, and taking the difference. Thus my expressing congestion as a function of traffic density may approximate TTI's methodology. In any case, density seems to predict TTI's congestion costs.

Figure 23. Historical Congestion Costs in Chicago by Traffic Density



Source: TTI, 2005

5.7.1 Results: A Mathematical View

In a hypothetical Chicago without transit, I predict auto travel by converting transit passenger miles to auto vehicle miles using the average vehicle occupancy described in section 3.2.1. Transit riders would likely join the roadway system at the average vehicle occupancy rate. This assumption may be a liberal estimate, as vehicle occupancies might increase in the absence of transit, especially given parking constraints. This function makes the simplifying assumption that any VMT is added to or subtracted from the road network with roughly the same spatial and temporal distribution as the existing traffic.

The six-county region in 2003 experienced 60.5 billion VMT on a road network of 23,850 road centerline-miles, resulting in a traffic density of 2.54 million annual VMT per road centerline-mile, and estimated¹⁶ congestion costs of \$4.08 billion. This translates into a cost of roughly 6.7¢/VMT. In addition, transit services in 2003 provided 3.6 billion passenger miles traveled. Therefore, without transit, I suggest that Chicago would experience congestion according to the following traffic density:

¹⁶ TTI (2005) reports congestion costs of \$4.27 billion, but this data point is slightly above the line of best fit in the graphs above, so the estimated congestion cost by the trend line is \$4.08 billion.

$$\frac{V + \left[P \times (1 - R) \times \frac{1}{O} \right]}{C} = D = 2.57 \text{ million VMT per centerline-mile}$$

$$\text{Congestion Costs} = f(D) = 9.316e^{(0.0024 \times D)} = \$4.40 \text{ billion}$$

Where: V = automobile vehicle-miles traveled
P = transit passenger-miles traveled
R = medium-term backfill rate of automobiles
O = average automobile occupancy
C = roadway capacity in centerline-miles
D = automobile traffic density

My results suggest that the difference between current congestion levels and their levels in the absence of transit is approximately equivalent to at least \$323 million. That is, if 25% of transit passengers were to join the roadways at the current spatial and temporal distribution of auto travel for a 1.5% increase in overall VMT, average congestion costs would rise from 6.7¢ to 7.3¢ per vehicle mile. Because these costs are incurred by all vehicles on the roadways, this 1.5% increase in travel would cause overall congestion costs to rise by at least 9.5%.

This is probably a conservative estimate, for a number of reasons. Transit use is often disproportionately high during peak periods compared to autos, so transit riders might join the most congested roadways at their most congested times, imposing high marginal costs. Parking constraints might also lead to high parking costs, imposing high additional costs on autos. In addition, the 75% of transit riders whom I have assumed would shift their travel patterns would likely do so at some cost (either inconvenience or additional congestion), which I do not estimate. Further research is needed to quantify this cost, but it suggests that an accurate quantification of congestion costs may be higher than these estimates.

5.7.2 Results: a Graphical View

These same numbers can be derived graphically, as shown in Figure 24. Specifically, the congestion cost function can also be used to derive an inverse demand function for automobile travel in Chicago. As above, I assume that congestion costs are a function only of automobile (not transit) travel. Implicitly, I omit the congestion effects of transit buses.¹⁷

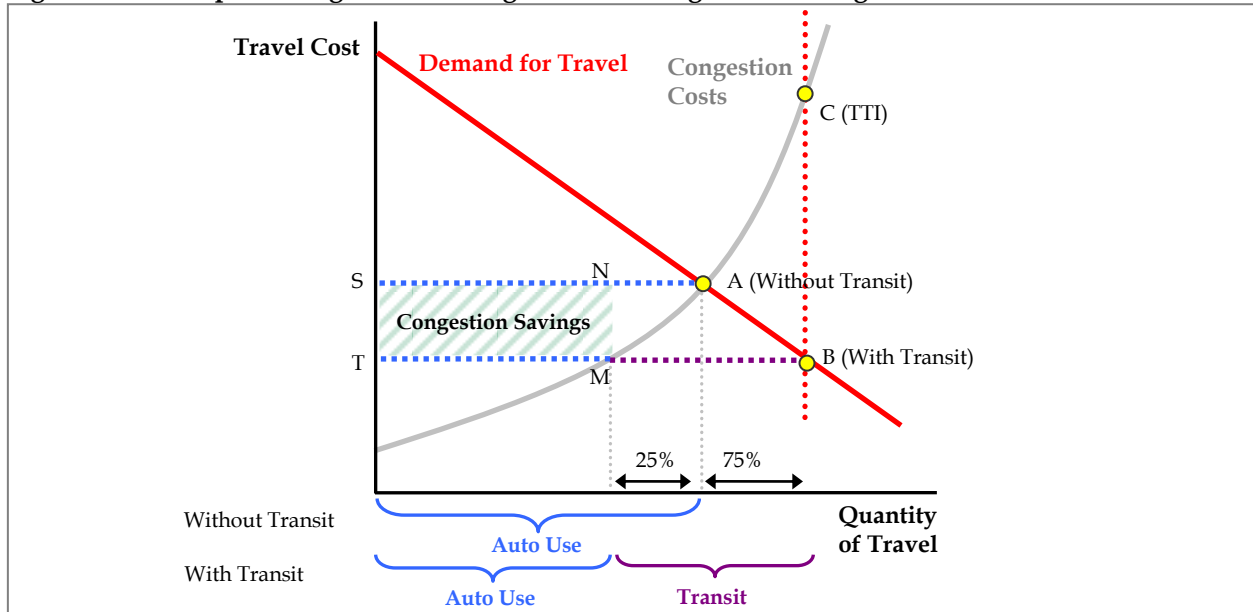
Figure 24 begins with curve MAC, a schematic representation of how rising demand produces rising congestion costs, given static roadway infrastructure. With a transit system, travel costs are T, and both auto travel TM and transit travel MB is consumed at equilibrium B. Without a transit system, 25% of former transit riders continue to drive in the same distribution of current travel (NA), while 75% either peak-shift or are deterred entirely by travel costs of S at equilibrium A. We now have two points: prices are lower and more is consumed at B, and

¹⁷ While buses in mixed traffic contribute to roadway congestion (perhaps more congestion per vehicle than cars), CTA and Pace buses comprised only 0.2% of vehicle miles traveled in the RTA district in 2005.

prices are higher and less is consumed at A. These points indicate the downward-sloping demand curve for auto travel with respect to congestion.

In their calculations, it appears that Texas Transportation Institute assumes overall demand for travel is inelastic and follows the dotted red line to point C. As described in section 5.6.1, this is probably an upper bound.

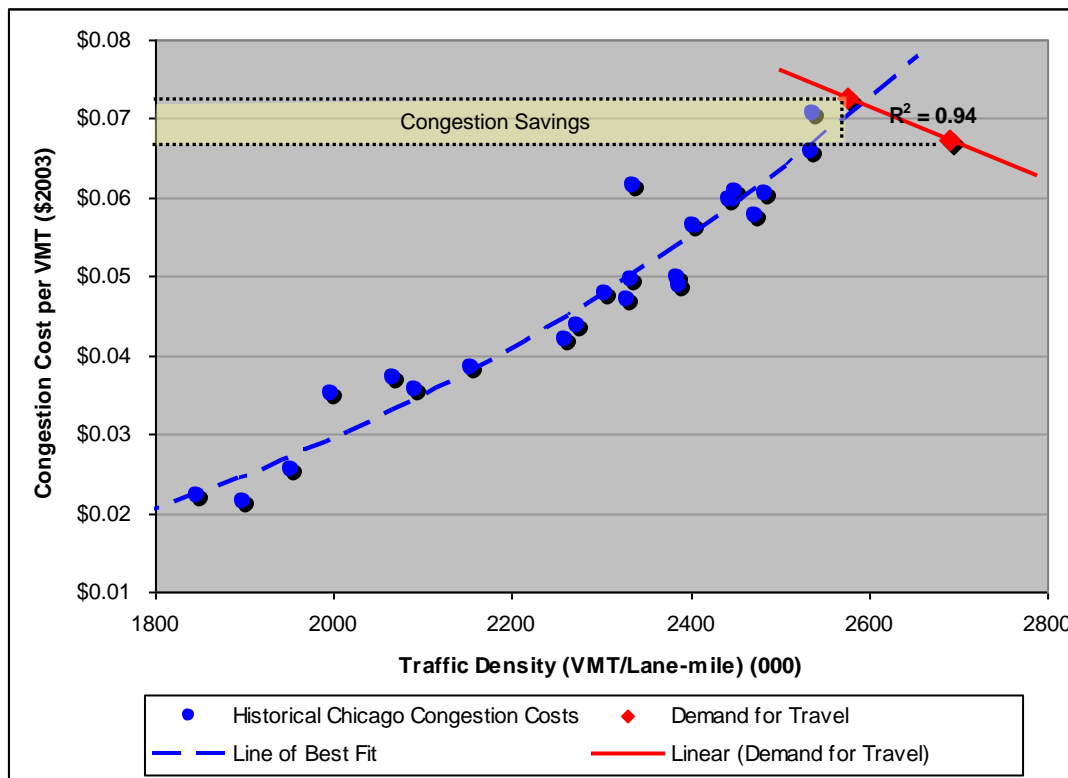
Figure 24. Conceptual Diagram Modeling Transit's Congestion Savings



The change in welfare between with-transit costs T and no-transit costs S for the original autos TM (STMN) are the real congestion benefits a transit system provides. Using actual data for Chicago, as shown in

Figure 25, this area is calculated to be \$323 million. To reflect the uncertainty associated with the assumed backfill rate of 0.75 and the unknown cost of compensatory peak-shifting, I take \$323 million as a lower bound, and the TTI figure of \$1,577 as an upper bound.

Figure 25. Estimating Congestion Savings from Transit in Chicago



5.8 Sensitivity Analysis of Congestion Relief

Table 24 indicates that my analysis is sensitive to initial parameters. By definition, the real congestion benefits of transit services in the Chicago region could be zero if auto demand is so elastic that the backfill rate is 100%. On other hand, if auto demand with respect to congestion costs is so inelastic that the backfill rate is 0%, transit’s congestion relief benefit reaches \$1,577 million. This analysis is only intended to be a rough measurement of a likely lower bound of transit’s role in congestion relief, and the value of a transit network to its riders.

Table 24. Sensitivity Analysis of Initial Parameters to Congestion Model

Parameter	Baseline Used	Range Tested	Congestion Relief (\$m)
Auto “Backfill” Rate	0.75	1.00 – 0.50	\$0 - \$671
Avg. Auto Occupancy	1.18	1.60 – 1.00	\$236 - \$486

5.9 Consumer Surplus and Low-Cost Mobility Benefits

Although the elasticity of auto demand tends to moderate transit’s congestion relief effects, the extra trips on transit may represent value to the passengers. Here, I attempt to quantify this value as passengers’ consumer surplus. Consumer surplus also gauges the utility passengers derive from the transit service, thereby capturing a host of benefits such as travel time and avoided costs of car ownership. While predicting the utility that might be derived if

government undertook other activities besides transit is beyond the scope of this paper, consumer surplus provides an important measure of the value of mobility to transit passengers. A number of economic evaluations use this technique (Winston and Maheshri, 2006; Small, 1999, 142-147; Nelson et al., 2006).

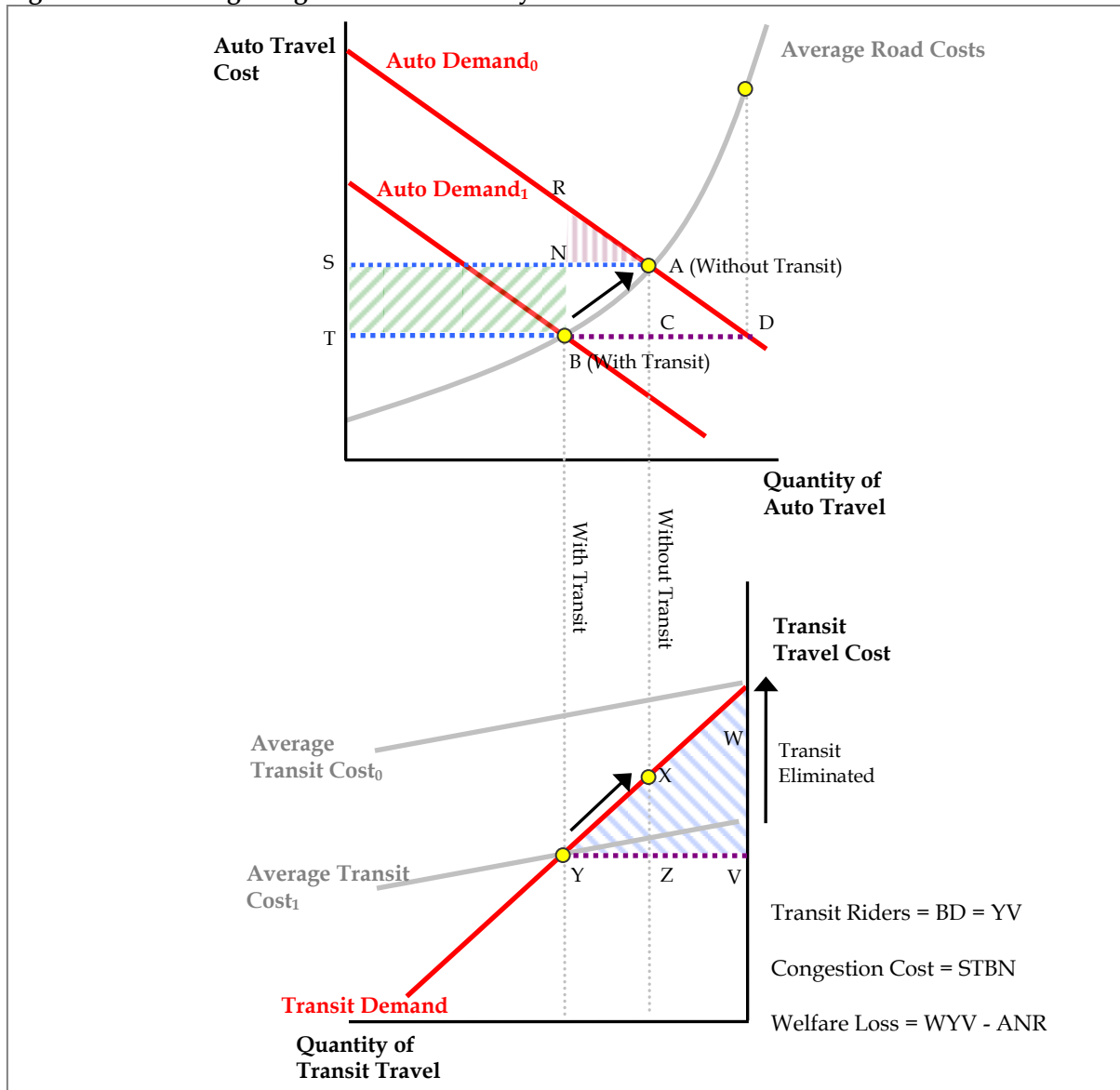
5.9.1 The Value of Low-Cost Mobility

A passenger chooses to travel because she derives utility from the trip above and beyond her travel costs. However, for low-income residents, the fixed costs of car ownership may be an obstacle to work-based trips with value to the metropolitan economy. A transit system provides mobility at relatively low and incremental costs to the user. The loss of transit, therefore, might price transit-dependents out of the mobility market altogether. The potential value of enabling economic activities or mobility is captured in the transit riders' willingness to pay, or consumer surplus.

5.9.2 Extending the Congestion Model

The congestion relief model can be extended to measure this benefit. Figure 26 models the effect of eliminating transit on roadway congestion levels. The markets for automobile and transit travel are shown, with the lower diagram for transit drawn in reverse. The current with-transit city finds equilibrium points of B and Y, where drivers endure costs of T, and BD (or YV) transit use occurs. Because transit exhibits network economies of density, average transit costs to travelers decline with service consumption due to reduced waiting times (Small, 1992; Mohring, 1972). Transit trips ZV represent transit riders with a relatively high consumer surplus, such as captive riders. Eliminating transit increases demand for autos (shifts the demand curve Auto Demand₁ outward to Auto Demand₀), and may make demand more inelastic because fewer alternatives exist. Former transit riders BC join the road network following its current distribution patterns, increasing road travel costs from T to S, while former passengers CD either shift their travel times, or not travel at all. Auto drivers still on the road suffer losses STBN, transit riders' consumer surplus WYV is lost, and the 25% of transit riders switching to auto gain welfare ANR.

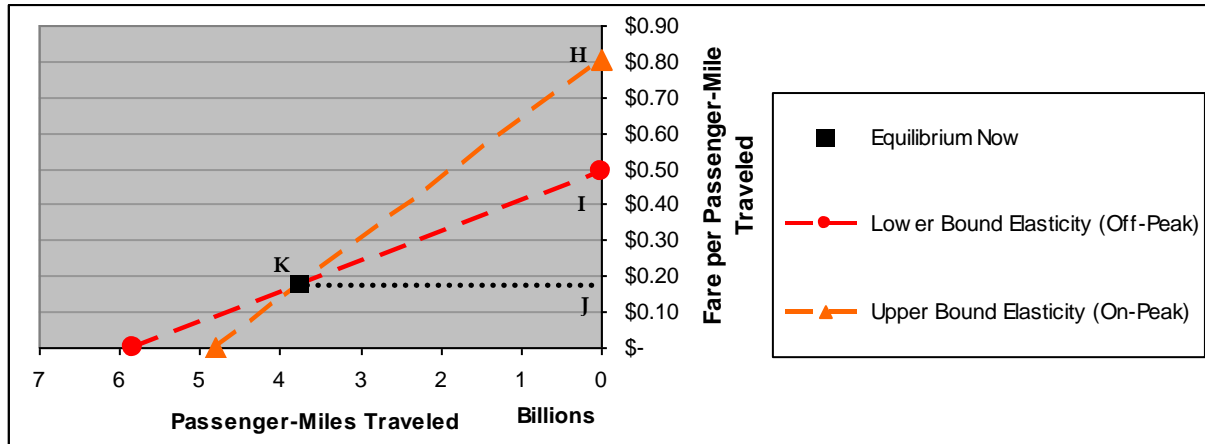
Figure 26. Modeling Congestion and Mobility Benefits of Transit



Data for Chicago is estimated using elasticities of demand as defined by the Chicago Transit Authority to derive the demand curve for transit. In its predictions of the impacts of fare changes, CTA uses a demand elasticity with respect to fares of -0.28 on-peak, and -0.56 off-peak (CTA, 2003, 53-54). While this describes fare prices and not total travel costs, both are expressed in dollars per mile traveled, and the technique has been used by others (Harford, 2006). I assume that the same elasticities define the slope of the demand curve for transit, and estimate consumer surplus by extrapolating willingness to pay for all RTA services' passenger-miles. In Figure 27, point K represents the RTA in 2005, when it collected approximately \$660 million in fare revenues for supplying 3.8 billion passenger-miles of service (NTD, 2005), for an average fare of 18¢ per PMT. Total consumer surplus of transit riders would fall between \$592 million (IKJ) assuming on-peak demand, and \$1.18 billion (HKJ) assuming off-peak demand for all services. Since transit serves a mix of on-peak and off-peak riders, a more accurate estimate is probably somewhere in between. To reflect this uncertainty and the assumptions behind this

calculation, I take these two figures as upper and lower bounds. The small welfare loss in the automobile market from reductions in the number of autos (ANR in Figure 26) amounts to \$34 million, so I estimate transit mobility benefits lost if transit is eliminated at \$1,150-\$558 million.

Figure 27. Mobility Benefits of Transit, Measured by Consumer Surplus



5.10 Who Benefits?

This analysis has shown that in rough terms, transit in Chicago is providing measurable congestion and mobility benefits to auto drivers and passengers. With a view to understanding the implications for a subsidy structure, how are these benefits distributed?

5.10.1 Congestion Reduction

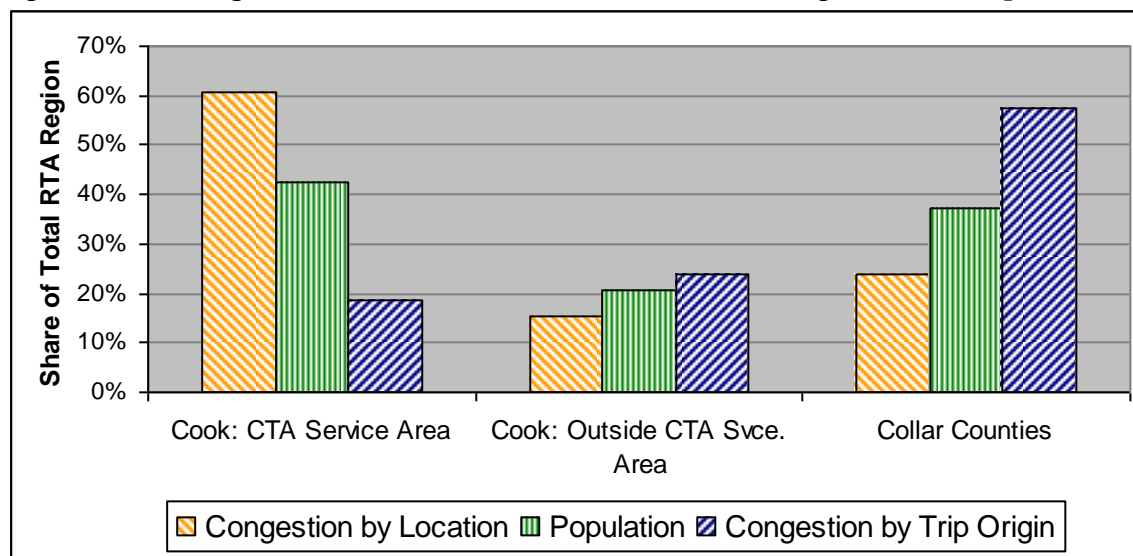
Most congestion in Chicago is occurring within the central city, which is also where transit use is the highest. Based on the CATS travel demand model with congested speeds for 2005, 76% of the automobile vehicle-hours of delay in the six-county region on a typical weekday morning happened on roads in Cook County, three-quarters of which was within the CTA's service district (approximately equivalent to the City of Chicago). By inferring trip origins based on the travel matrix used by CATS to compute the congested speeds for home-based work trips, this analysis shows that trips beginning in Cook County and the CTA Service Area accounted for a disproportionately small share of this congestion. Table 25 and Figure 28 illustrate the results, along with a comparison of population.

Table 25. Automobile Congestion by Location and Trip Origin in the RTA Region

	Auto-Hours of Delay (AM Peak)				Population	
	by Congestion Location	% of RTA	by Trip Origin	% of RTA	2005/6 Census Estimate	% of RTA
Cook: CTA Service Area	954,521	61%	405,395	19%	3,700,000	44%
Cook: Outside CTA Svce. Area	242,947	15%	520,882	24%	1,588,655	19%
Cook County (total)	1,197,468	76%	926,277	43%	5,288,655	63%
Lake	151,150	10%	327,144	15%	713,076	8%
McHenry	25,857	2%	261,851	12%	312,373	4%
Kane	35,672	2%	288,981	13%	493,735	6%
DuPage	121,667	8%	187,871	9%	932,670	11%
Will	37,891	2%	184,377	8%	668,217	8%
Collar Counties	372,237	24%	1,250,225	57%	3,120,071	37%
Total RTA Region	1,569,705		2,176,502		8,408,726	

Source: adapted from Murga, 2007. Total auto-hours of delay do not equal because the calculations for congestion location are based on a shorter AM time period. Population figures are from U.S. Census, 2005 and 2006 estimates. CTA service area population is an estimate based on CTA, 2003.

Figure 28. RTA Region's Relative Contribution to Automobile Congestion, and Population



Source: adapted from Murga, 2007

Thus, although the region's congestion happens mostly in the urban core, the drivers causing it predominately originate in the outlying areas. The 5 collar counties are home to 37% of the RTA Region's population and only 24% of its congestion, yet drivers beginning in these counties create 57% of the regional congestion in the morning peak. By contrast, those in the CTA service area are responsible for only 19% of the region's traffic delays, yet 61% of congestion occurs in this area. These results are probably the result of a higher transit mode share in the CTA, and the fairly long auto trips from the collar counties to the Loop. Since the CTA serves 82% of the region's transit trips (Table 2), and most Metra passengers are accessing downtown Chicago, transit ridership appears to be highest where auto congestion is concentrated. If transit riders were to drive instead, they would likely join the road network in its most congested conditions, where the marginal congestion cost of their joining would be

high. This situation implies that the congestion relief benefits from transit accrue disproportionately to auto drivers who originate in suburban Cook county and the collar counties.

5.10.2 Mobility Benefit

This analysis suggests that transit riders derive utility from their travel, implying a mobility benefit that accrues to their origins and destinations. This benefit might be captured with fares, but differential pricing is difficult in mass transit, and the effectiveness of such a strategy is unknown.

5.11 Congestion and Mobility: Conclusions

Traffic congestion in Chicago occurs for a variety of reasons, from the organization and scheduling of human activities, to the lack of price signals in driving. Traditional policy responses to traffic have been to construct more roadway capacity or subsidize public transportation. Congestion pricing is dogged with difficulties, and growing evidence implies we cannot build our way out of congestion, but public transit can be a way to moderate congestion and provide mobility benefits. I speculate on several mechanisms through which this may be true.

This chapter explores the role of public transit in congestion relief in Chicago. I suggest a way to quantify the congestion and mobility benefits from Chicago transit services by comparing the current congestion levels to a hypothetical no-transit scenario in a mathematical and graphical way. I construct this counterfactual scenario by modeling a city where congestion has reached a new medium-term equilibrium in the absence of public transportation. Since automobile congestion appears to be exponentially related to growth in auto travel on the roadways, I predict congestion costs using estimated vehicle miles of travel.

Next, I acknowledge that because transit's value may be in allowing travel irrespective of congestion, not all transit riders directly contribute to congestion relief, but I assert that this mobility has value. I suggest a simple way to quantify this using consumer surplus.

Finally, I map out the incidence of transit's congestion and mobility benefits, and conclude that the current equilibrium between transit use and automobile congestion in Chicago is a delicate balance. Most congestion occurs in and around the central city, yet is disproportionately caused by drivers hailing from outlying areas. Most congestion also occurs where transit use is the highest implying that gains or losses of transit passengers would have significant consequences for auto traffic. The models I construct here indicate that if 25% of transit riders were to switch to the roadway system along current patterns, this 1.5% growth in overall VMT would cause congestion costs to increase by almost 10%.

In financial terms, this chapter concluded that public transportation in Chicago confers direct congestion benefits to auto drivers somewhere in the range of \$323-1,577 million, depending on the elasticity of demand for auto travel with respect to congestion costs. This range is almost certainly conservative, since at the lower bound I have discounted the congestion effects of 75% of transit riders and omitted any inconvenience or congestion costs associated with their compensatory measures. In addition, insofar as public transportation enables passenger

mobility despite congestion conditions and at a low cost to the passenger, transit provides a mobility benefit in the range of \$558-\$1,150 million, as valued by passengers.

6 How Other Cities Do It: Lessons Learned from Transit Finance in North America and Western Europe

The purpose of this chapter is to briefly survey the operating funding mechanisms of other major transit systems which may provide lessons for the current situation in Chicago. First, I outline the role of the U.S. Federal Government in transit finance. Second, I make remarks on the role of passenger fares in the funding of transit operations, and caution against relying on farebox revenues as an indicator of efficiency. Third, I describe the primary revenue sources for transit operations, the mechanisms by which the revenues are generated for 15 major transit systems Western Europe, Canada, and the U.S. Fourth, I summarize the major themes and patterns that emerge from this survey, and describe their relevance to the development of an ideal funding framework.

6.1 *Transit Finance: the Status Quo*

There is no singular urban public transit finance model for large cities in the U.S. or Western Europe. All transit agencies charge passenger fares, yet these revenues are largely a product of a policy decision than an indicator of efficiency, and rarely cover the full costs of system operations. The U.S. federal government provides some funding to all transit agencies, although mostly in the form of capital grants, while central governments in Western Europe play a larger role in capital and operating assistance. Beyond these two sources, American mass transit systems rely on some form of government subsidy, but the structure and magnitude of these subsidies vary widely from agency to agency. Transit funding structures in Western Europe derive subsidies from a rich mix of local, regional, and central government levels which offer important insights to the American context but which are sometimes difficult to compare.

Furthermore, these funds are derived from a variety of government jurisdictions in vastly different political and institutional contexts. Urban and suburban services are sometimes operated – and funded by – separate agencies with separate financial arrangements. Some agencies receive significant revenues from their state government, while others function with entirely regional or local funding. Central governments in Western Europe play a bigger role in transit operating revenues than does the U.S. Federal government. Some funding mechanisms provide stable revenues year-on-year, while others are more exposed to political or economic fluctuations. In sum, funding varies widely.

6.2 *U.S. Federal Role in Transit Finance*

The U.S. federal government does play a role in public transportation finance, although largely through the administration of capital grants.¹⁸ In the 1970s and 1980s, federal operating assistance was central to defining the subsidies from other levels of government (Wachs, 1989), but this practice ended in the 1990s. Revenues from a federal gas tax, currently set at 18.4¢/gallon and 24.4¢/gallon for gasoline and diesel fuel respectively (EIA, 2007b, Table EN-1), are allocated to the federal Highway Trust Fund and Mass Transit Account. These accounts are separate from general government revenues, and the proceeds are spent in multi-year

¹⁸ Sections of this chapter draw from Antos (2005), and Antos and Zegras (2007).

transportation spending bills, the most recent of which is SAFETEA-LU (for “Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users”) in 2005. Although the federal government allows local “flexing” of highway funds for mass transit projects, the early administrative and financial modal division tends to hinder intermodalism.

Under SAFETEA-LU’s allocation rules, transit agencies in large urban areas are not eligible for operating grants. Some federal funds are applied to operating costs in large agencies as preventive maintenance and other funds, but these amounts are small and account for only 7% of operating funds in large cities (NTD, 2005, 25). Approximately two-thirds of all federal capital funding amounts for large urban transit agencies is allocated by formula based on characteristics of the metropolitan area, need, population, and national goals. Some funds are reserved for the FTA’s New Starts program, which awards capital funds to construct new transit projects on a competitive basis. All federal funds come with certain conditions, many of which are governed by environmental legislation and agencies.

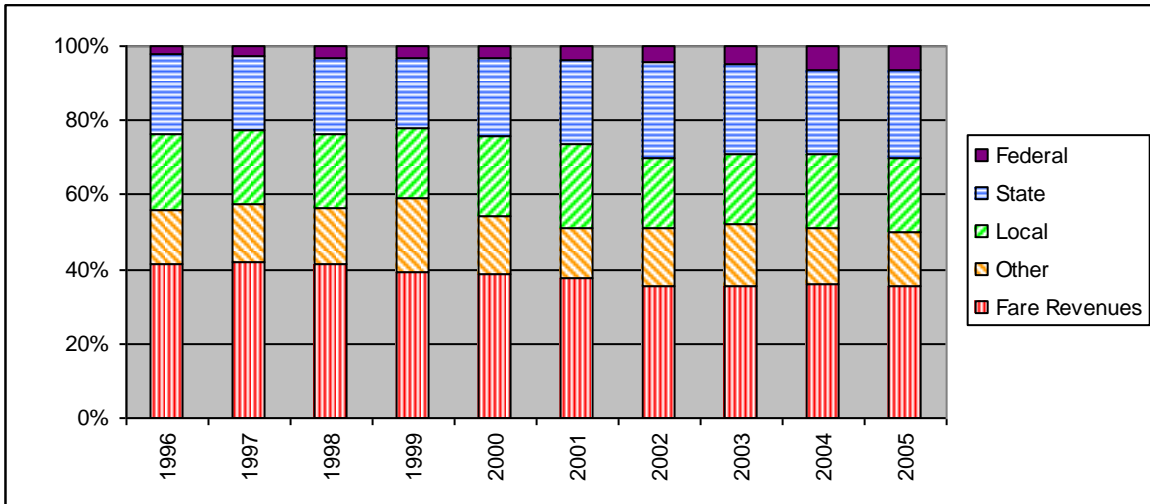
Even though the federal government’s involvement in urban transit operating finance is limited to capital projects, its influence is still fairly significant in capital funds. In federal fiscal year (FFY) 2007, Illinois is slated to receive \$416 million in formula funds (FTA, 2006a), the vast majority of which is dedicated to the Chicago metropolitan area (\$382m) (FTA, 2006b). In addition, Chicago transit is currently the successful recipients of New Starts funds, and federal sources for capital transit finance in Chicago totaled \$439 million (CATS, 2006, 3-2).

6.3 The Role of Passenger Fares in Transit Finance

The amount of operating funds generated from passenger fares varies widely among large transit properties in the U.S., Western Europe, and Canada. Fares likely represent the value of the marginal transit trip to the transit rider, while subsidies represent the payment by government for the benefits generated by transit use. Though some cities manage to increase fares in small, frequent increments, most transit agencies raise fares in fairly hefty and infrequent proportions. However, some of the increases in the most recent years may be the product of differentiated fares between cash and smart cards. As the technology becomes more ubiquitous, many transit agencies have increased cash fares above pass or smart card fares to discourage the use of cash.

Over the past ten years, fare revenues have accounted for a dwindling share of transit operating funding in the U.S. More specifically, while funding for all public transit in U.S. cities over 1 million inhabitants has risen by about 30% in real terms overall, fare revenues have increased by only 12% (NTD, 2005). Therefore, from almost 42% of operating funds in 1996, this proportion has fallen to around 36%, as shown in Figure 29.

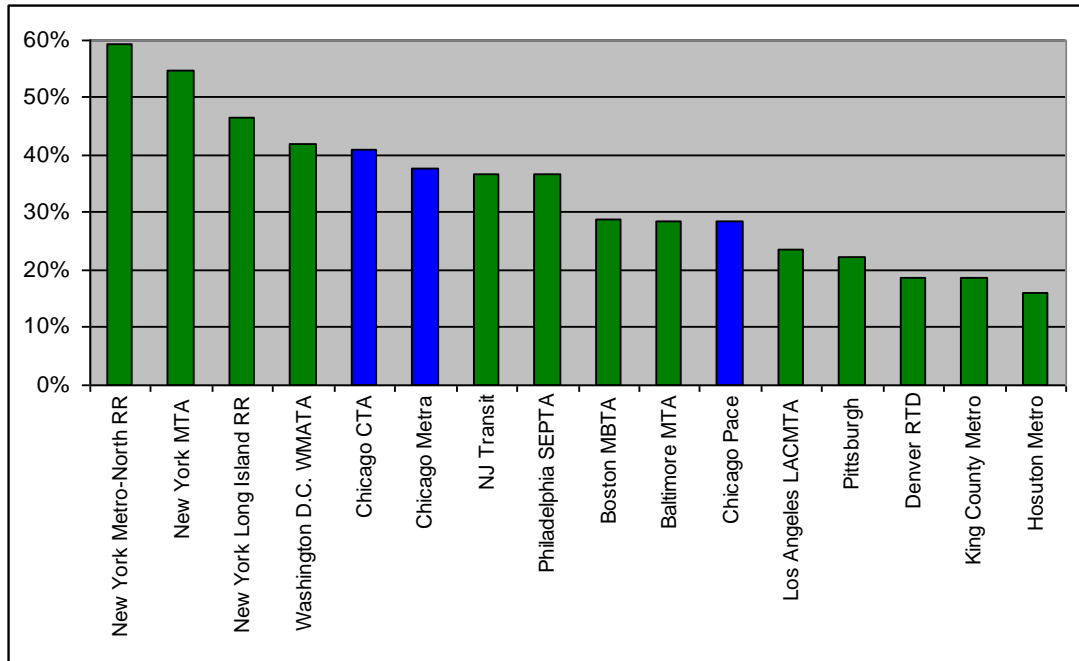
Figure 29. U.S. Transit Operating Revenue Sources in Large Cities



Source: NTD, 2005, Table 28. All agencies, all modes, cities over 1 million inhabitants.

However, these national trends mask significant variation between agencies. Among agencies operating more than 900 vehicles in maximum service, fare revenues cover anywhere from 16% (Houston Metro) to 55% (New York MTA) of operating costs in 2005. Also, any average of large U.S. transit agencies will be skewed by New York City, which alone accounts for a third of the nation's transit riders alone.

Figure 30. Fare Recovery Ratios for Large U.S. Transit Agencies



Source: NTD, 2005, Table 1¹⁹

6.3.1 Fare Recovery as Policy Decision, Not Efficiency Measure

Fare levels are usually set by a policy decision and can be unrelated to the efficiency of a transit agency. The magnitude and sporadic nature of fare increases in comparison to inflation suggest that fares are often more the product of a political decision than the inevitable outgrowth of economic or operational requirements. Fare increases are often highly politicized. Since 1983, the RTA Act governing transit services in the Chicago metropolitan region has mandated that the combined budgets of the service boards achieve a 50% revenue recovery ratio. Los Angeles County MTA has restricted fare increases because of a 1996 legal Consent Decree (FitchRatings, 2006).

Despite the allure of judging a transit agency's efficiency by its fare recovery ratio, a transit operator might be more fairly judged along two measures: 1) its unit costs of production, which are largely a function of labor costs and human resource allocation, and 2) its capacity utilization. An agency's ability to fill its available seats may be largely a function of service planning decisions, the relative attractiveness of driving, and the city's urban form, in its consequent tendencies to both concentrate flows of passenger demand and determine accessibility gained per trip length.

The fare recovery ratio is a poor proxy for both of these more accurate efficiency measures. As to the first, passenger fares in the U.S. are rarely tied to the costs of labor or materials. For the second, even a transit agency's ability to more fully utilize its capacity can be unrelated to a fare recovery ratio. For example, imagine two bus routes could provide the same number of vehicle-miles, capacity utilization, and passenger-miles, as shown in Figure 31. If the average

¹⁹ Agencies operating over 900 vehicles in maximum service. "PT Fare Revenues" plus "DO Fare Revenues" divided by total operating funds applied. Agencies with VOMS > 900 (entries 9186, 6048 and 4105 removed as outliers).

trip length on the first route is half that of the second, it will turn each seat over twice as frequently and produce double the fare revenue as the second. Is this first line twice as efficient as the second? Since trip lengths are partially a function of the urban environment's accessibility and the marginal cost of providing longer trips is often minimal, fare revenues are often several steps away from capacity utilization. Similarly, the design of a transit network could encourage or discourage transfers, inflating or deflating the fare revenues, depending on the agency's transfer policies. It seems inaccurate to evaluate a transit system's performance based solely on fare recovery ratio.

Figure 31. Hypothetical Bus Routes

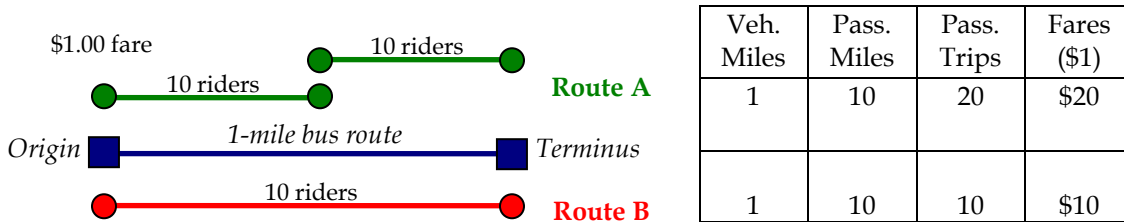


Table 26 shows that the fare ratio in these same U.S. agencies is often unrelated to how well they utilize their capacity. For example, commuter rail services in Baltimore, Philadelphia, and Chicago attract more trips per vehicle-hour than New York's Metro-North services, yet these achieve half to three-quarters of the fare recovery ratio. Boston's heavy rail system captures a very high number of trips per vehicle hour, despite its relatively low recovery ratio. Capacity utilization on bus systems does appear to be correlated with fare recovery ratio, however. In short, it is often misleading to judge the efficiency of a multimodal transit agency in a large city by its fare recovery ratio. Two better indicators, I argue, are its unit costs of production, and its capacity utilization.

Table 26. Fare Recovery Ratio and Capacity Utilization of Large U.S. Transit Agencies

	Fare Ratio	Pax Trips per Vehicle-Hour		
		Comm. Rail	Bus	Heavy Rail
New York Metro-North RR	59%	50.1	-	-
New York MTA	55%	-	74.0	98.1
New York Long Island RR	46%	48.8	-	-
Washington D.C. WMATA	42%	-	44.8	105.4
Chicago CTA	41%	-	44.9	50.5
Chicago Metra	38%	55.4	-	-
NJ Transit	37%	38.0	30.1	-
Philadelphia SEPTA	37%	54.1	49.1	107.6
Boston MBTA	29%	56.3	51.6	164.1
Baltimore MTA	29%	56.3	40.5	67.8
Chicago Pace	28%	-	23.4	-
Los Angeles LACMTA	24%	-	50.4	-
Pittsburgh	22%	-	27.8	-
Denver RTD	19%	-	28.3	-
King County Metro	19%	-	29.3	-

Source: NTD, 2005

6.3.2 Dangers of Focus on Fare Revenue

I speculate that emphasis on fare revenue in the short-term could lead to behavior that is ultimately counterproductive to a transit agency's long-term goals of balanced and growing ridership. Faced with insufficient operating funds and lacking the will or ability to raise fares, an agency might look to trim its most lightly-used or marginal services – usually off-peak and non-radial services, or services to far-flung, lower-density areas. From the agency's perspective, this is entirely logical: the agency minimizes fare revenue losses while saving operating costs, and the short-term problem is solved. But such focus on preserving transit services only where they yield the highest fare revenues could be short-sighted.

In the long term, feedback loops in auto ownership and land use may offset any temporary financial gains to the agency.

- If transit services are trimmed to serve the peak-hour commute only, transit commuters are likely to buy cars for their non-commute travel needs. With the marginal cost of driving now relatively low because so much of auto ownership is sunk costs (AAA, 2007), marginal mode choice decisions are now much less favorable to transit. Running transit only where its fare recovery ratio is high will ultimately undermine ridership and in the long run, efficiency.
- If transit services are reduced, the accessibility of nearby land is reduced, the next prospective tenant will be less likely to ride transit, and the real estate market and local zoning may be less likely to produce the population density needed to support public transit.
- By concentrating resources on peak-hour commuting to the downtown central business district only, the agency is likely to face higher operating unit costs because its services will be more peaked and less balanced.

Ridership losses accompanying these phenomena might lead to further fare revenue losses, undercutting some of the primary benefits of a transit system.

6.4 The Role of Other Operating Subsidies in Transit Finance

Beyond passenger fare revenues and a small amount of federal funds, then, all U.S. transit agencies must rely on public subsidies from local, regional, state, or other sources. In addition, Central Governments in Western Europe do play a role in operating subsidies. The amount and structure of these subsidy structures vary widely from agency to agency and evade general characterization. In the U.S., entire NCHRP reports describe the heterogeneity of transit funding mechanisms from the state and local levels (e.g., NCHRP, 2006). Therefore, this section briefly describes the institutional and political context of 15 large transit agencies, the major revenue streams that pay for operating expenditures, the jurisdiction of their source, and the mechanism by which they are decided upon, collected, and allocated to the transit agency.

I label each operating subsidy revenue source by jurisdiction, as shown in Table 27.

Table 27. Classification of Operating Revenues

Jurisdiction	Criteria
Fares	Collected directly from passengers. Ex-post reduced fare reimbursements not included where possible.
Other Own-Source	Generated by some specific action of the transit agency beyond core transit services (investments, leasebacks, advertising, real estate, congestion charges, tolls, parking etc.)
Federal	Originating from the U.S. Federal or Central Governments, and earmarked directly for public transit.
State	Originating from a U.S. state, or some jurisdiction larger than a metropolitan area but smaller than a national government. European “regions” are included if significantly larger than the metro area.
Regional	Generated solely in the larger metropolitan region, which may include multiple counties or states. Revenues from municipalities as part of a regional arrangement are counted here.
Local	Originating from the central city only, or from smaller government units corresponding to municipalities.
Other	Any source for which more information is unavailable, or which does not fit in the above categories.

6.4.1 New York MTA

The funding structure for the New York Metropolitan Transportation Authority (NY MTA) is organized around seven operating units: New York City Transit, Long Island Railroad, Metro-North, a Capital Construction operation, and a Bridges & Tunnels unit. In 2006, tolls on major tunnels and bridges into Manhattan are budgeted to gross over \$1.2 billion in tolls while requiring \$392 million in expenses, netting around \$900 million to help cross-subsidize mass transit operations.

In 2006, the MTA budgeted an \$8.6 billion financial plan (NY MTA, 2006) including farebox revenues of \$3.7 billion, and significant amounts carried over from unexpected subsidies in 2005. MTA debt service amounts to \$1.34 billion annually.

Table 28. FY06 New York MTA Operating Revenues (\$ millions)

Farebox Revenues	\$ 3,734.0	43%	Fares
<i>NYC Transit</i>	\$ 2,762.9	32%	
<i>Metro-North Comm. Rail</i>	\$ 451.3	5%	
<i>LIRR</i>	\$ 448.8	5%	
<i>Long Island Bus, Staten Island RR, Other</i>	\$ 70.7	1%	
Bridges & Tunnels Tolls (Gross)	\$ 1,238.0	14%	Own-Source
Dedicated Taxes	\$ 2,621.1	30%	
<i>MMTOA (business, sales tax)</i>	\$ 1,274.0	15%	State
<i>Petroleum Business Tax</i>	\$ 616.0	7%	State
<i>Mortgage Recording Tax (MTA District)</i>	\$ 391.0	5%	State
<i>Urban Tax (mortgage tax in NYC only)</i>	\$ 327.5	4%	Local
<i>Other</i>	\$ 12.6	0%	Other
State/Local Subsidies	\$ 568.0	7%	
<i>ow: New York City</i>	\$ 160.5	2%	Local
<i>ow: Suburban NY Counties</i>	\$ 164.5	2%	Regional
<i>ow: New York State directly</i>	\$ 190.9	2%	State
<i>ow: Connecticut DOT</i>	\$ 52.1	1%	Regional
Other Revenue	\$ 440.0	5%	Other
Total Operating Revenues	\$ 8,601.1		

Source: NY MTA, 2006

Beyond farebox revenues and toll proceeds, the remaining revenues are derived from a variety of small taxes and funds, some of which are local and other which are statewide, and all of which are largely removed from annual appropriations processes. The biggest of these is the Metro Mass Transportation Operating Assistance fund, a mix of taxes earmarked for transport. While some funding sources are expressly allotted to different modes, particularly revenues generated in suburban areas dedicated to the commuter railroads, enough funding comes with no strings attached that the MTA is able to exercise discretion in where it spends these revenues.

In 2006, the MTA received approximately \$3.2 billion in state and local subsidies from a wide variety of sources of varying levels of relevance to transit, \$2.6 billion of which were receipts from dedicated taxes outside of annual budget cycles, and the remaining \$568 million of which were paid by areas benefiting from MTA services: New York State, New York City, Connecticut, and suburban New York counties in the service district north of the city and on Long Island. The largest subsidy sources were proceeds from dedicated proportions of statewide taxes on businesses, petroleum businesses, a mortgage recording tax, and the state sales tax. An “urban tax” on commercial property mortgages in New York City only provides additional revenue for the MTA.

6.4.2 Washington D.C. WMATA

The Washington Metropolitan Area Transit Authority (WMATA) was established in 1967 as a compact between the District of Columbia and adjacent communities in Maryland and Virginia. In some ways, WMATA is an institutional anomaly different from most American cities: the District of Columbia receives federal funds as its own state and city, the rail system provides extensive service in surrounding Maryland and Virginia, and federal lawmakers have strong

interest in the city as well. As such, WMATA spans jurisdictional boundaries on several levels, and makes decisions in a complex environment of political oversight (Puentes, 2004).

WMATA’s construction from 1969 to 1999 has been largely funded by capital dollars received directly from the federal government (GAO, 2005). Recently, WMATA has been grappling with the dual challenge of reinvesting in its aging infrastructure and meeting the capacity demands of steadily growing ridership.

Table 29. FY06 WMATA Operating Revenues (\$ millions)

Farebox Revenues	\$ 479.1	46%	Fares
Own-Source Revenues	\$ 100.0	10%	Own-Source
Operating Subsidy	\$ 434.6	41%	
<i>ow: District of Columbia</i>	\$ 165.5	16%	Local
<i>ow: Maryland</i>	\$ 164.2	16%	Regional
<i>ow: Virginia</i>	\$ 104.8	10%	Regional
Debt Service Subsidy	\$ 27.5	3%	Other
Reimbursables	\$ 11.2	1%	Fares
Total Operating Revenues	\$ 1,052.5		

Source: WMATA, 2005

Of a \$1.1 billion operating budget, the Authority recovers 46% from farebox revenues, or 57% if one includes non-fare revenues and exclude debt service subsidy and reimbursables. The rest of the cost is made up by local subsidies: a negotiated arrangement between the members of the WMATA Compact (WMATA, 2005, 8). Costs are divided between each district by a series of complicated formulas for rail and bus depending on population density, services provided, and ridership (WMATA, undated), and each jurisdiction pays their share with different funding sources. The District of Columbia pays mainly from a 20-cent gasoline tax, parking and traffic fines, vehicle registration fees, and restaurant and hotel taxes. Maryland relies on gas tax revenues and vehicle fees, while Virginia uses a 2% tax on gasoline retailers in Northern Virginia dedicated to WMATA for part of its share, and then supplements that amount with general revenues (Puentes, 2004). Almost all of WMATA’s subsidies are allocated through annual budget processes, making WMATA unusual amongst peer agencies in that it does not have a dedicated funding source.

6.4.3 Philadelphia SEPTA

Southeastern Pennsylvania Transportation Authority (SEPTA) provides all bus, rail, and paratransit services in a five-county metropolitan region. Similar to Chicago, the service district consists of the city of Philadelphia, and four suburban counties (Bucks, Chester, Delaware and Montgomery).

The State of Pennsylvania also plays a significant role in SEPTA: it appoints two Board members, and provides nearly half of all operating subsidies and capital funds. The centerpieces of the state’s operating funding are two matching grant arrangements between the state and recipient counties known as Act 3 and Act 26. Under these laws, the state generates revenues dedicated to public transit via small fees on motor vehicle tires and rental cars, a 3% auto lease tax, and a reserved stream of around 1% of the state sales tax, and then supplements this amount with additional funds from general revenues and the Lottery Fund. In recent years, especially under the leadership of Governor Rendell, former mayor of Philadelphia, SEPTA has

received additional state bonds for capital projects and funds flexed from highway sources, but these funds do not recur.

Table 30. FY06 SEPTA Operating Revenues (\$ millions)

Farebox Revenues	\$ 325.9	34%	Fares
Senior Citizen Reduced Fare	\$ 52.3	5%	Fares
Shared Ride Program Reimbursement	\$ 17.3	2%	Regional
Other Own-Source Revenue	\$ 24.5	3%	Own-Source
State Basic Operating Subsidy	\$ 203.6	21%	State
Local Funds - Various Programs	\$ 72.3	8%	
<i>ow: Philadelphia County</i>	\$ 58.1	6%	Local
<i>ow: Suburban Counties</i>	\$ 14.2	1%	Regional
State - Various Programs	\$ 129.6	14%	State
Route Guarantee	\$ 3.0	0%	Other
Federal Preventive Maintenance	\$ 31.2	3%	Federal
Highway Flex Funds	\$ 92.1	10%	State
Total Operating Revenues	\$ 951.8		

Source: SEPTA, 2006, 15

To access the full subsidy amounts established by the state, local counties must come up with a local match at a specified ratio. Local matches “assigned to” each of the counties are derived formulaically based on the deficit carried by the transit services provided in each county, not simply based on services provided.

6.4.4 Boston MBTA

The Massachusetts Bay Transportation Authority (MBTA) is governed by a 9-member Board of Directors, appointed by the Governor. The MBTA’s subsidy structure was changed dramatically in 1999 to a new funding mechanism known as “Forward Funding.” Prior to 1999, the MBTA operated with a fairly open-ended source of state funds, an arrangement which produced low fares, expanding service and ridership, but also rising costs and heavy debt load.

The MBTA now has two stable, dedicated revenue streams: a portion of the state sales tax, and assessments on towns in its service district (MBTA, 2006, 11-12). First, revenues from 1% of the 5% statewide sales tax (20% of revenue yield) are dedicated to the transit agency, which resulted in \$704 million in FY05.²⁰ This means that sales taxpayers in all of Massachusetts help pay for transit services in the eastern part of the state. Second, 175 cities and towns in the MBTA’s service area pay the agency population-based fees called “assessments.” In FY05, these assessments ranged from \$65 million from the City of Boston to \$1,000 from the small town of Ashby, located 51 miles from downtown, and totaled \$136 million (MBTA, 2005, E-2). Both the sales tax proceeds and the assessments are indexed to inflation but include a ceiling and floor to the overall revenue amount for stabilization.

²⁰ MBTA (2007), FY2005 column labeled “Revenue Receipts from State Sources.”

Table 31. FY05 MBTA Operating Revenues (\$ millions)

Farebox Revenues	\$ 334.0	26%	Fares
Advertising, Real Estate, etc.	\$ 40.1	3%	Own-Source
Other Income	\$ 30.5	2%	Own-Source
Federal Preventive Maintenance	\$ 10.9	1%	Federal
Assessments on Service District	\$ 136.0	11%	Regional
State Sales Tax	\$ 712.6	56%	State
Total Operating Revenues	\$ 1,264.1		

Source: MBTA, 2007

Historically, sales tax receipts in Massachusetts have risen faster than inflation, so this structure might in theory work to the MBTA's advantage. However, in the past five years, receipts have been sluggish, ridership has been flat, and rising health care and fuel costs have consumed subsidy growth. In 2002 and 2003, the MBTA received roughly its statutory minimum funding. Partially as a result, the Authority increased fares in 2007 for the third time since Forward Funding, the rough equivalent of doubling nominal fares in 7 years.

Forward Funding also transferred the repayment of all interest and principal on past and future capital debt to the agency's balance sheet. A large debt load of \$8.1 billion now burdens the MBTA (MA Transportation Finance Commission, 2007, 9) the debt service for which currently consumes 30% of operating expenditures.

6.4.5 Los Angeles LACMTA

The Los Angeles County Metropolitan Transportation Authority, or Metro, is the region's MPO, public transit operator of buses and 4 rail lines for 1.1 million rides per day, and roadway authority. Metro is bound by a 1996 Consent Decree to expand bus service hours to a certain amount and keep fares low (Moody's, 2004). The agency carries around \$3.5 billion in capital debt.

Table 32. Amended 2005 LACMTA Financial Plan (includes capital revenues) (\$ millions)

Passenger Fares, Advertising	\$ 276.4	9%	Fares
Sales Tax Proceeds	\$ 1,738.5	58%	
<i>Proposition A</i>	\$ 621.0	21%	Regional
<i>Proposition C</i>	\$ 640.6	21%	Regional
<i>California Transportation Development Act</i>	\$ 317.4	11%	State
<i>Other + Carryover</i>	\$ 159.5	5%	Other
Federal, State, Local Grants	\$ 635.3	21%	Regional
Financing Proceeds	\$ 311.5	10%	Own-Source
Investment and Leaseback Income	\$ 50.5	2%	Own-Source
Total Operating and Capital Revenues	\$ 3,012.2		

Source: LACMTA, 2006²¹

Table 32 shows LACMTA's overall financial plan, including capital revenues. Operating revenues are not explicitly designated as such, but all known operating expenditures total around \$1.1 billion. By this metric, farebox revenues account for just over a quarter of operating expenditures.

²¹ Overall financial plan summarized from LACMTA (2006) page II-7, operating expenses from p. II-10 line 10 and p. II-11 line 13.

The agency receives subsidy for its \$3 billion financial plan through four primary mechanisms. Proposition A and C, passed by voters in 1982 and 1991 respectively, gives Metro the proceeds from two incremental one-half percent sales tax, for a total of one percent, yielding \$1.2 billion in 2005. Second, Metro receives revenues from the California Transportation Development Act, a one-quarter percent allocation of the entire state retail sales tax which is allocated to California counties by the State Board of Equalization. Finally, California's State Transit Assistance is a general public transit subsidy derived from a 4.75% tax on the sale price of diesel fuel and 4.75% of the state's 9-cent per gallon tax on gasoline. These revenues are allocated to counties to improve public transportation – 50% based on county population, 50% as a match to local transit operators' fare collections. In this way, almost all of Metro's revenues are generated by standalone sales tax funding mechanisms outside of annual budget cycles.

6.4.6 San Francisco (BART)

San Francisco, Alameda, and Contra Costa counties established the Bay Area Rapid Transit (BART) District in 1957 to build a new heavy rail system. Rail operations began in 1972, and today the system carries around 310,000 passengers a day. Fare revenues make up around half of BART's operating revenues, and the District's primary subsidy is an incremental half-percent sales tax collected in the three-county area. The BART District can set this rate collectively. 75% of the proceeds from this tax go directly to BART, while the remaining 25% go to the San Francisco Bay Area's Metropolitan Transportation Commission (MTC), an umbrella financial organization for transit. However, the MTC allocated around \$60m in toll revenue capital funds back to BART for a project to extend service to the San Francisco Airport.

In addition, BART receives a portion of property tax revenues collected in the three counties (rate set by the State of California), as well as various smaller local contributions, paratransit reimbursement, and a contribution from San Mateo County which benefits from the San Francisco Airport extension.

Table 33. FY05 BART Operating Revenues

Farebox Revenues	\$ 233.7	53%	Fares
Transaction and Use (Sales Tax in district)	\$ 118.9	27%	Regional
Property Tax (in district)	\$ 22.4	5%	Regional
Other Income (includes investment income)	\$ 17.1	4%	Own-Source
Capitalized Costs (transfers from capital)	\$ 33.6	8%	Federal
Local Financial Assistance	\$ 16.7	4%	Regional
Total Operating Revenues	\$ 442.4		

Source: BART, 2006

BART currently carries approximately \$700 million in outstanding debt (BART, 2006, 4-15), and this figure is declining despite the additional debt from the Airport extension. BART reports some operating costs related to capital projects as negative operating revenues – essentially a transfer from capital funds for what “should” have been capital.

6.4.7 San Francisco (Muni)

The San Francisco Municipal Railway Corporation (Muni) runs bus, light rail, and trolley/cable car services in the city proper of San Francisco. Institutionally, Muni is more akin to a

Department to the City and County of San Francisco than a quasi-state agency. Although Muni is closely linked financially and politically to the Mayor and City of San Francisco, its revenue structure is largely formulaic and independent of yearly city budgetary processes.

Table 34. FY05 Muni Operating Revenues (\$ millions)

Farebox Revenues	\$ 121.9	25%	Fares
Parking Proceeds (Meters + Violations)	\$ 132.3	27%	Own-Source
City General Fund Contribution	\$ 98.9	20%	Local
Intergovernmental Local/Regional Taxes	\$ 81.6	17%	Regional
Miscellaneous Own-Source (advertising)	\$ 4.5	1%	Own-Source
One-Time Lease/Leaseback Revenue	\$ 13.6	3%	Own-Source
Capitalized Costs (transfers from capital)	\$ 5.2	1%	Federal
Paratransit Reimbursement	\$ 15.5	3%	Regional
Transit Impact Development Fee	\$ 13.1	3%	Other
Total Operating Revenues	\$ 486.6		

Source: Muni, 2005, 73

Farebox revenues make up 25% of operating revenues, and fares have historically been low compared to other transit agencies. Muni's subsidy comes from four main sources. First, the City of San Francisco dedicates to Muni 40% of a 25% citywide parking tax on off-street spaces, and the first \$7.6 million of parking meter collections (Muni Dept. of Parking & Traffic, 2001). Second, the City allocates Muni a portion of its general revenues, an amount which is indexed to inflation and determined by formula. Third, Muni receives formulaic share of the Transit Impact Development Fee, a \$10 per square foot tax on downtown non-residential buildings within a defined area in San Francisco. Fourth, the agency receives a smattering of local sources: a set proportion (0.25% of 8.5%) of sales taxes collected in San Francisco County, federal preventive maintenance funds, and an allocation of state sales tax set by MTC.

Many observers feel that Muni's funding is stable but inadequate (San Francisco Planning and Urban Research Association, 2006). In past years, Muni has closed budget gaps with one-time measures like leaseback deals, but it is controversial for the City to raise parking taxes. Muni has published several proposals for new revenue streams in their annual reports and budgets. In addition, Muni receives significant capital subsidies from MTC, which is in turn backed by net toll surpluses from the Bay Area Toll Authority on bridges in the region.

6.4.8 Atlanta (MARTA)

The Metropolitan Atlanta Rapid Transit Authority's (MARTA) subsidy structure is straightforward: a dedicated 1% sales tax on its immediate service district: Fulton County, DeKalb County, and the City of Atlanta. In FY05, this revenue stream totaled \$307m, or 66% of all revenues. Fares contribute \$96million or 21% of revenues, and the balance consists of federal or own-source revenues.

Table 35. FY05 MARTA Operating Revenues (\$ millions)

Farebox Revenues	\$ 96.2	21%	Fares
Other Operating Revenues + Real Estate	\$ 4.7	1%	Own-Source
Sales Tax from Service District	\$ 307.3	66%	Regional
Federal Preventive Maintenance	\$ 40.4	9%	Federal
Investment Income	\$ 7.8	2%	Own-Source
Other Revenues	\$ 9.6	2%	Other
Total Operating Revenues	\$ 466.0		

Source: MARTA, 2005

MARTA carries around \$2 billion in debt, which consumes around \$110million per year in debt service. Interestingly, the sales tax collected for MARTA does not follow closely the de facto service area. Some stations are very close to counties who do not contribute to MARTA. There may be a growing desire for other counties such as Clayton and Gwinnet counties to help fund MARTA (Dorsey, 2005).

6.4.9 Portland (TriMet)

TriMet covers three counties in the Portland region with 44 miles of light rail and around 500 buses. Portland is a relatively young system whose ridership and services have grown rapidly in the past twenty years, and service expansions are pending New Starts awards.

Fares cover 23% of operating expenditures. Smart card technology has enabled TriMet to raise fares regularly by small amounts each year. Unusually for U.S. transit agencies, TriMet is strongly linked to regional land use planning through Portland's MPO.

Table 36. FY05 TriMet Operating Revenues

Farebox Revenues	\$ 59.5	20%	Fares
State/Fed Operating Grants	\$ 56.1	18%	
Federal preventive Maintenance	\$ 30.0	10%	Federal
State of Oregon (various)	\$ 26.1	9%	State
Payroll Taxes	\$ 157.3	52%	Regional
Cigarette Taxes	\$ 1.2	0%	Regional
Other Sources (advertising, interest, etc.)	\$ 30.5	10%	Own-Source
Total Operating Revenues	\$ 304.5		

Source: TriMet, 2005a

Unique among large transit agencies, TriMet's largest funding source is a payroll tax of 0.6318% of gross wages earned in the service district in all governments and private businesses (TriMet, 2005b, 70). Without guaranteed funding minima or maxima, TriMet's subsidy structure is thus linked to the economic performance of the entire metropolitan region in the short term. In the long term, however, basing transit funding as a proportion of wages may provide a counterweight to the tendency of transit labor costs to rise above the rate of inflation. In addition to the payroll tax, TriMet also receives some state grants and applies most of its federal funds to operations.

6.4.10 Montreal (STM)

Société de Transport de Montréal (STM) operates bus and heavy rail metro services in Montreal, while AMT (*Agence Métropolitaine de Transport*) operates suburban commuter rail lines. STM

reports to a metropolitan government called MUC, which encompasses all 63 municipalities on the island on Montreal. Fare revenues cover 44% of operating costs, while the mainstay of the agency's subsidy structure has been contributions from the municipalities within the agglomerated City of Montreal. It is unclear how these amounts are decided.

Table 37. 2004 Montreal STM Operating Revenues (\$ millions CAD)

Farebox Revenues	\$ 368.2	43%	Fares
Metro Region of Montreal + Longueuil	\$ 264.8	31%	Regional
Province of Quebec	\$ 69.6	8%	State
Suburban Contributions for Services	\$ 61.1	7%	Region
Advertising, Rents, etc.	\$ 17.3	2%	Own-Source
Investments (Federal, Provincial subsidies)	\$ 60.8	7%	Federal
One-time Reserve Fund contributions	\$ 5.9	1%	Other
Total Operating Revenues	\$ 847.7		

Source: STM, 2005, 44

6.4.11 Paris (STIF)

The *Syndicat des Transports en Île-de-France* (STIF) organizes all public transport in greater Paris, while RATP, SNCF, and the OPTILE bus network operate services. The *Regie Autonome des Transports Parisiens* (RATP) runs the Métro system, the suburban tramways, the major urban and suburban bus routes, some suburban lines, and some other services within the urban core of Paris, and the *Société Nationale des Chemins de Fer* (SNCF), operates the French national rail routes into Paris as well as the rest of the suburban lines. Because of the particular financial and institutional arrangements, STIF is essentially an oversight and monitoring agency with little control over revenues or operations (Cour des Comptes, 2005).

Table 38. 2004 Paris STIF Operating Revenues²² (€ millions)

Farebox Revenue	€ 1,820	28%	Fares
Payroll Tax (<i>Versement de Transport</i>)	€ 2,540	39%	Regional
Employer Subsidies (<i>carte Orange</i>)	€ 620	9%	Regional
Central Government	€ 610	9%	Federal
Local Municipalities	€ 490	7%	Local
Ile-de-France Region	€ 240	4%	Regional
Other sources	€ 260	4%	Other
Total Operating Revenues	€ 6,580		

Source: STIF, 2005, 37, "Fonctionnement" figures

Fare revenues represent around 28% of revenues. The centerpiece of transit funding in Paris is a payroll tax levied on all companies with more than 9 employees dedicated to transit, called the *Versement de Transport*. While local governments theoretically set these rates anywhere under the maximum allowed by Central Government, in practice most municipalities have reached this upper limit. In the Paris region, the rate ranges from 2.5% of wages in the central city to 1.3% in outlying suburbs (FitchRatings, 2003, 6). Proceeds from this tax made up nearly 40% of total revenues in 2004, or over €2.5 billion. The remainder of revenues come local governments, employed-subsidized transit passes (*carte Orange*), and other sources.

²² STIF (2005), p. 37, "Fonctionnement" figures.

6.4.12 London (Transport for London)

When the U.K. Parliament granted the mayor of London broad powers over transportation in 2000, the mayor created Transport for London (TfL) to consolidate urban public transport, suburban bus, major roads, and other modes in one agency. Prior to 2003, nearly all government funding for public transport came from the British central government through a discretionary process called the Spending Review. Although the Spending Review occurs every two years with an eye towards a planned third year, the mechanism produced uneven and unsteady revenues for transport in the metropolitan region. In practice, funding levels fluctuated widely, creating an atmosphere of start-stop funding which made strategic investment and long-term planning difficult.

Several Public-Private Partnerships (PPPs) were introduced to London Underground, where private companies manage and invest in major portions of infrastructure in the Tube. The purpose of the PPPs was in part to protect public transport from the vagaries of the Spending Review by “locking in” levels of infrastructure investment.

Table 39. 2005/06 Transport for London Business Plan (£ millions)

Farebox Revenue	£2,290	45%	Fares
Congestion Charging (gross)	£254	5%	Own-Source
Other Income (incl. investments)	£336	7%	Other
Central Government grant	£2,196	43%	Federal
Local Precept tax	£20	0%	Local
Total Operating Revenues	£5,096		

Source: Transport for London (2006b) Table 13A and 13B, pp. 72-73

TfL’s 2005/06 Business Plan outlines operating revenues of around £5 billion. Fares make up approximately 45% of these, while London’s Congestion Charge grosses around £250 million, or 5% of revenues. The remaining government operating subsidy in London comes almost entirely as direct grant from the Central Government. In fact, the UK essentially has no government between the very local level and the national government. TfL’s consequent dependence on central government grants is unique among the peer agencies analyzed here, and this threatens the agency’s fiscal flexibility and structurally discourages risk-taking. Section 6.6.2 discusses this issue in further detail.

6.4.13 Madrid (CRTM)

The *Consortio Regional de Transportes de Madrid* (CRTM) was founded in 1987 as a single organizing authority for public transport in the region of Madrid. The CRTM oversees *Metro de Madrid* which runs urban rail, *Municipal de Transportes de Madrid* which runs local buses and other services, and various other service operators. Since the creation of the CRTM, capacity has expanded, and public transport ridership in Madrid has risen from around 950 million annual passengers in 1986 to 1.54 billion in 2003.

Table 40. 2003 Madrid CRTM Operating Revenues (€ millions)

Farebox Revenues	€ 623.1	48%	Fares
Transfer from Region of Madrid	€ 414.3	32%	Regional
Central Government of Spain	€ 143.6	11%	Federal
Transfer from City of Madrid	€ 110.7	9%	Local
Other Revenues	€ 4.8	0%	Other
Total Operating Revenues	€ 1,296.5		

Source: CRTM, 2003, 58

Fares make up just under 50% of all operating revenues, while transfers from the region of Madrid account for an additional 32%. The central government of Spain and the City of Madrid each contribute roughly 10%, for a total operating budget of €1,297 in 2003. So while taxes are not allocated to CRTM explicitly, the majority of subsidy is from the region of Madrid, whose revenues are in turn derived from shares of national taxes on personal income, consumption (VAT), and business (S&P, 2005, 2).

6.4.14 Barcelona (ATM)

In the mid-1990s, a regional consensus was reached between State of Spain, the Region of Catalonia, and the City Council of Barcelona that a regional approach to public transport finance and operations was the best way forward (TiS.pt, 2003, 6). Against a backdrop of devolution of powers from the Central Government to the regions in Spain, the *Autoritat del Transport Metropolità* (ATM) was formed as a voluntary consortium of all municipalities and administrations that provide transport in Catalonia (EMTA, undated) including the urban operators *Entitat Metropolitana del Transport* (EMT), *Transports de Barcelona*, and *Ferrocarril Metropolità de Barcelona*, who operate on 4-year contracts.

Table 41. 2003 Barcelona ATM Operating Revenues (€ millions)

Farebox Revenues	€ 330.0	46%	Fares
Transfer from Region of Catalonia	€ 148.9	21%	Regional
Central Government of Spain	€ 118.0	16%	Federal
Local Municipalities	€ 120.0	17%	Local
Total Operating Revenues	€ 716.8		

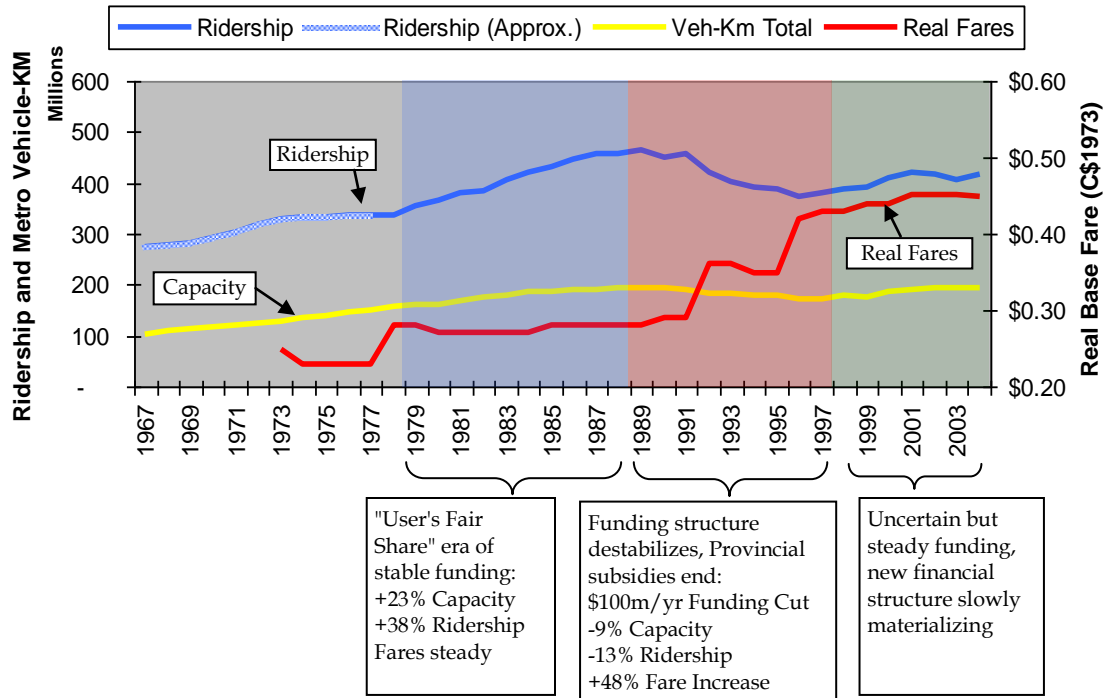
Source: ATM, 2004

Barcelona recovers around 45% of costs through fares, and the remaining deficit is divided roughly evenly between the central government of Spain, the region of Catalonia, and local municipalities. ATM appears to depend on its sponsor governments for the amount and division of this subsidy amount each year from the governments' general revenues, although it is unclear how this amount is agreed upon.

6.4.15 Toronto (TTC)

Although the TTC's finances are currently in a state of flux, Toronto is notable for its past financial arrangements. As shown in Figure 32, from around 1978 to 1988, Toronto operated under the expectation that fares cover 68% of operating costs, with remaining subsidies split between the Province of Ontario (16%) and the City of Toronto (16%). During this period which also coincided with an economic boom in the city, ridership grew 37%, capacity by 23%, and fares remained approximately steady (TTC, 2003, 17).

Figure 32. Toronto TTC Historical Ridership, Capacity, and Fares



Source: Soberman, 1997; TTC, 2003; TTC, 2005

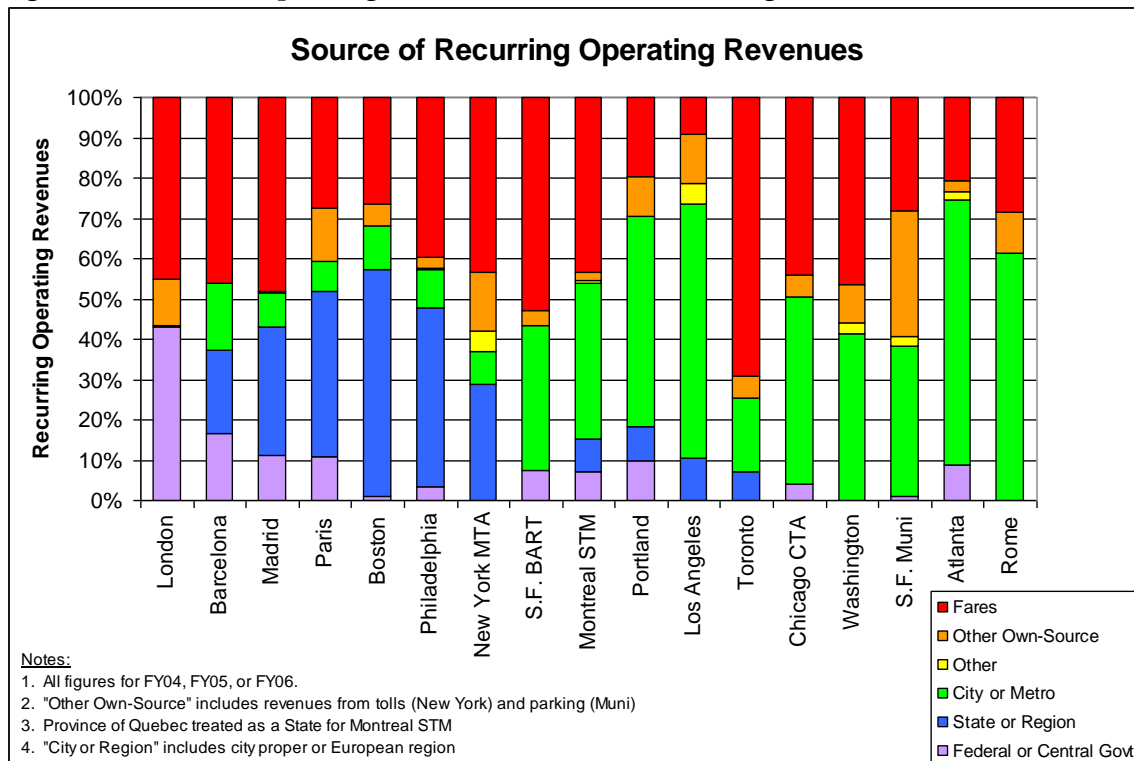
Table 42. 2004 Toronto TTC Operating Revenues (\$ millions CAD)

Farebox Revenues	\$ 685.4	69%	Fares
City of Toronto Contributions	\$ 182.0	18%	Local
Province of Ontario	\$ 70.0	7%	State
Other Revenues	\$ 53.4	5%	Other
Total Operating Revenues	\$ 990.9		

Source: TTC, 2005

However, this funding mechanism has since ended, and TTC appears to depend primarily on the City of Toronto for operating subsidies. Fare revenues continue to be very high by international standards, although the base fare was only \$2.00 CAD in 2005 (TTC, 2005). This apparently high fare recovery ratio may indicate low unit costs, or an inconsistency in the way the TTC handles debt – further research is needed. In 2005, the provincial government dedicated a portion of the gas tax to the TTC, which has been used for capital projects.

Figure 33. Source of Operating Revenues at Selected Transit Agencies



6.5 How Others Do It: Observations

While the operating revenue structures across these 15 cities vary widely, some major themes do emerge. Figure 33 summarizes the results of the preceding case studies.

6.5.1 Fares

It appears that most large transit agencies recover between a quarter and a third of their expenses through passenger fares, while very large systems like London, New York, Madrid reach 50%. Toronto appears to be unique among its peers in this analysis for sustaining a fare recovery ratio closer to 70%. With the exceptions of Portland and Toronto, nominal fares are rarely tied to inflation either by statute or in practice, and fares tend to be increased infrequently and in large increments.

6.5.2 Central Government

The U.S. federal government contributes little to operating funds, although federal support plays a greater role in smaller or newer systems such as Portland. In Europe, central governments usually fund 10-20% of operating expenses, and central and provincial operating support may be returning in Canada. London is unique among its peers in its reliance on central government for nearly all of its operating subsidies.

6.5.3 Sales Tax

Many U.S. transit agencies rely heavily on a dedicated sales tax, where the state levies a general sales tax and returns a percentage of the proceeds collected to the transit agency. The jurisdictions from which sales taxes are dedicated vary significantly, often creating large

discrepancies between taxes collected and transit services delivered. For example, the MBTA receives sales taxes from everywhere in Massachusetts, thus receiving a portion of taxes on transactions well beyond its service district. By contrast, some counties right next to a MARTA station in Atlanta do not pay sales taxes to the transit agency. Other sales tax districts better align with services provided, such as LACMTA, WMATA, and SEPTA.

6.5.4 Payroll Tax

Portland and Paris are unique in this study for generating the operating subsidies from payroll taxes. While Paris' rate is much higher than that of Portland (1.4-2.6% compared to 0.6% of wages), both cities rely on these revenues for the majority of their operating subsidies.

6.5.5 Automobile Taxes and Fees

Several transit agencies derive revenues directly from taxes and fees on private autos. Muni receives some of the City of San Francisco's parking revenues, Transport for London receives congestion-charging revenues, and New York MTA is allotted toll revenues from bridges and tunnels into Manhattan. Other agencies achieve the same effect without an explicit linkage: the contributions to WMATA from the counties it serves originate mostly from gas tax revenues.

6.5.6 Incremental vs. Allocative

While many transit agencies receive portions of a sales or other tax, it is important to distinguish between an increment added to an existing tax, and the government simply deciding to dedicate a portion of existing tax revenues to transit. For example, citizens living around the BART and LACMTA transit network agreed to raise their tax rate and dedicate its yield to transit. Those Californians now pay higher sales taxes. The MBTA's Forward Funding, on the other hand, merely dedicated some sales tax revenues to transit without altering the base sales tax rate – the shift was allocative, not incremental.

6.5.7 Differential Rates

Very few large transit systems generate revenues from taxes with differential rates for urban and suburban inhabitants. Paris and Chicago are the two exceptions to the rule in this analysis, where residents closer in to the central city pay higher tax rates than those closer to the metropolitan fringe. New York charges an additional mortgage tax on transactions occurring within Manhattan only. Most other systems either tax at one rate for transit, or not at all.

Although no explicit tax rates are involved, other transit systems do achieve the same effect of taxing those closer to the city more than those further out. For instance, Boston's local assessments charge each municipality a fee based on population, which effectively imposes higher rates on the inner cities and suburbs. WMATA and NY MTA receive less subsidies from outlying counties than from inner areas.

6.6 How Others Do It: Practical Lessons Learned

Understanding how some other big cities pay for their transit systems, what lessons can be learned from the experiences in the U.S. and abroad? Based on the preceding synopses, I theorize that transit subsidy mechanisms should ideally adhere to these desirable principles:

1. Public subsidy should be less than or equal to the social benefits.

2. Revenues should be generated so as to align the magnitude and incidence of transit's burdens with its beneficiaries. The benefit-cost ratio for each beneficiary should be similar.
3. The subsidy structure should be tailored as closely as possible to the underlying mechanism for transit's benefits.
4. The subsidy mechanism should provide long-term, stable revenues that rise at or above inflation.

Section 7.4 address the question of public transportation's net social benefits. Here, I highlight the best practices through which other cities attempt to achieve objectives 2, 3, and 4.

6.6.1 Diverse Beneficiaries Suggest Diverse Revenues

This thesis suggests a variety of beneficiaries of public transportation, implying that a closely-tailored subsidy structure would include a similar variety of revenue sources. The experience of other transit revenue structures suggests that this arrangement has practical as well as theoretical appeal. Any good investor will distribute her capital across a number of stocks to spread her risk, and transit agencies are no exception. Most agencies have some control over their fare revenues, yet depend on others at some level for the rest. To spread the risk of one funding source going sour, transit agencies should seek to derive major revenues from at least two or three different sources, preferably even more. For instance, the MBTA gets revenues from roughly two sources: state sales taxes, and local assessments which are largely paid from property taxes. Madrid and Barcelona's funds originate from three levels of jurisdictions, all of which share revenues and which are derived from a mix of Value-Added Tax, income tax, and business taxes. New York's operating subsidies come from a wide variety of taxes and jurisdictions ultimately based on the real estate market, businesses, petroleum use, and a sales tax in southern Connecticut, suburban New York State, the outer boroughs, and Manhattan itself.

By contrast, excessive reliance on a single source for operating subsidies is theoretically less than ideal, and risky and frustrating in practice. For example, MARTA gets nearly all of its revenues from a dedicated sales tax, yet its future is threatened by a potential reduction in the sales tax rate, so the agency has no other revenue source to fall back on besides fares. SEPTA is currently balancing its budget with one-time infusions of flexed highway funds at the state level, but the agency cannot rely on these funds to continue indefinitely. Transport for London is currently frustrated that it must rely almost exclusively on grants from the UK central government for long-term business plans (Transport for London, 2005).

Indeed, the most robust transit agencies in this analysis have been able to respond to cutbacks in subsidy from one source by substituting other sources. In Europe, these shifts often took place in the context of political decentralization, where the devolution of fiscal autonomy from central governments to regions appears to have caused an increased level of transit capital funding (Favero, 2006). U.S. transit agencies have responded to the cutback in federal operating subsidies with higher state and local funds.

6.6.2 Stable Revenues Means "Locking In" Long-Term Responsibility

From a practical perspective, the risk of paying for public transportation with a diverse pool of revenue sources is that each source may feel free to opt out of the arrangement, or that the logic

of collective action will fail to produce funding increases when and if expanded service is desirable.

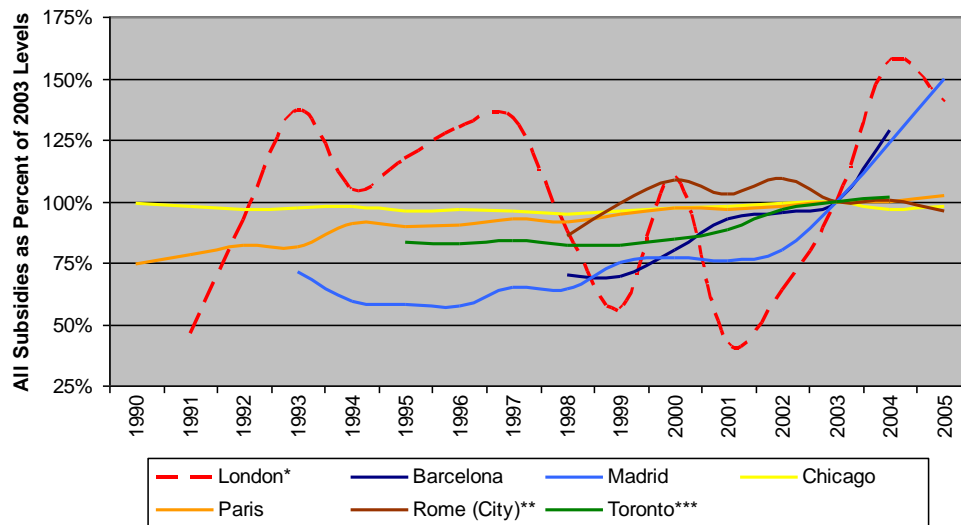
Of the agencies studied here, transit systems appear to succeed when they can rely on a stable funding stream whose year-on-year variations are small. The explanations for this may range from inflexible labor contracts, the difficulty of fare increases, or the multi-year funding required for infrastructure. London Transport, the predecessor to Transport for London, was funded by the UK National Treasury through a bi-annual budget process whereby funding fluctuated widely. The resulting atmosphere of start-stop funding made strategic investment decisions difficult and long-term planning difficult. Toronto TTC faced similar challenges in the late 1980s when the provincial government of Ontario ended their operating subsidies. The TTC raised fares and the City of Toronto stepped up funding to try and make up the difference, but overall subsidies declined, and service cuts and fare increases led to ridership losses.

Regardless, without stable funding commitments, sponsor governments can engage in a game of chicken: no jurisdiction wanting to fund transit, and all sides using the others' inaction as an excuse for their own – with the end result being no action at all. If a transit funding structure produces these outcomes, the entire region could end up with less public transit than it would Pareto-optimally otherwise produce.

The balance of evidence from other cities suggests that a good way to mitigate this problem is to identify the beneficiaries responsible for transit subsidy, and “lock in” or dedicate this source with a long-term arrangement outside of annual budget processes. Many cities studied here use systems of formulas or dedicated proportions of taxes, whereby responsibility for transit funding is divided amongst jurisdictions via a common understanding of burden. Dedication of revenues approximates a long-term contract between the transit agency and the budget-making legislature. European transit agencies appear to sign multi-year funding agreements with their sponsor governments, with effective results. Voter referenda such as Los Angeles' Propositions A and C seem to bypass the Legislature almost entirely, forming a direct contract between taxpayers and transit. London's recent Prudential Borrowing regime has committed the UK Treasury to a five-year borrowing plan for capital investment.

The experience in London also shows that getting sponsor governments to commit to a set funding stream is a prerequisite to empower local initiative for more transit funding. After the Congestion Charge succeeded in raising around £200 million for Transport for London in its first year, the UK Central Government proposed to reduce the agency's grant by the same amount for the following year, leaving TfL frustrated that its entrepreneurship might be undermined (TfL, 2005). If jurisdictions decide to tax themselves for transit revenues, they need guarantees that any new money will be a true increment to transit funding.

Figure 34. Stability of Historical Transit Operating Subsidies in Selected Cities



Source: Antos, 2005. *London includes all London Transport Grant. ** All revenues for the City of Rome. ***Toronto includes fare revenues. All All data corrected for inflation using data from EuroStat, Ontario Ministry of Finance, and the U.S. Bureau of Labor Statistics Consumer Price Index.

6.6.3 Closely-Tailored Revenues Means Looking Beyond the Sales Tax

Many of the cities presented here rely on sales taxes, which poses theoretical and practical difficulties. Theoretically, sales taxes are not closely tailored to the underlying mechanisms of transit’s social benefits, and their ability to stand as “proxies” for these benefits may diminish in the future.

Practically, although the sales tax yield in a healthy economy has historically outpaced inflation, this may not be true in the future. First, the growth of internet retail purchases shelters a growing portion of economic activity in the U.S. from local sales taxes. Second, a post-manufacturing, globalizing economy may tend to consume fewer taxed goods and more untaxed services, further slowing sales tax receipts (Boston Globe Editorial, 2007). Third, discretionary spending on consumer goods may decline quickly during an economic slowdown, yet cities rely on public transit to provide low-cost mobility even in hard times. In addition, sales taxes tend to be regressive, exacting a higher proportion of income from those least able to pay.

6.6.4 Closely-Tailored Revenues Means Looking Beyond the Gas Tax

Some of the transit systems in cities surveyed here receive revenues exacted from the automobile system. Muni receives parking revenues from the City of San Francisco, London transit riders benefit from the congestion charging scheme, and transit in New York is cross-subsidized by toll revenues on auto access to Manhattan. Other cities fund transit from auto taxes in less direct ways: the Pennsylvania government has flexed highway dollars funded from gas taxes to plug SEPTA’s operating budget, the U.S. Federal Government contributes some gas tax-backed to preventive maintenance activities, the District of Columbia uses gas tax revenues to fund WMATA, and Canadian provinces may soon dedicate a portion of gas taxes to transit. In theory, it is rational to tax automobiles to pay for public transit on second best grounds. If

transit helps mitigate the environmental and congestion externalities of autos, it is reasonable to ask auto drivers and society to pay for the benefits received.

However, a gas tax may be a poor mechanism to do so, because consumption of fuel is only a weak proxy for the benefits of public transit. Ideally, an automobile tax to fund transit should be closely tailored to the basis of why automobile travel is harmful, and in the amount to which transit benefits auto drivers. In earlier chapters, I showed that transit helps mitigate some of the external costs of the automobile system, but that emissions and safety costs are a function of total mileage driven, while congestion (and some safety) costs depend on traffic density and are concentrated in space and time. A gas tax will be a good proxy for transit's mobility and safety benefits only, and only insofar as fuel consumption corresponds to total miles driven, which in turn will be only loosely related to the congestion and mobility benefits that transit provides.

Practically speaking, gas tax revenues may not keep pace with the needs of the transit system, for a number of reasons. Rising fuel efficiency may mean that less gasoline is required to drive the same distances. Fuel price fluctuations and the introduction of alternative fuels may dampen demand for gasoline. Politically, although gasoline costs are only 20% of the cost of auto ownership, gasoline is one of the few variable costs of driving,²³ making demand fairly inelastic. The consequent political difficulty of raising gas taxes to keep pace with inflation may tend to undermine revenues.

6.7 How Others Do It: Conclusion

The structure of operating revenues in large public transit agencies in North America and Western Europe varies widely, but several common themes do emerge. Fares are rarely tied to inflation, and usually make up around a third of revenues, but can range between 25-50% of revenues. The farebox recovery ratio is often the result of a policy decision or voter preference, and using it as an efficiency indicator can have harmful results. Except for London, central governments play a small role in funding transit operations.

Beyond fares and federal revenues, transit systems rely on a wide range of taxes, fees, auto charges, and dedicated revenue streams to pay for their daily operations. Based on a survey of 15 transit agencies' finances, I suggest that the best funding structures are those where: transit's beneficiaries shoulder its financial burden in roughly similar proportions; the subsidy mechanism is closely tailored to the needs and benefits of transit; and the revenues are delivered to the agency in a stable manner. I conclude by recommending that transit funding structures be based on a range of diverse sources, should "lock in" long-term funding commitments from sponsor governments, and should look beyond the sales and gas taxes for revenues that are perhaps better proxies for transit's benefits, including funds from the automobile system.

²³ The American Automobile Association (2007) estimates that a typical driver (medium sedan, 15,000 miles per year) spends 52.5 cents per mile to own a car, of which 9.4 cents is spent on gasoline. Variable costs (gas, maintenance, and tires) make up 14.9 cents per mile of the total.

7 Conclusion: New Directions for Transit Finance in Chicago

The purpose of this thesis is to suggest a framework for funding transit, and to recommend a range of potential funding mechanisms for the public transportation system in Chicago based on an understanding of how transit should and can be publicly funded. After quantifying the magnitude of some of transit's social benefits in the Chicago region, I highlighted practices from transit agencies around the world that upheld the theoretical principles and practical concerns of public transportation finance.

This final chapter combines the results of previous chapters to present an approximate cost-benefit analysis of Chicago's transit system, and to map out the distribution of these benefits for comparison with the current RTA funding structure. In broad terms, I find that transit's key benefits probably outweigh its subsidies - by approximately 50% by my central estimates - and that the group which is benefiting the most compared to their current contribution to operations is auto drivers, and perhaps downtown property owners. Based on these results, and drawing on the lessons learned from transit funding abroad, I offer recommendations for a new funding instrument, emphasizing roadway tolls as a particularly theoretically and practically appealing policy alternative.

7.1 Assessing Chicago's Current Funding Structure

In this section, I assess the structural characteristics, magnitude, and incidence of the current transit subsidy system in Chicago against the principles and practices of successful transit funding identified in previous chapters.

The current RTA funding regime faces a number of structural difficulties. First, although a diverse set of beneficiaries and a prudent risk-spreading strategy would ideally imply a range of revenue sources and sponsors, Chicago relies on essentially one funding source: the dedicated sales tax, as defined by the state. The state's match of this amount is drawn primarily from state sales tax and income taxes.

Second, although the 1983 RTA law has generated stable revenues protected from annual budgetmaking, their formulaic distribution has produced uneven results for the three service boards, and a peculiarity of the structure has eliminated the incentive to raise additional funds for transit. While perhaps originally intended to empower the RTA to plan regionally, the 15% of revenues reserved for the Regional Transit Authority's discretion discourages local initiative or risk-taking to add additional funds to transit, since any added increment can be frustrated by an equal offset in discretionary funds. As a result, Chicago may have less transit than it would have otherwise Pareto-optimally produced.

Third, the sales tax alone appears to be an inadequate proxy for the wide range of social benefits provided by transit services in the Chicago region. Some of the benefits of a public transportation network are avoided costs of the automobile system, mobility benefits to riders, and agglomeration benefits to the economy. An ideal funding mechanism for transit would latch onto the underlying cause of these external costs from the automobile, and tax according to transit's ability to mitigate them. A sales tax is probably peripheral to many of these benefits.

7.2 Evaluating Chicago's Current Transit Funding Amount

In Chapters 3, 4, and 5 I quantify several major social benefits of public transportation in Chicago: air pollution, congestion relief, mobility benefits, and safety. These high and low estimates of results are summarized in Table 43, along with a central estimate.

Table 43. Summary of Social Benefits of Chicago Transit in a Typical Year

Type of Benefit	Low (\$2005)	High (\$2005)	Central (Midpoint) Estimate
Air Quality	\$26	\$536	\$281
Safety	\$291	\$631	\$461
Congestion Relief	\$323	\$1,577	\$950
Mobility Benefits	\$528	\$1,150	\$839
Total	\$1,168	\$3,894	\$2,531
Current Subsidy to RTA (2005)			\$1,096

Overall, I find that the benefits of public transportation in Chicago outweigh its subsidy. Confirming the findings of the Moving Beyond Congestion campaign, however, my central estimates conclude that the real goods and services that Chicago obtains from publicly subsidizing its transit system are greater than they would otherwise be in the absence of transit. If transit were eliminated in Chicago, taxpayers would regain roughly \$1.1 billion in annual subsidy, but lose a durable asset which is providing roughly \$2.5 billion in social welfare benefits in a typical year. From a social benefit-cost perspective, public subsidy to operate transit is likely justified.

7.2.1 Comparison with MBC Analysis

In its Final Report, the Moving Beyond Congestion campaign performs a benefit-cost analysis on transit operations which differs from my own in several respects (RTA, 2007b, 73). They conclude that the RTA's 30-year operating need of \$10 billion would save nearly \$29 billion in social costs. Because unit costs appear to have been eliminated from the published tables, comparison is difficult. Notably, the MBC's report differs in structure: the MBC presents the cumulative social costs of continuing Chicago's current funding arrangements (assuming, crucially, that a 1% revenue loss translates into a 1.5% service and ridership loss) over a 30-year time period, as a net present value. My analysis presents a typical year, undiscounted. On the whole, although our methodologies differ in several ways, my findings agree with MBC that the loss of transit would result in high congestion costs to motorists, and our conclusions are broadly similar.

7.3 Evaluating Chicago's Current Transit Funding Incidence

In view of transit finance, it is important to know not only whether transit is justifiable enterprise, but whether the subsidy mechanisms generally distribute the financial burden of transit to its beneficiaries in similar proportions. To answer this question, this thesis makes a rough estimate of the incidence of benefits, in support of the theoretical framework described in Table 1 in section 1.5.1. Because incidence in a complex market is difficult to determine, I make

several simplifying assumptions for each benefit type. Where appropriate, I further divide benefits between the CTA Service District (approximately the City of Chicago), and the rest of the region (suburban Cook County and the collar counties). I assume that passenger-trips by service board approximate the origins of transit riders, and that the impacts of all Metra and Pace trips accrue to outside the CTA service district.

7.3.1 Emissions

As shown in chapter 3, transit reduces air pollution in two ways: by moving passengers more efficiently than autos, and by improving automobile efficiency through congestion relief. I assume that the benefits of emissions reductions accrue to three jurisdictions depending on the type of pollutant. I classify carbon monoxide as local, ground-level pollutants (NO_x, VOCs, etc.) as metropolitan, and greenhouse gases as national. Direct reductions from efficiency accrue to the origin of transit trips, while indirect reductions through congestion relief are credited to the location of congestion.

7.3.2 Safety

Transit's effect on safety is threefold. First, when mass transit takes cars off the road, overall chances of crashing declines, a benefit which I assume accrues to motorists. Second, since a portion of these benefits are external in the form of reduced medical and emergency response costs, I assume that the state of Illinois also receives a benefit. Third, train and bus operations create modest safety risks of their own, the external costs of which I presume imposes a cost on the towns served by transit. I assume that the balance of these costs is internalized to the RTA service boards in the form of insurance.

7.3.3 Congestion

Chapter 5 estimated that public transit saves congestion costs, a benefit which I assign to motorists. I further divide this benefit based on modeling results on the location of congestion and the origin of the autos causing it. As shown in section 5.10.1, modeling analysis reveals that although congestion is concentrated in the City of Chicago, the majority of the drivers causing and experiencing it originate from outside the CTA's service district (Murga, 2007). Thus the majority of transit riders are riding transit where their addition to the roadways would be the most damaging, and the majority of transit's congestion benefits accrue to suburban drivers.

7.3.4 Mobility Benefits

Transit provides considerable benefits to those onboard, for various reasons: by saving car ownership costs for choice riders, by providing those unable to drive access to opportunities, and by providing an equitable baseline of mobility to all. I assign these benefits to passengers based on passenger-trips by service board as in section 7.3.1, even though the downstream incidence of these benefits may be more complex.

This methodology is summarized in Table 44.

Table 44. Basis for Calculating Incidence of Chicago Transit Benefits

Benefit of RTA Transit	Basis for Division of Benefits	Location of Beneficiary			
		CTA Service Area	Collar & Suburban Cook	General Metro Area	State or World
Less time and gas spent in congestion	Origin of congestion-causing trip	18%	82%	0%	0%
Less local pollution from congestion	Location of congestion	61%	39%	0%	0%
Less ground-level pollutants	Metropolitan	0%	0%	100%	0%
Less local pollution from efficiency	Origin of transit trips	82%	18%	0%	0%
Less greenhouse gases	State/World	0%	0%	0%	100%
Consumer surplus of riders	Origin of transit trips	82%	18%	0%	0%
Fewer accidents with other autos	Location of all vehicle travel	57%	43%	0%	0%
External safety costs of transit (negative)	Origin of transit riders	82%	18%	0%	0%
Lower medical and emergency costs	State	0%	0%	0%	100%

7.4 Chicago's Dilemma

The challenge facing Chicago is that current RTA operating revenues are inadequate to pay for existing operations. The region may soon be forced to choose between raising fares, cutting service, and increasing funding. In this thesis, I assessed the overall value of public transportation to the region, and found that a conservative analysis justifies added funding to maintain current levels of service. The immediate issue at hand is that the inadequacy of current revenues threatens to reduce service. The insufficiency of current RTA funding is not *per se* a reason to change transit funding, the current crisis has forced the issue. Because I concluded that transit's benefits likely outweigh its costs, increasing subsidy to preserve the social benefits is theoretically justified.

However, this thesis leaves to future research the thorny question of whether the optimal transit subsidy amount should be equal to the social benefits it produces. Theoretically, financial literature suggests that one should invest in an enterprise up to the point where the internal rate of return equals the discount rate: that is, where costs equal benefits. In Chicago, however, a significantly higher RTA subsidy would mean that the service boards could likely cut fares, expand service, or invest in new infrastructure, which could implicate capital resources (my analysis is limited to operating revenues) and would in turn alter the initial calculation of social benefits. Practically, government cannot undertake every project whose benefits exceed costs, because citizens' unwillingness to submit to taxation as well as the marginal welfare losses associated with raising public funds through taxation (Snow and Warren, 1996; Allgood and Snow, 1998) tend to limit available resources. The availability of federal funding for cost-effective capital investments would appear to make these investments promising. The effect of adding a dimension of capital funds on the optimal transit funding principles explored here is a major area of future research. But because eligibility for capital discretionary funds require demonstration of the fiscal capacity to pay the increased operating costs, this thesis provides a building block for the analysis of expanding transit capacity through capital investment.

As policymakers in Chicago seek to alter the existing transit finance arrangement by potentially changing the 1983 RTA Act, they have few best practices or principles of optimal funding to guide them. Practically speaking, then, how should this additional subsidy be funded? Who should pay more?

7.5 Results: How the Current RTA Statute Compares

To help answer this immediate question, I compare the incidence of benefits in Chicago with the current funding arrangement to determine which jurisdiction or group, if any, may be receiving benefits disproportionate to the burden they bear. I use the central estimates calculated in earlier chapters.

Table 45. The Size and Incidence of Social Benefits of Transit (Central Estimates)

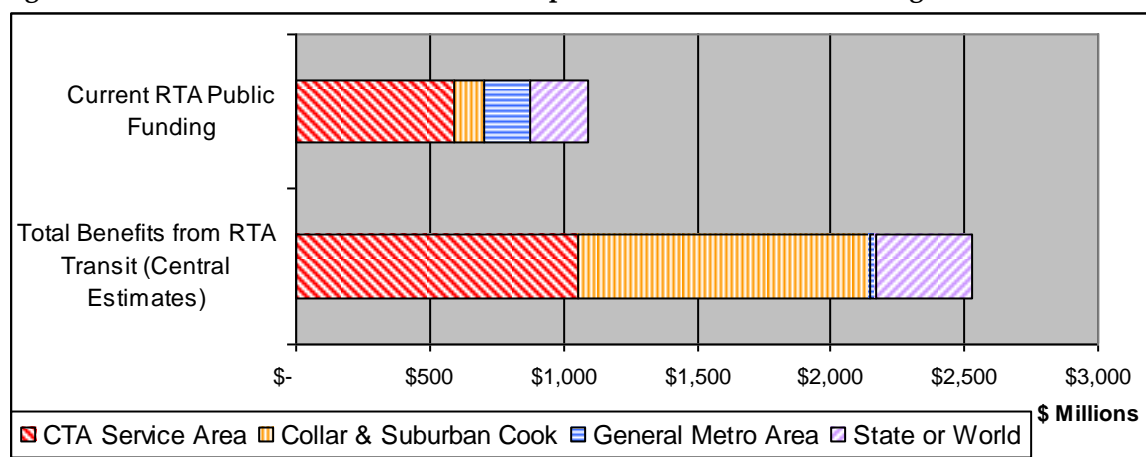
Quantifiable Benefit (\$m)	Beneficiary				Total
	<i>Auto Drivers</i>	<i>Directly Served Communities</i>	<i>General Metropolitan Area</i>	<i>State or World</i>	
<i>Congestion</i>	Less time and gas spent in congestion	Less local pollution from congestion	Less ground-level pollution from congestion	Less GHGs from avoided congestion	
	\$950	\$11	\$27	\$75	\$1,063
<i>Economic</i>	---	Mobility benefits to riders	---	---	
		\$839			\$839
<i>Safety</i>	Fewer accidents with other autos	Increased safety costs of transit	---	Lower medical + emergency costs	
	\$375	-\$29		\$116	\$462
<i>Emissions</i>	---	Less local pollution from efficiency	Different/Less ground-level pollution	Less GHGs from efficiency	
		\$3	-\$6	\$170	\$167
Total:	\$1,325	\$824	\$21	\$361	\$2,532

Table 45 summarizes the magnitude and incidence of transit's benefits in Chicago. Taking these numbers as control totals for the assumptions in Table 44, the overall incidence is further divided between the CTA service area and the rest of the metropolitan area. The results are displayed and compared to the current RTA subsidies in Table 46 and Figure 35.

Table 46. Incidence of Transit Benefits (Central Estimates) Compared to Current RTA Funding

Benefit of RTA Transit (\$ millions)	Location of Beneficiary				Total
	CTA Service Area	Collar & Suburban Cook	General Metro Area	State or World	
Less time and gas spent in congestion	\$ 171	\$ 779	\$ -	\$ -	\$ 950
Less local pollution from congestion	\$ 7	\$ 4	\$ -	\$ -	\$ 11
Less ground-level pollutants	\$ -	\$ -	\$ 21	\$ -	\$ 21
Less local pollution from efficiency	\$ 3	\$ 1	\$ -	\$ -	\$ 3
Less greenhouse gases	\$ -	\$ -	\$ -	\$ 245	\$ 245
Consumer surplus of riders	\$ 688	\$ 151	\$ -	\$ -	\$ 839
Fewer accidents with other autos	\$ 214	\$ 161	\$ -	\$ -	\$ 375
External safety costs of transit (negative)	\$ (24)	\$ (5)	\$ -	\$ -	\$ (29)
Lower medical and emergency costs	\$ -	\$ -	\$ -	\$ 116	\$ 116
Total Benefits from RTA Transit (Central Estimates)	\$ 1,058	\$ 1,091	\$ 21	\$ 361	\$ 2,532
	42%	43%	1%	14%	
Current RTA Public Funding	\$ 587	\$ 113	\$ 176	\$ 220	\$ 1,096
	54%	10%	16%	20%	

Figure 35. Incidence of Transit Benefits Compared to Current RTA Funding



The incidence of the current transit funding structure in Chicago compares favorably to the incidence of its benefits in several respects, but falls short in other areas.

The RTA sales tax structure generally aligns tax revenues to the origins of transit riders. That is, jurisdictions are paying sales tax to transit roughly according to its value to passengers, and the origins of those passengers. In 2005, the RTA received 84% of its sales tax revenues from Cook County, and 16% from the Collar Counties – similar to 82% of passenger trips on the CTA and the remaining 18% on suburban Pace and Metra. I measure rider benefits as \$839 million, and sales tax receipts from the six counties totaled \$587 million in 2005. This comparison is very rough, and could be refined with further research, but the general conclusion holds: the size and incidence of the sales tax roughly reflects passengers’ mobility benefits.

On the theory that the benefits of mobility eventually accrue to riders’ destinations as well as their origins, this finding may suggest that transit passengers’ destinations are receiving

benefits they do not explicitly pay for. If most passengers are traveling to and from the Loop, this might be an argument for expanded transit funding from downtown businesses. As mentioned in section 6.4, a payroll tax has worked well in Paris and Portland, but this is an area for future research.

The state of Illinois' contribution to public transit, via its 25% match of sales tax revenues (which I label "metropolitan") and supplemental funds from general revenues, roughly corresponds to the emissions and safety benefits it receives. Some of the benefits of reducing auto collisions on the roadways accrue to the state in avoided costs for health care programs, state police, and the Department of Transportation. In addition, air pollution reductions accrue to everyone in the region, so the logical beneficiary is probably the state government.

Chicago's transit finance mechanism falls short in two areas. First, the benefits of greenhouse gas reductions should theoretically accrue to everyone in the world – yet it is impractical to fund transit from a world government. But unlike ground-level pollutants which impose costs on a regional level, the nature of atmospheric air pollution means that an emission of carbon dioxide anywhere is problem everywhere. In a theoretical sense, greenhouse gases may best be dealt with at a global scale. However, state and national governments have begun taking an interest in reducing greenhouse gases, so the beneficiary of the 1.2 million tons of carbon emissions avoided by public transit in Chicago may be the state of Illinois or the U.S. federal government. This might be an argument for increased state or federal funding for transit operations. Depending on the structure of future potential greenhouse gas regulation, the RTA and its service boards might endeavor to sell carbon offset "credits" for revenues. Illinois Governor Blagojevich's greenhouse gas initiative may be an opportunity for the state to pioneer in this previously unexplored policy arena.

More importantly, my findings suggest that suburban auto drivers in Chicago are receiving greater benefits from transit than they currently pay for. I estimated that public transportation is currently improving the safety and congestion of roads to the tune of over \$1 billion per year, yet autos explicitly contribute little money to transit operations.²⁴ In addition, I estimate that the beneficiaries of congestion relief are drivers who originated outside of the CTA service area or outside of Cook County, and that the beneficiaries of improved traffic safety are auto drivers throughout the region.

7.6 New Directions for Transit Subsidy in Chicago

As transit policymakers consider changes to the 1983 RTA Act to preserve current transit services, my findings suggest that a particularly theoretically appealing revenue source is motorists. Based on a relatively comprehensive review of transit's social benefits in Chicago, and after comparing the amount and incidence of these benefits with the RTA statute, this thesis concludes that automobile drivers currently receive disproportionately more benefits than they pay.

²⁴ It may be argued that some of the "State Financial Assistance" might be derived indirectly from gas or other automobile taxes, even though they are appropriated from general revenues. Illinois does generate significant revenues from taxes on private vehicles which are not earmarked for roads. Regardless of the incidence, the amount of discretionary state funds is small relative to transit's benefits to the auto.

Bearing in mind the practical lessons learned from other transit agencies, I offer several policy alternatives to structure a new funding mechanism based on revenues from the automobile system. It is important to distinguish between taxing automobiles to 1) make auto drivers face the marginal social costs of their actions, and 2) provide funding to a transit system for the social benefits it provides (Gillen, 1997, 199). I focus only on the second, and leave exploration of the first to future research.

7.6.1 Option 1: Increase the Sales Tax

As the MBC campaign report suggests, an additional 0.25% sales tax on all counties in the RTA Region, on an incremental or allocative basis, would yield around \$270 million per year (RTA, 2007b) and generally resolve the current gap in operating funding. Since the collection mechanisms are already in place, implementing such a policy would likely be straightforward.

However, this option has low theoretical appeal. A sales tax is not narrowly tailored to automobiles, nor is it tailored to the particular automobiles who currently derive significant benefits from public transportation. An across-the-board sales tax hike would hit all current payees equally, yet this analysis has shown that transit's benefit to motorists has a suburban focus, implying that an increase to the sales tax would exact more from the central city than is warranted. Alternatively, an increase only to the collar counties' sales tax would need to be fairly high to raise similar revenues. Taxing all sales in the suburban areas for the externalities of a smaller subset of downtown commuters might be politically infeasible.

7.6.2 Option 2: Increase the Gas Tax

Extrapolating from MBC's final report, adding a 4-8% tax on gasoline in the six-county region might generate \$260-520 million per year. This policy would be straightforward to administer, and its collection mechanism is already in place.

However, a gas tax suffers from several practical difficulties, as described in section 6.6.4, that are likely to undermine its effectiveness as a revenue source. Theoretically, the price or use of gasoline is only loosely related to the congestion and mobility benefits that transit in Chicago provides. Drivers consume gas no matter where or when they drive, but transit's congestion benefits occur in very peaked spatial and temporal patterns. Moreover, drivers already pay for the primary share of the cost of the highway network through gas taxes, while the commercial beneficiaries of the roadway access system do not shoulder its costs directly. Given motorists' anger at recent fuel price increases, it may be more feasible to generate revenues by other means. Ideally, an automobile tax to fund transit should be levied on the basis of why automobile travel is harmful, and the degree to which transit can mitigate this harm for drivers. A sustainable funding structure for transit should latch onto the root tendency to consume auto travel, and tax according to how well transit mitigates the resulting costs. The consumption of gasoline is a moderate proxy for this.

7.6.3 Option 3: Mileage-Based "Pay-As-You-Drive" Fees

Variable car fees, similar to the structure of pay-as-you-drive insurance, makes several improvements to the gasoline tax. Such a program would present less visible costs to the driver, perhaps increasing its political viability. Unlike the gas tax, future fuel efficiency would not undermine this program's effectiveness, and charges could capture the accident externality described in section 4.1. It may be a small step to tie miles driven to a standard emissions

profile based on vehicle type, and a “polluter pays” surcharge could be added to this scheme in the future.

However, pay-as-you-drive programs also have downsides. The collection mechanisms are only partially in place, and initial administration costs could be high. A cost placed on each vehicle mile traveled equally is a close proxy for transit’s safety benefits, but an imperfect one for the congestion benefits that transit provides. Practically, the entire RTA district or state of Illinois would need to switch to a variable insurance program at the same time to reap its full benefits, since allowing high-mileage drivers to remain on fixed rate insurance plans undermines the savings to low-mileage drivers. Politically, the optimal difference between low- and high-mileage drivers might be wide, causing a political backlash from high-mileage drivers who might have to pay considerably more.

7.6.4 Option 4: Parking Tax

A tax on parking to fund RTA transit services could be more narrowly tailored to downtown auto drivers who are benefiting from the transit system. The City of San Francisco effectively contributes \$130 million per year in parking proceeds to transit. Furthermore, the portion of a parking tax that falls on downtown businesses could be justified based on the value they receive from accessing transit passengers. For a detailed discussion of a parking tax to pay for transit in Chicago, see Misiak (2005).

7.6.5 Option 5: Road Tolls

Adding congestion-based tolls to roadways in the Chicago metropolitan region is perhaps the most theoretically satisfying way presented here to finance a gap in transit funding. Although a major drawback to expanded tolls would be the capital costs of adding toll facilities, emerging technologies could potentially reduce these costs to more viable proportions.

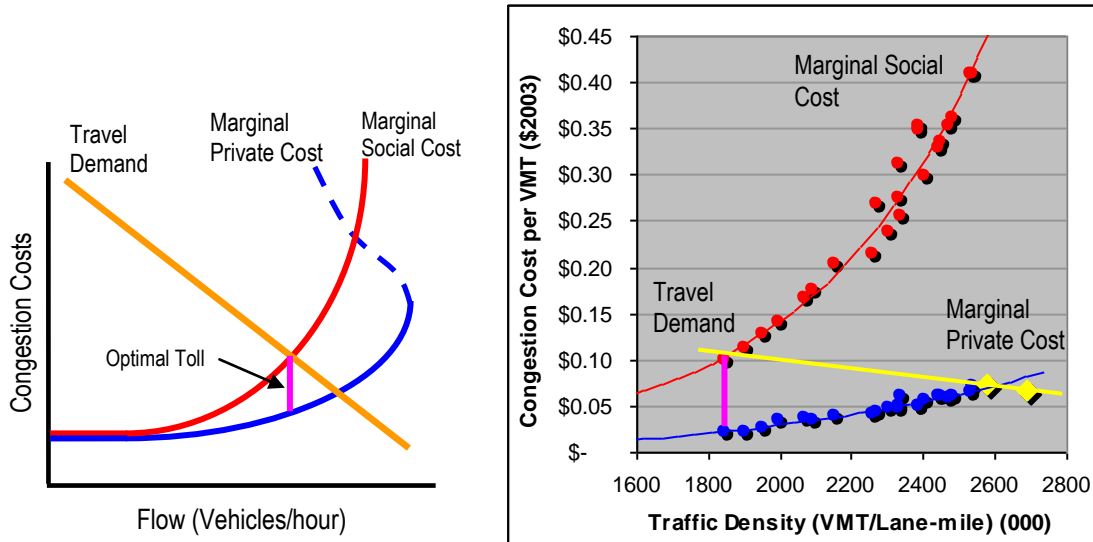
This thesis suggests that public transportation is providing substantial benefits to auto users that they do not pay, and that of all transit beneficiaries, drivers may be paying the least relative to what they receive. However, these safety and congestion benefits seem to be especially concentrated in certain areas at specific times. Unlike variable pay-as-you-drive fees, gas taxes, or sales taxes, therefore, tolls can be very closely tied to the congestion relief, safety, and mobility that transit offers.

It is important to distinguish between charging automobiles to motivate behavior, such as making drivers face the marginal social costs of their decisions, and charging automobiles to meet financial goals, such as compensating transit for its social benefits, or generating enough revenues for a construction project.

In the first instance, economic theory states that an optimal congestion toll should be charged to force auto drivers to face the marginal social costs of their decisions. This toll should equal the difference between social costs and private costs where marginal social cost equals marginal willingness to pay, illustrated by the small vertical line in Figure 36. This analysis contains the basic ingredients to estimate this amount for Chicago. Taking the first derivative of the congestion cost function I estimated in section 5.6 yields the marginal social cost curve. The with- and without-transit equilibriums form the demand curve for auto travel with respect to congestion costs. Thus, the analysis suggests that an economically optimal toll for Chicago

would therefore average around 8¢ per vehicle mile, with higher tolls on the peak than the off-peak. This finding also suggests that in its current condition, every new car accommodated on Chicago roads at the current distribution of travel patterns now imposes marginal external congestion costs to the tune of 41¢ per mile.

Figure 36. Optimal Roadway Tolls for Chicago



In the second instance, tolling can also be designed to compensate transit for the benefits it provides, which has particular relevance to a new funding structure in Chicago. Since I quantify the value of those safety and congestion benefits with a range, Table 47 estimates the average toll amounts that would be needed to adequately compensate transit (approximately \$400 million).

Table 47. Hypothetical Road Toll Amounts for Ideal Transit Funding

Toll Applied to:		
VMT (mill.)	Road Type	Optimal Toll per Mile
60,512	All Roads	0.6¢
30,300	Interstates and Principal Arterials	1.4¢
18,043	Interstate Highways only	2.2¢

Since tolling every road would be impractical, Chicago might look to simply toll existing interstate highways, or perhaps some principal arterials as well, especially since VMT is disproportionately concentrated on these high-volume roadways. My research suggests that an average toll of around 2¢ per vehicle mile, similar to current toll levels in the region (Illinois State Toll Highway Authority, 2007), would generate approximately \$400 million per year with negligible VMT reductions, and would fall well below the “optimal” toll level of 8¢ per mile.

Roadway tolls in Chicago would likely encounter political resistance, primarily because they may price some drivers out of the market. However, the dedication of revenues to transit could compensate for this decreased mobility. If such a system were to emulate the successful

congestion charging regime in London, it would ideally be accompanied by improved capacity and quality on the public transportation system. In this situation, drivers discouraged from the roadways by the tolls would likely enjoy adequate alternatives to driving. Indeed, the experience of London suggests that congestion-based auto fees to improve public transit enjoy a synergy of theoretical and political appeal.

Roadway tolls to fund transit in Chicago would be a sustainable, growing revenue source for transit, and it would be drawn from those who should ideally be paying more. History has shown that auto travel demand is rising and is projected to continue growing (CATS, 2005, 5.2). From the RTA's perspective, the value of its services to bypass and relieve congestion will only grow as traffic and demand continue to grow in Chicago, and a dedicated source of toll revenues would allow it to capture the value it creates.

7.7 Thesis Conclusion

As an oft-overlooked piece of urban policy in America, the finance of public transportation systems holds great potential to be a part of the solution to the difficult problems facing cities. Transit funding varies widely in the U.S. and Western Europe, and these important structures often bear little relation to the needs and benefits of public transportation. Chicago, for example, appears to be on the brink of changing the way it allocates resources to its public transport, yet can rely on little theoretical guidance on where any new revenues should come from, and why. To fill this apparent void, this thesis attempted to offer a more rational approach to the finance of transit, based on the various environmental, safety, congestion, and mobility benefits a public transportation provides, and used Chicago as a case study to do so.

My findings concluded that the benefits of transit in Chicago probably outweigh its costs, and that most of the beneficiaries of public transport are paying subsidies roughly in accordance with their benefits with the exception of motorists and possibly commercial interests who benefit from the roadway access system. By comparing the size and incidence of transit's benefits to its current costs, I find evidence that auto drivers are receiving more benefits than they pay for, primarily in the form of congestion relief. Most transit passengers are on board where congestion is the most concentrated, and where their addition to the roadways would cause high marginal costs. Auto drivers in Chicago stand much to lose in the reduction of transit services, yet they contribute little directly to its funding. If they may be legitimately asked to step up to the plate and contribute a more equal share to the finance of public transport, I offer a range of instruments to do so, suggesting that one particularly theoretically and financially appealing instrument may be roadway tolls.

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List of Acronyms

CARB	California Air Resources Board
CATS	Chicago Area Transportation Study
CBD	Central business district
CO	Carbon monoxide
CTA	Chicago Transit Authority
DNR	Department of Natural Resources
EPA	Environmental Protection Agency
EIA	Energy Information Administration
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	Greenhouse gas
IEPA	Illinois Environmental Protection Agency
IPCC	International Panel on Climate Change
MPG	Miles per gallon
MPO	Metropolitan Planning Organization
NIPC	Northeastern Illinois Planning Commission
NO _x	Nitrogen oxides
NTD	National Transit Database
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
PMT	Passenger miles traveled
RTA	Regional Transportation Authority
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
TTI	Texas Transportation Institute
UITP	Union International des Transports Publics
VMT	Vehicle miles traveled
VOC	Volatile organic compounds