Measuring Urban Transportation Performance

A Critique of Mobility Measures and a Synthesis

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Executive Summary

While peak hour travel is a perennial headache for many Americans — peak hour travel times average 200 hours a year in large metropolitan areas — some cities have managed to achieve shorter travel times and actually reduce the peak hour travel times. The key is that some metropolitan areas have land use patterns and transportation systems that enable their residents to take shorter trips and minimize the burden of peak hour travel.

That's not the conclusion promoted by years of highway-oriented transportation research. The Urban Mobility Report (UMR) produced annually by the Texas Transportation Institute and widely used to gauge metropolitan traffic problems has overlooked the role that variations in travel distances play in driving urban transportation problems.

This report offers a new view of urban transportation performance. It explores the key role that land use and variations in travel distances play in determining how long Americans spend in peak hour travel.

- Travelers in some cities - those with more compact development patterns - tend to spend less time in peak hour traffic because they don't have to travel as far.
- If every one of the top 50 metro areas achieved the same level of peak hour travel distances as the best performing cities, their residents would drive about 40 billion fewer miles per year and use two billion fewer gallons of fuel, at a savings of $31 billion annually.
- In the best performing cities the typical traveler spends 40 fewer hours per year in peak hour travel than the average American because of the shorter distances they have to travel.

In the best performing cities—those that have achieved the shortest peak hour travel distances - such as Chicago, Portland and Sacramento, the typical traveler spends 40 fewer hours per year in peak hour travel than the average American. In contrast, in the most sprawling metropolitan areas, such as Nashville, Indianapolis and Raleigh, the average resident spends as much as 240 hours per year in peak period travel because travel distances are so much greater. These data suggest that reducing average trip lengths is a key to reducing the burden of peak period travel.

Ranking Metropolitan Areas on Peak Period Travel Times

The additional travel time associated with longer average trip distances is the chief determinant of which metropolitan areas have the longest travel times. Longer trip distances add 80 hours a year or more to peak travel times in Nashville, Oklahoma City, Richmond, and Nashville. Areas with the shortest average travel distances, including Chicago, New Orleans, Sacramento and New York, have among the lowest total hours of peak period travel.

These results are a stark contrast to the picture of urban transportation painted by the UMR, which has long been used to measure traffic problems and compare cities. A close examination shows that the UMR has a number of key flaws that misstate and exaggerate the effects of congestion, and it ignores the critical role that sprawl and travel distances play in aggravating peak period travel.

The Travel Time Index: A Flawed Tool for Diagnosing Transportation Problems

The central analytical tool in the Urban Mobility Report is the Travel Time Index (TTI), which is the ratio of average peak hour travel times to average free flow travel times. On its face, the Travel Time Index seems like a reasonable way to compare city transportation systems. And if all cities had similar land use patterns and densities and had the same average trip lengths, then the TTI would be a fair measure. But city land use patterns vary substantially, and as a result the Travel Time Index conceals major differences in urban transportation between different cities.

According to the UMR, the worst traffic was in Los Angeles, Washington and Atlanta. But a re-analysis of the data shows that residents in at least ten other metropolitan areas, including Richmond, Raleigh-Durham, Detroit and Kansas City, spent the most time traveling in peak hours. Again, the key reason for the difference is the much longer-than-average peak period travel distances in those cities.

Limitations of the Urban Mobility Report's Methodology

Our detailed analysis of the methodology of the Urban Mobility Report suggests that it is an unreliable guide to understanding the nature and extent of transportation problems in the nation's metropolitan areas.

The Urban Mobility Report's key measure - the Travel Time Index—is a poor guide to policy, and its speed and fuel economy estimates are flawed. In the aggregate, the analysis appears to overstate the costs of traffic congestion three-fold and ignores the larger transportation costs associated with sprawl. Specifically:

- The Travel Time Index used in the UMR is based on a questionable model of how traffic volumes affect traffic speeds, and it uses an unrealistic and unattainable baseline of zero delay in computing congestion costs. The structure of the Travel Time Index conceals the effect of sprawl and travel distance on travel time.

- The key statistic underpinning the UMR's findings is based on the difference in travel times between peak and non-peak periods, but the study's travel time estimates are based on volume data, not on actually observed travel speeds.

- The model used to convert volume data to estimated speeds was calibrated by "visual inspection" of the data, and the line chosen to reflect the data isn't based on statistical analysis; a line fit with a simple quadratic equation would produce much higher estimates of peak hour speeds and consequently lower levels of peak hour delay.

- The UMR speed/volume model relies on daily, rather than hourly (or minute-by-minute) traffic volumes, meaning that the authors must make strong assumptions about the distribution of traffic between peak and non-peak hours.

- The claims the UMR makes about trends in travel times over time and across cities do not correlate with other independent measures of travel times. Survey data on observed speeds from Inrix, a private aggregator of travel time data gathered from commercial vehicles, and self-reported travel times from the Census and National Travel Survey are not consistent with the conclusions of the Urban Mobility Report. Neither the total change in travel time, measured nationally, nor the pattern of changes in travel time across metropolitan areas is consistent with the estimates of increased delay presented in the Urban Mobility Report.

    - Data from speed measurements monitored by Inrix suggest that the UMR methodology overstates the Travel Time Index by about 70 percent.

    - Data from the National Household Travel Survey show that nearly all of the increase in peak commuting times was due to longer trips rather than slower travel speeds.

    - The pattern of changes in commuting times between 1990 and 2000 shows that there is no correlation between changes in peak delays estimated in the UMR and changes in commute times reported in the Census.

- The UMR claim that travel times have increased is a product not of direct observations but is an artifact of the structure of the UMR's speed/volume equations, for which there is no independent confirmation. As long as volume increases more than capacity, the UMR model mechanically predicts slower speeds and travel times.

- There are strong reasons to doubt the UMR claim that slower speeds associated with congestion wastes billions of gallons of fuel.

    - The UMR estimates of fuel consumption are based on a 29 year-old study of low-speed driving using 1970s era General Motors cars, which is of questionable applicability to today's vehicles and to highway speeds.
    - The UMR extrapolates these data outside of the speeds for which they were intended and changes the functional form used in the original study in a way that exaggerates fuel consumption associated with speed changes.

- The UMR fuel consumption results are not consistent with other, more recent estimates of fuel economy patterns and ignore the savings in fuel consumption associated with modest reductions in travel speeds.
- The UMR ignores the fuel consumption associated with longer trips in sprawling metropolitan areas.

Adjusting the UMR estimates to account for each of these issues produces a significantly lower estimate of the cost of congestion. Adopting a more reasonable baseline for congestion-related delays, using the Inrix Travel Time Index, adopting a lower value of travel time, and adjusting fuel consumption estimates would imply that the cost of congestion in monetary terms is perhaps less than 70 percent lower than the figure claimed in the UMR. For the 51 metropolitan areas analyzed here, this means that the UMR overstates the cost of congestion by about $49 billion.

A re-analysis of the data in the UMR paints a very different picture of transport problems. Trip distances grew rapidly in the 1980s and 1990s, but have stopped growing since then. Between 1982 and 2001, average commute trips nationally got three miles longer. Our calculations, based on data from the UMR, suggest that average travel distances increased in three-quarters of the 50 largest metropolitan areas over this time period. Since 2001, however, peak period travel distances have been shrinking in most metropolitan areas, and the average travel distance has declined about 1.0 percent.

The Nation Needs Better Measures of Urban Transportation Performance

The key role of sprawling development patterns in driving peak period travel and the limitations of the Urban Mobility Report presented here underscore the need for a much improved system for measuring and comparing the performance of urban transportation systems. A new system for measuring urban transportation performance should embrace five important elements.

1. Emphasize accessibility--the proximity and convenience of destinations--not just mobility.
2. Include comprehensive measures of land uses, trip lengths and mode choices as well as travel speeds.
3. Incorporate new and better data on travel speeds and commuting patterns
4. Adopt an open, multi-disciplinary process to select, validate and continuously improve measures.
5. Provide measures that can be used to guide policy and evaluate investments rather than simply raise alarm about traffic delays.

This report was prepared by Joseph Cortright, an economist with Impresa, Inc., in Portland and senior policy advisor for CEOs for Cities. It was commissioned by CEOs for Cities, a national organization of urban leaders, and supported by the Rockefeller Foundation.

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Introduction

Traffic congestion is a hardy and annoying urban perennial. If, as Ed Glaeser (2004) has argued, cities are the absence of space between people, then traffic is the inevitable friction that keeps them apart.

Understanding, measuring and dealing with transportation problems are key challenges for city and national leaders. For nearly three decades, the Urban Mobility Report, produced by the Texas Transportation Institute has been regarded as providing a clear, quantitative benchmarking of the state of traffic congestion through the nation. The Institute's annual releases of the report, ranking metropolitan areas by their degree of congestion, are widely reported in the media.

The Urban Mobility Report claims to offer three major insights about traffic congestion in American cities:

> Traffic congestion costs Americans $87.2 billion and wastes 2.8 billion gallons of gasoline annually.
>
> Congestion has grown steadily worse and cost of traffic congestion measured in constant dollars has nearly tripled from $290 per person in 1982 to $750 per person today.
>
> The Travel Time Index can be used to measure differences in traffic congestion problems across metropolitan areas.

This paper presents evidence that each of these claims is either dubious or incorrect. A closer look shows that the Urban Mobility Report paints a misleading and incomplete picture of urban transportation problems. The study is plagued by outdated data, flawed concepts and questionable assumptions about traffic. It turns out to be a poor guide for policy.

This analysis unfolds in five parts. First, we provide a brief description of the Urban Mobility Report (UMR), its history and methodology, and describe how it is used and the role it plays in transportation policy debates. We also review earlier literature that critically examined the UMR's methodology.

Second, we take a close look at the "Travel Time Index" the key measure underlying the Urban Mobility Report's conclusions. We find that it provides a misleading and unrealistic tool for measuring congestion and critically ignores the role of land use and accessibility in shaping urban travel. The Travel Time Index produces a distorted view of the size and nature of urban transportation problems and misidentifies those metropolitan areas with the most costly and wasteful transportation systems.

Third, we examine the models used to compute the Travel Time Index and find that they are not supported by robust statistical analysis. We also compare the UMR's estimates of the Travel Time Index and changes in travel times over the past two decades to independent estimates of these variables and find little support for the UMR's key conclusions.

Fourth, we consider the UMR's claims that traffic congestion wastes fuel. We find that the UMR has used outdated data and extrapolated data outside the statistical range for which it is valid and ignored fuel savings attributable to moderately slower travel speeds.

Fifth, to illustrate the potential for developing a more accurate and useful way of understanding urban transportation performance, we present a new set of metrics, based on and consistent with the data contained in the UMR. These metrics correct the shortcomings of the "Travel Time Index" by illustrating the contribution of travel distances to variations in metropolitan peak-period travel times. These metrics underscore the important role that sprawl and metropolitan form play in shaping travel.

As currently structured, the UMR places all of its emphasis on travel speed and ignores the role that land use and travel distance play in driving the cost of urban transportation. The report's key metric, the Travel Time Index, rewards places where people can drive fast, even if they must drive much farther. It is a measure that gives credit for going nowhere, fast.

One note on terminology. The transportation field is rife with technical terms and abbreviations. Both the Texas Transportation Institute and its headline statistic–the Travel Time Index–go by the abbreviation "TTI", so to avoid confusion, we have adopted the convention of using TTI exclusively to refer to the statistic rather than the organization. When we refer to the Texas Transportation Institute we use its full name, and we describe its work by the title of its report: The Urban Mobility Report, which we abbreviate as "UMR." The UMR focuses on peak period travel, defined as two four-hour periods each weekday, from 6 am to 10 am and from 3pm to 7 pm. The data in the report reflect the travel experience of all peak period travelers and all types of trips. While in common parlance we would describe many of these travelers as commuters—persons traveling back and forth to work—not all peak period traffic is commuting, and not all commuters travel during these peak periods. Occasionally, to simplify the exposition, we will use the term "commuter" to refer to peak period travelers. Except for the Census and NHTS commuting data reported in Section 3, this report addresses all peak period trips for all purposes.

Our analysis focuses on the nation's 51 largest metro areas, which includes all metropolitan areas with one million or more population. This group corresponds closely to those metropolitan areas classified as "very large" or "large" in the Urban Mobility Report. According to the UMR, these areas account for 81 percent of the nation's total cost associated with congestion-related delays and fuel consumption. These represent the areas with the nation's largest transportation challenges and provide a more reasonable set of areas for comparisons than examining all of the nation's metropolitan areas. This is the same set of areas that has been included in a series of other publications prepared for CEOs for Cities (Cortright, 2006, , 2008).

The author wishes to express his thanks to the Rockefeller Foundation for providing funding for this analysis and to CEOs for Cities for its sponsorship and guidance. Benjamin De La Pena at Rockefeller and Carol Coletta at CEOs for Cities immediately grasped the importance of this work, and were tireless allies and trusted advisors in executing this project. I am also deeply grateful to David Levinson, Jennifer Dill, Rob Puentes, Scott Bernstein, and Todd Litman, as well as two anonymous reviewers who provided valuable criticisms of earlier drafts. The opinions expressed in this report and any remaining errors are mine alone, of course.

I would also like to acknowledge the willingness of David Schrank and Tim Lomax of the Texas Transportation Institute to share their data and answer questions about their methodology. I applaud the transparency with which they have constructed their dataset and the care they have taken to revise historical data to reflect later methodological changes. Even though this paper is critical of many of their findings, their openness to discussion is praiseworthy. We hope this paper leads to a wider discussion of how best to measure urban transportation system performance and gives policy makers a more diverse and useful set of metrics for tackling this persistent problem.

1. About the Urban Mobility Report

The Urban Mobility Report (UMR) has been published since 1982 by the Texas Transportation Institute, an arm of Texas A&M University, (Schrank & Lomax, 2009b). The report's lead authors are Tim Lomax and David Shrank, who have worked on the underlying research since the report's inception.

The UMR assembles traffic data for each of the nation's 439 metropolitan areas and develops estimates of average travel speeds in peak and non-peak hours and uses these estimates to compute a Travel Time Index, which is the ratio of average peak to non-peak travel times in each metropolitan area. It uses this index as its definition of time lost to peak period congestion and estimates an aggregate total amount of time lost annually for each metropolitan area. In addition, the report also estimates additional fuel consumption associated with slower peak travel speeds and produces a summary of total costs for the nation as a whole.

Although the report goes back to 1982, the authors have revised its methodology several times over the years (Schrank & Lomax, 2009a). For example, they have added estimates of the impact of mass transit on peak hour travel and estimated the effects of traffic management programs on travel speeds. To their credit, the authors have also been candid about the effect of revised methods on their findings. After adopting a revised model in 2002, the authors acknowledged it reduced their prior estimates on the amount and cost of delay (Schrank & Lomax, 2003). They also have been careful to produce revised estimates for prior years using the latest methodology, so that results from one year can be directly compared to other years.

The UMR's principal finding is that traffic congestion is a significant and growing problem in metropolitan areas across the nation. The report claims that traffic congestion causes the average peak period traveler 43 hours of lost travel time yearly, and that these time losses more than doubled since 1982. Overall, it estimates the value of lost time and excess fuel consumption is $87 billion annually.

The Urban Mobility Report is widely reported and repeated. The release of the 2009 version of the report was accompanied with press coverage in national news magazines and major daily newspapers around the country (See Table 1).

Table 1. Selected news coverage of the 2009 Urban Mobility Report

Publication	*Headline*	*Date*
Baltimore Sun	No letup in city traffic congestion	July 9, 2009
Los Angeles Times	Roads in Los Angeles and Orange counties most congested in the United States	July 8, 2009
San Francisco Chronicle	Bay Area Drivers delayed 50 hours a year	July 7, 2009
Seattle Post-Intelligencer	Traffic congestion down but costs to commuters still up	July 9, 2009
Time	America: Still Stuck in Traffic	July 9, 2009
Washington Post	Auto Congestion: DC Area Ranks Second in Nation	July 8, 2009

Source: Google News Search.

The results of the Urban Mobility Report are also often used to develop comparative rankings of the severity of urban transportation problems in different metropolitan areas. These rankings identify the United States' "most congested cities," for example (Woolsey, 2008).

The report's conclusions about the cost and growth of traffic congestion are frequently invoked by legislators, interest groups and government officials (LaHood, 2009). They are widely used as the basis for arguments that more money should be invested in transportation. Following the release of the report, the President of the Transportation Development Foundation released a statement, calling the report "a real wake-up call to political leaders and the public," and asserting, "The answer is clearly more highway and public transit capacity." (Transportation Development Foundation, 2009)

The report is also widely cited in academic literature and reports. The Urban Mobility Report is a common reference for authors who want to illustrate the importance or severity of the traffic congestion problem (Arnott, Rave, & Schob, 2005; Lewis, 2008; Parry & Walls, 2007). In a few cases, authors use metropolitan level data on variations in congestion as part of other statistical analyses (Downs, 2004; Parthasarathi & Levinson, 2010; Winston & Langer, 2006).

In the policy arena, the UMR generates more heat than light. It is offered up as proof of the size of the nation's congestion problem. But there's little evidence that it is used to either at the federal, state or local levels to allocate funds, select among alternative investments, or evaluate the transportation plans.

While the UMR is cited frequently, our review of the literature suggests that few authors have carefully examined the concepts or the methodology employed to produce its conclusions. There are a handful of exceptions.

In 2001, the Surface Transportation Policy Project identified several shortcomings in the 1999 edition of the UMR and produced its own set of supplementary measures (Surface Transportation Policy Project, 2001). Starting from the UMR's measures of congestion—which it took at face value—the authors adjusted metropolitan estimates of travel delay to account for the share of the population driving to work and to account for the presence of transit alternatives to private car commuting. In 2002, the State of Washington dropped its financial sponsorship of the report, citing concerns about the reliability of the data used to compute travel speeds and raising concerns that the UMR modeling did not recognize the effects of the state's efforts to improve operational speeds through practices like ramp metering and high occupancy vehicle lanes (Pryne, 2002).

In response, subsequent versions of the UMR have addressed the effect of transit and operational improvements on travel times. The current version of the report estimates, for example, that public transportation saves 640 million hours of traffic delay that would otherwise cost the nation $13.7 billion (Schrank & Lomax, 2009b).

In his comprehensive survey of the causes and consequences of traffic congestion, Anthony Downs questioned the validity of the UMR's use of "free flow" conditions as a reasonable baseline for computing the extent of delay (Downs, 2004). In his view, the zero congestion baseline is a false premise because its hypothetical—that anyone could build enough capacity to handle all travel demand—is not just expensive, but an impossibility. In addition, even the measured level of congestion cost, about 7.69 minutes delay per traveler per trip in 2000, is not unduly burdensome. Litman (2009) points out that the costs associated with congestion are much smaller than other social costs associated with transportation, including pollution and accident-related costs. But despite his skepticism of the baseline, Downs does not suggest an alternative and in fact relies on the UMR data for a series of statistical analyses of the effects of congestion on urban economic performance.

Robert Bertini's (2005) comprehensive review of the definition and measurement of congestion examines the Urban Mobility Report. He observes that "the main mission of the UMR is to convert traffic counts to speeds, so that delay can be computed." (page 9) He notes some of the weaknesses of traffic count data from the Highway Performance Monitoring System: many traffic counts are three years old and are based on very limited samples, including 48-hour counts. Average daily traffic estimates are effectively rough estimates factored up from sample data and are subject to a variety of errors (Wang & Kockelman, 2009). Other reviewers have noted that the UMR is based on modeled speeds and not direct empirical measurements, and that the models may not capture important variations among metropolitan areas (Pryne, 2002). The Urban Mobility Report also relies on what Bertini describes as "seemingly arbitrary assumptions" about vehicle occupancy, peak period travel characteristics and the relationship between volume and speed. Bertini also argues that the UMR places too little emphasis on variations in travel distances among metropolitan areas and notes that in some cities, shrinking average travel distances at least partially offset the effects of congestion on travel time.

The Urban Mobility Report estimates the dollar value of time lost to congestion using an estimate of $15.4 per person-hour. Other analysts have questioned the appropriateness of that choice. Winston and Langer (2006) suggest using a value of 50 percent of the average wage rate (per person-hour) and their re-estimate of congestion costs suggests a total cost of congestion substantially smaller than that estimated in the Urban Mobility Report.

Todd Litman (2010a) echoes the concerns about using zero congestion as the appropriate baseline for computing the costs of congestion-related delay. In addition, he points out that sprawling development patterns can produce an improved ranking on the Travel Time Index, even though they result in greater vehicle travel and can easily result in longer travel times.

Each of these authors has raised concerns about the reasonableness of portions of the Urban Mobility Report, but usually only in passing. The remainder of this paper examines the UMR in greater detail, in an effort to evaluate more rigorously its usefulness as a guide to transportation policy and to suggest ways that it could be improved.

2. Evaluating the Travel Time Index as Guide to Transportation Policy

At the core of the Urban Mobility Report is the calculation for each metropolitan area of a Travel Time Index, which is the ratio of peak travel times to non-peak travel times. The Travel Time Index, in turn, serves as the basis for computing the total number of hours of delay. The equation for computing the Travel Time Index is as follows:

TTI = Congested Travel Time / Free Flow Travel Time

Here's an example of how the Urban Mobility Report uses the Travel Time Index to estimate of total delay in a metropolitan area. In 2007, the Travel Time Index across the United State's largest 51 metropolitan areas was 1.25. This means, for example, that a trip that takes 20 minutes in free flow conditions is estimated to require, on average, 25 minutes during peak travel times (25/20 = 1.25). After examining data for all of the nation's metropolitan areas and summing results for an entire year, the Urban Mobility Report estimates that the average commuter in these regions (which together account for a majority of the U.S. population) faces 36 hours of delay annually.

For some readers, the metric of hours per year will seem cryptic. It is perhaps more intuitive to convert the UMR measures to minutes per daily peak period traveler. We adopt the simplifying assumption that, on average, peak-hour travelers make two peak period trips per day.

For these 51 cities, the Travel Time Index implies that each peak-period traveler spent about 180 hours per year in peak-period travel. At 250 working days per year and 60 minutes per hour, this works out to total peak hour travel time of 43.2 minutes, or two peak hour trips of about 21 minutes and 40 seconds per day. The Travel Time Index implies that the typical peak hour trip would have taken about 17 minutes and 20 seconds in free-flow conditions, but because of traffic congestion, the trip actually took about 4 minutes and 20 seconds longer.[1]

About 90 percent of the estimated costs associated with congestion delays come from adding up this average 4 minutes and 20 seconds per peak period trip delay over all of the nation's travelers and over the course of a full year. At a value of time of $15.47 per person hour, the 36 hours of delay is valued in the UMR at $555 per year per peak hour traveler.

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[1] Proofs:
Total Hours Per Year: 36 congested hours + 144 un-congested hours = 180 total hours; 180 / 144 = 1.25.
Delay: 4.32 minutes per trip x 2 trips per day x 250 days per year / 60 minutes per hour = ((4.32*2)*250))/60)= (8.64*250)/60 = 2160/60 = 36 hours per year.
Travel Time Index: (4.32 minutes per trip delay + 17.28 minutes per trip un-congested travel time) / 17.28 minutes un-congested travel time = (4.32 + 17.28) / 17.28 = 21.60 /17.28 = 1.25

2.1 Baseline for Congestion Costs

The Travel Time Index defines free-flow travel speeds as 60 miles per hour on freeways and 35 miles per hour on arterials. The Travel Time Index calculates all of the additional time that peak period trips take any time average speeds on freeways and arterials are less than these values.

As Anthony Downs (2004) has pointed out, the central premise of the Travel Time Index is unrealistic. It assumes that somehow we can build enough roads so that everyone traveling at peak hours can have the same travel time that people enjoy when roads are operating far below capacity. It is far from clear that it would be physically, much less financially, possible to build so much highway capacity. Downs concludes:

> The "waste" of time and fuel generated by traffic congestion is to a great extent unavoidable; so presuming it could be eliminated is fantasy. Using a utopian free-flowing state as a measuring rod. . . should not be seen as a realistic measure of costs generated by congestion that might be avoided by policy changes. (Downs, 2004)

Chris Bradford echoes this point:

> There is no realistic, hypothetical state of the world in which we would experience perfect, free-flow traffic everywhere. It would not be feasible to build enough roads (or charge enough for them), particularly since free-flow speeds would entice more drivers onto the road. So to imply that there is $87 billion of waste to be saved -- and I think TTI does imply this -- is simply wrong. (Bradford, 2009)

It is not clear that every deviation from the zero-delay ideal can accurately be described as a cost. Using a lower baseline for defining costly congestion-related time delays—like 45 miles per hour on freeways, or 80 or 90 percent of free-flow speeds—would give a much lower estimate of the costs of congestion. In the United States, there are no large metropolitan areas that achieve a Travel Time Index of 1.0, nor is it the case that the economically optimal level of congestion is zero. It would be more reasonable to define costs in terms of some benchmark that is actually achieved in practice by some metropolitan area. This report considers an alternative baseline, based on actual performance, in Section 5.

2.2 Travel Time Index and Distance Variations

In some respects, the Travel Time Index would be a reasonable way of comparing the performance of urban transportation systems if all peak period trips were the same distance, or put somewhat differently, if the average distance of a trip were the same in each metropolitan area.

Curiously, for all of the detailed information it provides about metropolitan transportation performance and hours of delay, the Urban Mobility Report offers no data addressing either the average distance of peak hour trips or the **total** amount of time spent in peak hour travel. Nor does it discuss changes in travel distances or total peak hour travel times over time. The report is simply silent on the subject of how far Americans travel in the peak hour and how long in total they spend in peak hour traffic.

But, in fact, average peak period travel distances vary substantially among metropolitan areas. Some areas have relatively short distance peak period trips, on average, while others travel much greater distances. Table 2 presents the average peak period travel distances for each area based on the Urban Mobility Report's spreadsheet values. (Appendix A explains how travel distances were computed.)

Among these metropolitan areas with one million or more population, the average distance traveled daily in the peak period ranges from a low of 12.2 miles (per peak-period traveler) in New Orleans, to a high of 25.6 miles in Nashville. While the median metropolitan area has a peak period travel of 19.4 miles per peak traveler per day, a quarter of all metropolitan areas have daily peak period travel of more than 20.9 miles per day, and one quarter have daily peak period travel of less than 17.3 miles per day.

For comparison, Table 2 also shows total vehicle miles traveled by metropolitan area, as reported by the Federal Highway Administration (Federal Highway Administration, 2009). While these statistics are constructed from the same underlying data—the Highway Performance Monitoring System—they measure total travel (at all times, not just peak hours) and are expressed as per capita figures, rather than per peak period traveler. Despite the differences in definition, this data source also shows significant variation in travel distances across metropolitan areas. The fact that both the Urban Mobility Report and the FHWA vehicle miles traveled statistics are based on the HPMS signals our dependence on this source of data for assessing urban transportation.

Travel distances vary across metropolitan areas for a variety of reasons. One comprehensive review of more than 200 studies of the subject found that residential and job density, access to destinations like shopping and workplaces, the diversity of land uses, the design of the street network, and the availability and quality of transit and walking infrastructure all have significant impacts on the distances people travel (Ewing & Cervero, 2010). Some metropolitan areas are much more densely settled than others, so that more destinations are closer to households, shortening the average length of trips. Some metropolitan areas have very sprawling job patterns, with most jobs located far from the urban core, while others are much more compact (Glaeser, Kahn, & Chu, 2001).

Table 2: Peak Period Travel and Vehicle Miles Traveled by Metropolitan Area, 2007

Metropolitan Area	Average Peak Period Miles per Day	Average Vehicle Miles Traveled Per Capita per Day	Abbreviation
Atlanta GA	21.6	30.0	ATL
Austin TX	16.2	29.9	AUS
Baltimore MD	18.8	24.4	BAL
Birmingham AL	23.3	35.7	BIR
Boston MA-NH-RI	19.8	23.0	BOS
Buffalo NY	16.6	20.5	BUF
Charlotte NC-SC	19.1	34.5	CHA
Chicago IL-IN	13.5	21.2	CHI
Cincinnati OH-KY-IN	17.7	24.8	CIN
Cleveland OH	16.3	22.2	CLE
Columbus OH	19.9	26.1	COL
Dallas-Fort Worth-Arlington TX	20.9	29.1	DFW
Denver-Aurora CO	17.0	24.9	DEN
Detroit MI	20.9	26.3	DET
Hartford CT	19.9	25.1	HAR
Houston TX	22.1	37.7	HOU
Indianapolis IN	22.6	32.8	IND
Jacksonville FL	20.5	33.7	JFL
Kansas City MO-KS	21.6	29.6	KC
Las Vegas NV	17.6	29.0	LV
Los Angeles-Long Beach-Santa Ana CA	21.1	22.8	LA
Louisville KY-IN	21.7	27.1	LOU
Memphis TN-MS-AR	20.7	26.6	MEM
Miami FL	16.5	24.9	MIA
Milwaukee WI	17.2	24.3	MIL
Minneapolis-St. Paul MN	20.1	25.2	MSP
Nashville-Davidson TN	25.2	32.8	NAS
New Orleans LA	12.6	15.2	NO
New York-Newark NY-NJ-CT	18.9	17.0	NYC
Oklahoma City OK	24.1	32.5	OKC
Orlando FL	20.9	30.9	ORL
Philadelphia PA-NJ-DE-MD	17.4	20.3	PHI
Phoenix AZ	19.4	23.4	PHO
Pittsburgh PA	15.8	21.4	PIT
Portland OR-WA	16.0	20.1	PDX
Providence RI-MA	18.2	21.5	PRO
Raleigh-Durham NC	22.2	32.2	RAL
Richmond VA	22.5	29.0	RIC
Riverside-San Bernardino CA	18.2	23.4	RIV
Rochester NY	14.9	23.6	ROC
Sacramento CA	16.2	19.0	SAC
Salt Lake City UT	16.0	21.9	SLC
San Antonio TX	20.2	28.2	SAT
San Diego CA	19.8	23.7	SDO
San Francisco-Oakland CA	19.5	22.5	SFO
San Jose CA	19.0	22.4	SJO
Seattle WA	18.8	22.5	SEA
St. Louis MO-IL	20.7	29.6	STL
Tampa-St. Petersburg FL	17.8	28.1	TPA
Virginia Beach VA	18.0	23.3	VBA
Washington DC-VA-MD	21.5	23.2	WDC

Source: Urban Mobility Report and (Federal Highway Administration, 2009)

Because travel distances vary among metropolitan areas the Travel Time Index presents a partial and incomplete view of which metropolitan areas have the best and worst total travel times. To illustrate this, consider a hypothetical example. Suppose we have two cities: Sprawlville and Compact City. The principal attributes of our two communities are summarized in Table 3. In Sprawlville houses, jobs and other destinations are spread out and residents on average travel 20 miles in the peak hour. In Compact City, these destinations are close together and peak hour trips average 10 miles. For simplicity, we'll assume un-congested travel speeds in both cities are 30 miles per hour on average. And we'll assume that each city has five minutes of travel delay. This means average travel per day is 45 minutes in Sprawlville (40 minutes to travel 20 miles at 30 miles per hour, plus 5 minutes of delay) and 25 minutes in Compact City, (20 minutes to travel 10 miles at 30 miles per hour, plus 5 minutes of delay).

Table 3: A Hypothetical Comparison

	Sprawlville	Compact City
Average Trip	20 miles	10 miles
Un-congested Travel Time	40 minutes	20 minutes
Delay	5 minutes	5 minutes
Total Travel Time	45 minutes	25 minutes
Travel Time Index	1.12	1.25

Source: See Text

Our hypothetical example illustrates three key points about the Urban Mobility Report. First, the Travel Time Index will be twice as high for Compact City as for Sprawlville. In Compact City, the Travel Time Index is 25/20 or 1.25. In Sprawlville, the Travel Time Index is 1.12 (45/40). Even though both cities have the same amount of delay (5 minutes), because the Travel Time Index is computed as a ratio where the denominator is the total amount of time spent traveling, places with longer average trip lengths will have lower travel time indices. All other things being equal, if trips get longer (say the average commuter adds 5 more minutes to their trip), the larger will be the denominator in the equation, and the lower will be the Travel Time Index. Conversely, cities that shorten their average trip lengths will, all else equal, see an increase in their Travel Time Index.[2]

Second, focusing on the Travel Time Index obscures the fact that people in Sprawlville are traveling much farther and spending much more total time doing so than people in Compact City. The average daily travel time in Sprawlville is 20 minutes longer than the average daily travel time in Compact City. But this factor has no weight at all in the Travel Time Index calculation. The Travel Time Index makes the impact of longer travel distances actually disappear from view in describing urban transportation systems.

Third, while the UMR computes the added costs associated with the five minutes of delay in both cities, it ignores the added costs that the residents of Sprawlville have to pay in

[2] Except for Bertini 's (2005) work and a brief mention by Litman (2010a), this aspect of the Travel Time Index appears to have gone unnoticed in previous analyses of the Urban Mobility Report.

terms of the lost time and added fuel cost of traveling longer distances. In our example, the additional travel time associated with sprawl would be four times as large (20 minutes vs. 5 minutes) as the impact of delay.

Sprawlville and Compact City are hypothetical. But real-world examples show the way the Travel Time Index conceals key differences in urban transportation between different cities. Consider the UMR data for Charlotte and Chicago, shown in Table 4. Chicago has a Travel Time Index of 1.43 (the second highest overall, behind only Los Angeles), while Charlotte has a TTI of 1.25 (just about equal to the average). This would appear to indicate that urban travel conditions are far worse in Chicago. But the traffic delays in the two regions are almost identical (40 and 41 hours per year, or about 10 minutes per day). Chicago has average daily travel distances (for peak hour trips) of 13.5 miles, while Charlotte has average travel distances of 19 miles. Because they travel nearly 50 percent farther then their counterparts in Chicago, Charlotte travelers end up spending a lot more time in traffic, about 48 minutes per day, rather than 33 minutes per day.

Table 4: A Comparison of Charlotte and Chicago

	Charlotte	Chicago
Average Trip	19 miles	13.5 Miles
Un-congested Travel Time	38.4 minutes	22.8 minutes
Delay	9.6 minutes	9.8 minutes
Total Travel Time	48.0 minutes	32.6 minutes
Travel Time Index	1.25	1.43

The Urban Mobility Report focuses on one aspect of urban transportation: the number of additional hours that peak hour travelers spend traveling because of congestion-related delay. But congestion is neither the only nor even the most important determinant of the amount of time urban residents spend in peak period travel. Travel distances, which in turn are shaped by land use patterns and household and business location decisions, also play a key role in determining the extent and cost of peak period travel.

A more comprehensive indicator of the performance of urban transportation systems is total travel time. Although this statistic is not reported in the UMR, it can be computed from the Travel Time Index (by simply taking total delay per peak-period traveler, multiplying by the TTI and dividing by the TTI minus 1: for example, a TTI of 1.25 with delay of 9.6 minutes results in a total travel time of 9.6*1.25/.25 = 48.0 minutes).

Table 5 shows two rankings of our group of large metropolitan areas. The ranking on the left shows metropolitan areas ranked by the total number of hours of delay, as estimated in the UMR. The ranking on the right of the table shows metropolitan areas ranked by total travel time.

Table 5: Delay versus Total Travel Time

Total Hours of Delay			Total Hours of Peak Period Travel	
Los Angeles-Long Beach CA	70		Nashville-Davidson TN	284
Washington DC-VA-MD	62		Oklahoma City OK	252
Atlanta GA	57		Birmingham AL	245
Houston TX	56		Richmond VA	242
San Francisco-Oakland CA	55		Raleigh-Durham NC	234
Dallas-Fort Worth-Arlington TX	53		Memphis TN-MS-AR	233
Orlando FL	53		Detroit MI	231
San Jose CA	53		Orlando FL	230
Detroit MI	52		Kansas City MO-KS	229
San Diego CA	52		Louisville KY-IN	228
Miami FL	47		St. Louis MO-IL	226
Tampa-St. Petersburg FL	47		Houston TX	226
Denver-Aurora CO	45		Indianapolis IN	225
Baltimore MD	44		Washington DC-VA-MD	221
Las Vegas NV	44		Atlanta GA	220
New York-Newark NY-NJ-CT	44		Dallas-Fort Worth-Arlington TX	219
Phoenix AZ	44		Los Angeles-Long Beach CA	213
Riverside-San Bernardino CA	44		Jacksonville FL	209
Boston MA-NH-RI	43		Boston MA-NH-RI	208
Seattle WA	43		San Antonio TX	203
Chicago IL-IN	41		Minneapolis-St. Paul MN	202
Charlotte NC-SC	40		San Jose CA	200
Austin TX	39		Charlotte NC-SC	200
Indianapolis IN	39		Providence RI-MA	200
Jacksonville FL	39		Tampa-St. Petersburg FL	199
Minneapolis-St. Paul MN	39		Columbus OH	197
Sacramento CA	39		Hartford CT	196
Louisville KY-IN	38		San Diego CA	193
Philadelphia PA-NJ-DE-MD	38		New Haven CT	192
San Antonio TX	38		Seattle WA	191
Nashville-Davidson TN	37		Las Vegas NV	191
Portland OR-WA	37		Phoenix AZ	191
Raleigh-Durham NC	34		Denver-Aurora CO	190
Birmingham AL	32		Virginia Beach VA	190
Columbus OH	30		San Francisco-Oakland CA	186
Providence RI-MA	29		Baltimore MD	186
Virginia Beach VA	29		Pittsburgh PA	182
Oklahoma City OK	27		Rochester NY	177
Salt Lake City UT	27		Miami FL	174
St. Louis MO-IL	26		Philadelphia PA-NJ-DE-MD	174
Cincinnati OH-KY-IN	25		Austin TX	173
Memphis TN-MS-AR	25		Salt Lake City UT	169
Hartford CT	21		Buffalo NY	168
New Orleans LA	20		Riverside-San Bernardino CA	166
Richmond VA	20		Portland OR-WA	165
New Haven CT	19		Cincinnati OH-KY-IN	164
Milwaukee WI	18		New York-Newark NY-NJ-CT	163
Kansas City MO-KS	15		Cleveland OH	162
Pittsburgh PA	15		Sacramento CA	161
Cleveland OH	12		Milwaukee WI	156
Buffalo NY	11		New Orleans LA	138
Rochester NY	10		Chicago IL-IN	136

Source: Urban Mobility Report and Author’s calculations.

The metropolitan areas with the longest total peak period travel times are not those with the longest congestion-related delays. Of the ten metropolitan areas with the greatest levels of delay, according to the UMR, only two—Detroit and Orlando—ranked in the top ten metropolitan areas with the longest peak period travel times.

Looking only at delay gives a very different picture of the burden of peak hour travel than a more comprehensive view. For example, if one looks only at delay, one would assume that peak hour travel was much more onerous in San Francisco than in Kansas City: the average San Francisco commuter faces, according to the UMR, 40 more hours of delay annually than that of her Kansas City counterpart (55 hours versus 15). But the total travel time picture appears to be the opposite, when working with the UMR's summary statistics. The Kansas City commuter spends 229 hours per year in peak hour traffic, compared to just 186 hours for her San Francisco counterpart (a difference of 43 hours per year).

The length of peak period trips can change over time, based on a variety of factors, including urban density and development patterns and household and business location choices. When we construct estimates of peak period travel distances from data in the UMR (See Appendix A), it is apparent that in many metropolitan areas the effects of congestion have been largely or fully offset by shorter travel distances.

Consider the example of Portland, Oregon. Measured by the Travel Time Index, congestion has become much worse in Portland, growing from 1.07 in 1982 to 1.29 in 2007. But over that same period of time, the data in the UMR imply that average peak period travel distances in Portland have fallen one-sixth, from 19.6 miles per peak period traveler in 1982, to 16.0 miles per peak period traveler in 2007.[3] As a result, average peak period travel times have actually gone down, from 54 minutes per day to 43 minutes per day. So rather than getting three times worse (as implied by the Travel Time Index), the average peak period traveler in Portland actually experienced shorter travel times in 2007 than he did 25 years earlier.

In a sense, delay is a product not only of how many cars are on the road at peak hour (the Travel Time Index), but also a product of the degree to which a region's jobs, population, and other activities are separated from one another. Regions with long travel distances may suffer a travel time penalty partly because of congestion, but also because destinations are so far flung and everyone has to travel so far to reach them. Conversely, in the case of more compact metropolitan areas, the Travel Time Index makes no allowance for the fact that the residents of such regions are systematically less exposed to or less affected by congestion because they have travel shorter distances.

The use of the Travel Time Index and the focus on computing hours of delay presents a very partial and selective view of urban transportation systems. It does so to the exclusion of total travel time. As a result, the role of sprawl and land use patterns in

[3] See Appendix A for method used to compute average peak period travel distances. This analysis elaborates on the point made by Bertini (2005).

increasing travel times in many cities is effectively rendered invisible by the UMR methodology. The UMR's delay estimates neither reveal nor shed any light on why the residents of cities such as Nashville, Oklahoma City and Birmingham spend more time in peak period traffic than in every other large metropolitan area in the nation.

A study that purports to explain differences in travel time between metropolitan areas that does not address the information shown in Table 5 is at best a limited guide to setting policy. It is possible to expand the analysis of urban transportation system performance to address variations in travel distances. As an illustration, Section 5 of this report estimates the amount of travel time, number of miles traveled, amount of fuel used due to excessive peak period travel distances.

3. Estimating Congestion-related Travel Delays

The preceding section questioned whether the Travel Time Index was a useful concept for characterizing metropolitan congestion. This section examines whether the estimated values of the Travel Time Index presented in the Urban Mobility Report are reliable and accurate indicators in practice. At the core of the Urban Mobility Reports are estimates of congestion-related delays. These estimates are the result of complex calculations, based on data about highway travel volumes from around the nation combined with a model of how volume affects speed on freeways and arterials. This section examines these models and their accuracy and compares their results to other indicators of urban transportation systems that serve as checks on the reliability of UMR values.

3.1 Modeled vs. Actual Speeds

The Urban Mobility Report's key measure of congestion is how much longer it takes drivers to travel at peak hours than it does when roads are free-flowing. In essence, the Travel Time Index is all about speed. If the free flowing speed of a road is 60 miles per hour and it averages 30 miles per hour during the peak, the Travel Time Index is 2.00 (i.e. it takes 10 minutes for a five mile trip rather than just 5 minutes).

Given the central role speed plays in calculating the Travel Time Index, it would surprise most readers to know that the Texas Transportation Institute historically has not used any data that directly measures traffic speeds in metropolitan areas. Rather, the Urban Mobility report uses data on traffic volumes—the number of cars traveling on the nation's highways in each metropolitan area—to estimate the average speeds on its roads.

A few reviewers have noticed the report's reliance on volume rather than speed data to compute the index and recognized that this casts doubt on the robustness of the reports conclusions. Robert Bertini notes:

> No actual traffic speeds or measures extracted from real transportation system users are included, and it should be apparent that any results from these very limited inputs should be used with extreme caution (Bertini, 2005).

Because it is not based on direct observations of travel speeds, the Urban Mobility Report has to produce estimates of speeds from indirect evidence about urban travel patterns. This adds an unknown error into the estimates of congestion impacts. It also means the accuracy and reliability of the model used to estimate speeds is critical to the validity of the report.

In addition, because the UMR model translates volumes into speeds, any increase in volume in excess of an increase in capacity results in a lower estimated speed. This problem was noted by the Washington State Department of Transportation which noted that the UMR model effectively penalized it for increasing traffic flows because the model mechanically predicts greater volumes produce greater delays (Pryne, 2002). The UMR's claimed finding that congestion has increased steadily is not a direct observation, but rather an artifact of its model.

3.2 Volume to Speed Model Accuracy

The linchpin in the UMR's computation of its key metric—the Travel Time Index—is its use of a statistical model that converts highway road volumes to estimates of average travel speeds at peak travel times. While the actual computation is quite complex, in simplest form, the UMR takes data on travel volumes—the number of vehicle miles traveled by road type in each metropolitan area—and using its volume-to-speed formula, estimates how fast travel moves at different times during the day.

While it would be preferable to rely on direct observations of travel times, until recently such data did not exist for a wide range of metropolitan areas.[4] However, travel volume data are relatively plentiful and are collected and tabulated in reasonably consistent ways across the nation.

As a result, the model used to transform volume data into speed data drives the results of the study. If there were a simple, linear relationship between traffic volumes and speed, this would be a much more straightforward problem. But there is not. The relationship between traffic volumes and speeds is complex, dynamic, and non-linear. Up to some peak level of traffic volume, roads actually perform well, and then, past some tipping point (which varies by road and has some random characteristics), queues form on roads, and these backups get longer and longer as the number of vehicles trying to use the road exceeds its carrying capacity (which may deteriorate as traffic becomes more chaotic) .

The relationship between traffic volumes and traffic speed is one that defies simple-minded modeling. The consensus of the transportation literature is that highway traffic flows are subject to a kind of tipping point phenomenon. Up to a certain level of volume, there is little or no impact on average speeds. Beyond that point, it is increasingly likely that speeds will fall precipitously.

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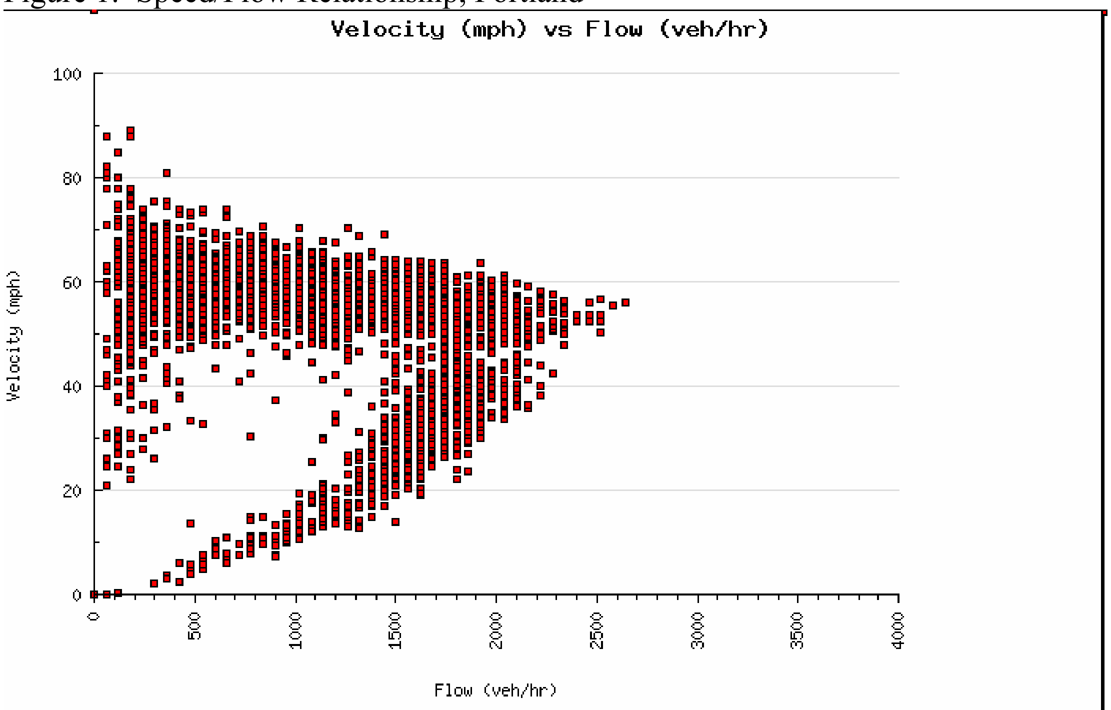
[4] For the past three years, Inrix, a Seattle based provider of real time traffic information has published data it gathers on travel speeds in metropolitan areas across the United States. The Texas Transportation Institute has announced that it will use these estimates, rather than its volume/capacity model to produce future Urban Mobility Reports.

Most empirical work examines the relationship between travel speeds and traffic volumes on an hourly or more frequent basis. Actual data collected for Interstate 5 (the principal North-South Freeway through the Portland Metropolitan Area) is shown in Figure 1, where the data show the average of speed speeds and volume observations, calculated on a minute by minute basis, for September 11, 2008, through Portland's Terwilliger Curves (a segment of Interstate 5), a heavily traveled commuter route just south of the city center. The diagram illustrates the "backward bending" character of the volume/speed relationship. For most travel volumes, traffic moves at speeds close to (or above) the legal limit. Above about 2000 vehicles per lane per hour, traffic reaches a critical point, queues propagate backwards to upstream links, which then slow down sharply. The throughput of upstream links is limited by their downstream bottleneck, the source of the congestion.

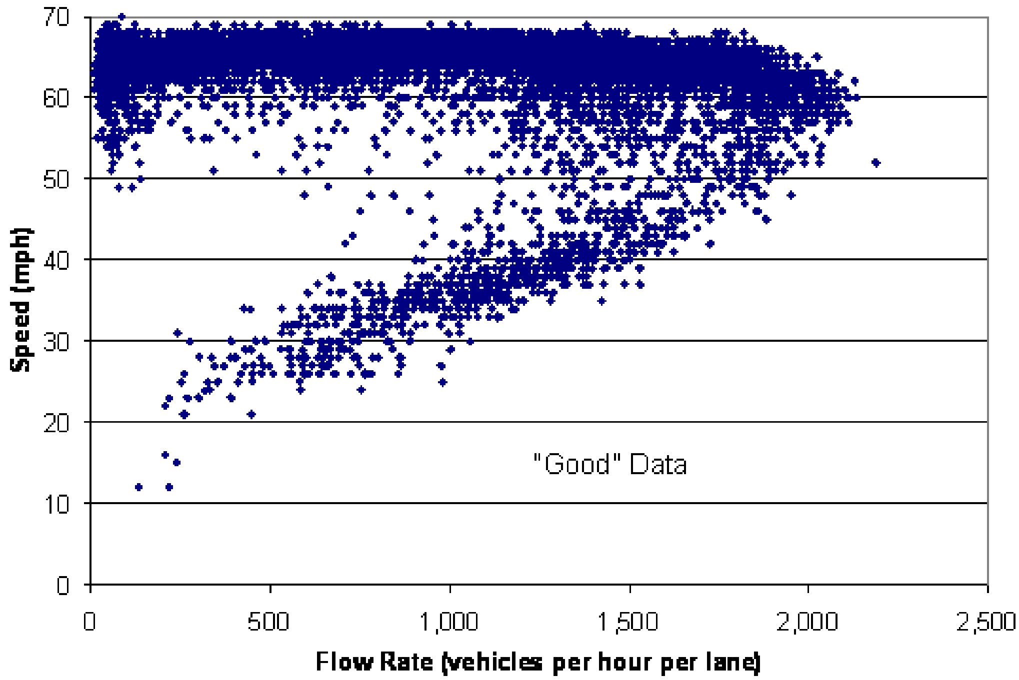
Figure 1: Speed/Flow Relationship, Portland



Source: (Intelligent Transportation Systems Laboratory, 2010)

The shape of this speed-volume relationship is well established in the literature. In their analysis of data to calibrate their volume/capacity model, the authors of the UMR provide a very similar chart summarizing combined data they gathered from four cities: Baltimore, Los Angeles, Phoenix and San Antonio (Schrank & Lomax, 2006). The chart contains the label "'Good Data" because the points shown represent a censored sample of observations selected by the authors of the UMR.

Figure 2: Hourly Speed-Flow Relationship



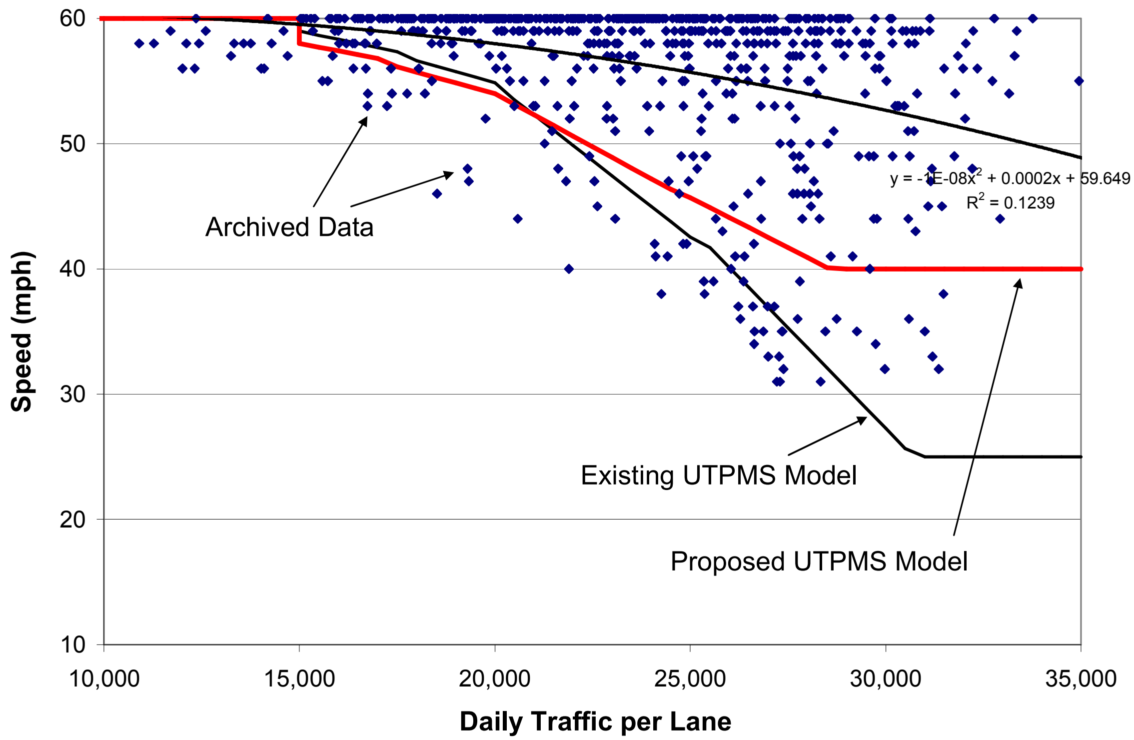
Source: Schrank & Lomax, 2006

While the shape of the hourly speed-flow relationship is well established, the authors of the Urban Mobility Report do not have access to hourly data on traffic volumes to make their calculation. Instead, they rely on the much more commonly available data on average daily traffic. As a result the Urban Mobility Report uses a model that estimates peak hour speeds based on average traffic flow per lane over a wide 24-hour period.

In 2006, the authors re-examined their methodology and changed parameters for their UTPMS Model (Schrank & Lomax 2006). This new model suggested that below about 15,000 vehicles per lane per day, average traffic speeds did not decline from free flow levels (60 miles per hour). Above 15,000 vehicles per lane per day, speed gradually declined to about 55 miles per hour. Above 20,000 vehicles per lane per day, traffic speeds declined more sharply with incremental volume. Figure 3 reproduces a chart showing the data and estimated speed-flow relationships from that report.[5]

[5] The legends "Archived Data", "Existing UTPMS Model" and "Proposed UTPMS Model" are from the original report. This analysis adds the curved regression line and accompanying equation. "UTPMS" stands for Urban Transportation Performance Measurement Study.

Figure 3: Daily Speed/Volume Relationship



Source: Schrank & Lomax (2006) "TTI New Speed Curves 13-14"

The authors explain that because there is no theoretical agreement on the appropriate functional form that should be used to fit the speed-volume data, that the researchers should simply "eyeball" the relationship and develop their own definition.

> . . . when trying to determine if detailed traffic data resembles the accepted speed-flow model, interpretations by the researcher were made based on visual inspection of the data instead of a mathematical model.
> (Schrank & Lomax, 2006)

In reality, every road performs differently, due to upstream and downstream bottlenecks, shoulder-width and grade/slope variations, traveler types, and so forth. The line "Proposed UTPMS Model" drawn in Figure 1 lies below about 80 percent of all the points, which suggests that 80 percent of the time, the model predicts that speeds will be lower than those actually observed in the dataset. A simple quadratic equation fitted to their data (the downward curving line that terminates at about 48 miles per hour at 35,000 average daily vehicles per lane) is shown for comparison purposes. It implies much higher speeds and much less deterioration in average speeds as volume increases than the model used in the Urban Mobility Report.

It is questionable whether a relationship estimated from a visual inspection of the data is a robust and defensible source for computing the speed reduction associated with higher volumes. As with art, the beauty of such "visual" estimation is in the eye of the beholder.

A different viewer could see a different relationship, and it would be neither more nor less valid than the one selected by the authors. This is crucial to the conclusions in the Urban Mobility Report because all of the subsequent computations of the costs of congestion (hours lost, additional fuel costs) are based squarely on the computation of the Travel Time Index. Different but equally reasonable assumptions about this visually estimated relationship would produce far smaller estimates of speed reductions from added volume and much lower estimates of congestion-related costs. The simple statistical analysis presented here suggests that the visual estimate made by the authors substantially overstates the impact of increased volume on travel speeds.

3.3 Hourly vs. Daily Volumes

The relationship between traffic volume and speed depends on traffic volume at specific times. An additional car traveling at the peak hour has a big impact on travel times. An additional car added at 5 am will have a very different impact on an urban roadway's performance than an additional car added at 5 pm. So measuring peak hour travel volumes is critical.

In theory, if the authors had access to continuous or even hourly data on traffic volumes they could estimate speeds separately for peak and non-peak hours using its volume to speed model. But the Urban Mobility Report is not based on these kinds of detailed data. Instead, it relies on average 24-hour travel volumes, a measure called "ADT" or average daily travel, again, because this has been the only consistent data available, through the FHWA's Highway Performance Monitoring System. To convert these daily data to peak hour data, the UMR assumes that in every U.S. metropolitan area, 50 percent of all travel occurs during the peak hours (6 to 10 am in the morning and 3 to 7 pm in the afternoons).

The URM does not address whether this estimate is accurate for all metropolitan areas and whether this ratio has remained constant over time. This assumption could significantly influence the accuracy of travel time estimates. If some metropolitan areas have a lower fraction of their traffic at these peak hours, this would overstate peak hour traffic and over-estimate delays. If the share of daily traffic traveling at the peak period has declined over time, this assumption would tend to overstate the increase in the Travel Time Index and consequently over-estimate delay.

The methodology that the Urban Mobility Report has chosen—to assume that peak hour travel is a fixed share of total travel and to assume that increases in traffic move in a linear and proportional way to traffic delays—means that increased daily traffic counts automatically translate into slower estimated peak period travel times. In effect, the UMR model is structured in such a way that if average daily volumes increase, peak period travel times are assumed to increase. Whether the peak period travel times actually increase in practice is not observed directly.

3.4 Validity Checks on Speed Estimates

The decision of the authors of the Urban Mobility Report to estimate traffic speeds based on capacity data was a pragmatic one. Until very recently, comprehensive, comparable and metropolitan level data on travel speeds on the nation's urban highways did not exist.

In recent years, however, the widespread deployment of wireless data networks and global positioning systems in the commercial transportation sector has created an entirely new and more detailed source of data on travel speeds. Today, a large fraction of commercial delivery vehicles in the United States (including long-haul trucks, UPS and FedEx delivery vehicles, private fleets, and taxis) are equipped with GPS systems and cellular data connections tied into real-time fleet management systems. These data pinpoint the speed and location of more than a million vehicles at all times.

A number of data aggregators use this information to generate real time data on traffic speeds on major roadways in every principal metropolitan area in the US. One provider of these data is a Seattle-based company, Inrix.

Inrix summarizes its data for metropolitan areas on an annual basis. For the past three years, Inrix has produced its National Traffic Scorecard that uses these data to identify the nation's biggest bottlenecks and to track trends in travel time on more than 47,000 miles of urban roads around the nation (Inrix, 2010).

The Inrix data are both more precise and more timely than the UMR estimates.[6] The Urban Mobility Report assumes that it can predict peak period speeds on the highway system by extrapolating from daily levels of traffic. Inrix reports that it monitors more than two million vehicles and track travel speeds on 250,000 miles of highways and city streets. The Inrix data are also timelier. The 2009 Urban Mobility Report was based on data for calendar year 2007 and was published in July 2009 (an 18-month lag). The Inrix National Transportation Scorecard produced estimates for calendar year 2008 nearly four months earlier (a 4-month lag).

Like the Urban Mobility Report, the Inrix National Transportation Scorecard computes a Travel Time Index for each of the nation's metropolitan areas; however, it uses its own actual data on speeds, as opposed to the UMR's use speed estimates based on daily volumes and a volume/speed model. The estimates also differ slightly in the roadways covered and geographies. The Inrix report uses Census-defined core-based statistical areas. The UMR gathers data for the urbanized portions of metropolitan areas and its estimates are based on traffic volumes measured on limited access roads and arterials.

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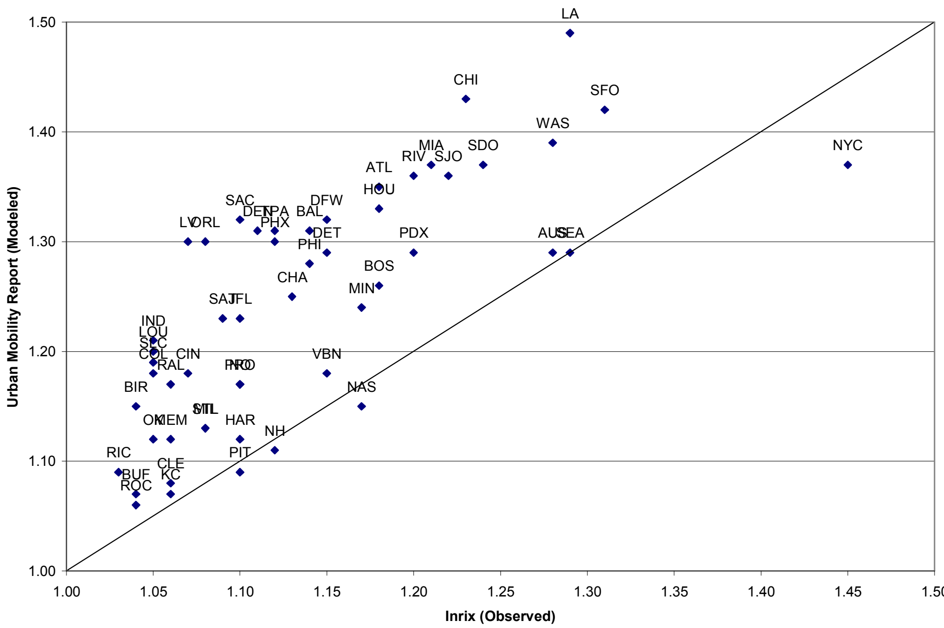
[6] To its credit, the authors of the Urban Mobility Report have announced their intention to use the Inrix data as the basis for future estimates of the Travel Time Index

Figure 4 compares the Urban Mobility Report's modeled values for the Travel Time Index for each of the 51 largest U.S. Metropolitan areas with the Inrix estimates of the Travel Time Index for those same metropolitan areas for 2007.

Figure 4: Urban Mobility Report and Inrix Estimates of Travel Time Index for Major Metropolitan Areas, 2007



Source: Inrix and UMR; data for 2007
(Note: For key to metropolitan area abbreviations, please see Table 2.)

The UMR values are consistently higher than those observed by Inrix. In only three cases—New York, Pittsburgh and Nashville—are the values observed by Inrix lower than the values estimated in the Urban Mobility Report. The line drawn at a 45 degree angle on the chart would be the point at which the travel time indices from the two different sources were exactly equal. If the two sources were measuring the same phenomenon in the same way, one would expect the observations for each city to be tightly clustered near this line. More than 90 percent of the time, the Urban Mobility Report estimates are higher than the Inrix values (above the line). Averaged across all these metropolitan areas, on a city-weighted basis the Urban Mobility Report estimate is a full ten points higher (1.24) than the observations recorded by Inrix (1.14). These data mean that the UMR estimate of the effect of congestion on speed is more than 70 percent higher (.24/.14).[7] It is worth noting that the Inrix data are positively correlated with the UMR estimates for the Travel Time Index (R^2=.54). Cities that score high on the UMR estimates also tend to score high in Inrix data.

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[7] Later, we show that the UMR estimates of the Travel Time Index are in the aggregate about 50 percent higher than those calculated by Inrix when we compute mean values on a population-weighted basis. The lower estimate of bias for the population-weighted mean appears to be entirely driven by a single case--New York City—where the UMR estimated Travel Time Index is lower than the Inrix estimate.

One difference between the UMR and Inrix TTI calculations is their choice of geography. The UMR uses data that applies to the Census-defined “urbanized areas” within metropolitan statistical areas. The Inrix data applies to the entire metropolitan statistical area. The urbanized area typically accounts for 80 percent of the population in metropolitan statistical areas, but this varies across metropolitan areas. To test whether the difference between these two geographical definitions had any effect on Travel Time Index calculations, we compared the percentage of MSA population in urbanized areas to the ratio of the Inrix to UMR travel time indices. In some metropolitan areas there is no difference between the MSA and the urbanized area population (almost all the area is urbanized). In other metropolitan areas, the urbanized population is a much smaller fraction of MSA population. If the difference in geographies accounted for the difference in Travel Time Index calculations, we would expect those metropolitan areas with the most urbanized populations to have very similar TTIs, whether computed by Inrix or UMR. Conversely, we would expect metropolitan areas with the smallest urbanized areas to have very different TTIs depending on the source. Our analysis shows that there is no correlation between the ratio of the two travel time indices and the share of the metropolitan area population that is in the urbanized area – $R^2 = .004$. This indicates that the difference between the two calculations is not attributable to the different base geographies.

The consistently lower values for the Travel Time Index reported by Inrix suggest that the UMR methodology substantially overstates traffic delays. While the Inrix data do not cover all of the streets in every metropolitan area, they do cover the major freeways and arterials where the bulk of peak hour traffic is concentrated.

3.5 Validity Checks on Travel Time Estimates

A key conclusion of the UMR is that congestion has grown dramatically worse over the past three decades. The report claims that for the nation as a whole, between 1982 and 2007, the average amount of time lost has increased from 14 hours per person to 36 hours per person. If these estimates are correct, we should be able to corroborate them by looking at other sources of data about travel times. In general, we would expect data to show increasingly lengthy commutes.

We have two independent sources of data on U.S. commuting patterns coinciding with the time period covered by the Urban Mobility Report. Both are based on national surveys of citizens. Here we compare the trends in commuting travel over time as computed using survey data with those implied by the Urban Mobility Report. Our two surveys are the U.S. Department of Transportation’s Household Travel Survey (NHTS) and the U.S. Census Bureau’s Decennial Census and American Community Survey.

3.5.1 National Household Travel Survey

The federal government periodically conducts a very detailed set of household surveys to assess transportation behavior. For nearly four decades, the NHTS has served as the nation's benchmark of personal travel. The 2001 version of this survey included a sample of more than 60,000 households and asked detailed questions about the purpose, distance, mode and travel time of their trips (Hu & Reuscher, 2004).

This survey is conducted only infrequently. The earliest year coinciding with estimates contained in the Urban Mobility Report is 1983, and 2009 is the most recent such survey. The most recent data from the Urban Mobility Report is 2007, and the latest year in which the two sources coincide is 2001. Our analysis therefore compares the trend in travel times over the 18-year period from 1983 to 2001, first based on the data contained in the Urban Mobility Report and then based on the National Household Travel Survey for those same two years.

Between 1983 and 2001, the Urban Mobility Report claims that traffic congestion grew much worse. According to the Urban Mobility Report, over that 18-year period the Travel Time Index more than doubled from 1.09 to 1.23, and the total cost of U.S. congestion delays more than tripled from $18 billion annually to $65.7 billion annually (in 2007 dollars). (Lomax & Shrank, 2009, page 4: Exhibit 2. National Congestion Measures, 1982 to 2007). These findings are driven by the claim that hours of delay increased from 14.7 per traveler per year to 34.2 hours per traveler per year.

Table 6. Travel Time Index and Delay, 1983 and 2001

	1983	2001	Change
Travel Time Index	1.09	1.23	+0.14
Delay (Hours per year)	14.7	34.2	+19.5
Delay (minutes per day)	3.5	8.2	+4.7

Source: Schrank and Lomax, 2009a

The Urban Mobility Report suggests that, compared to 1983, the average traveler had about 4.7 minutes of additional delay per day in 2001 (i.e.., 8.2 minus 3.5 minutes). This implies, that, all other things equal, one would expect the average peak hour commuter to have had to travel about 2.3 additional minutes per trip (assuming two peak period journeys per traveler, one in the morning and another in the afternoon).

If time lost to congestion is increasing and if the UMR is measuring it accurately, then one would expect the trend of increases in commuting times nationally to reflect the growing delays due to traffic. Commuting trips overwhelmingly occur at peak hours and account for the largest share of trips at the peak hour. The NHTS measures travel behavior in a different way than the Urban Mobility Report, which makes direct comparisons difficult. We would expect, however, that if peak hour travel times have increased substantially, this would show up in the form of longer commuting times for the average American.

The results of the 1983 and 2001 NHTS for average commute times and distances are summarized in Table 7.

Table 7: Average commute length, time, and distance from National Personal Transportation Survey, National Household Transportation Survey, 1983-2001 (Privately Owned Vehicles)

Variable	Units	1983	2001	Change
Length	Miles	8.8	11.8	+3.0
Time	Minutes	17.9	22.9	+3.0
Average Speed	Miles per Hour	29.3	31	+1.7

Source: (Gordon, Lee, & Richardson, 2004)

According to the survey, between 1983 and 2001, the average length of a commuting trip by private automobile rose by about 3 miles. The average time spent commuting (as reported by NHTS respondents) increased by five minutes, from about 18 minutes to about 23 minutes. Average speed increased slightly from just over 29 miles per hour to 31 miles per hour.

So, over these two decades, for the average commuter, the total distance traveled increased by 34 percent, while the time spent increased only 28 percent. Ignoring the increase in speed of travel, just the increase in the distance traveled accounts for all of the change in travel time. It would take almost six additional minutes to travel the additional three miles at 31 miles per hour, but travel times increased by only five minutes. In effect, average commuting times, controlling for changes in length of commutes, did not increase at all.

As a result, it is difficult to conclude that a change in traffic congestion had the effect of increasing average commuting travel times between 1983 and 2001. The average commuter in 2001 reported going farther—and faster—than the average commuter in 1983. If, as the UMR claims, congestion added an additional 2.3 minutes to each additional peak hour trip, one would expect the opposite pattern.

While peak period trips do not coincide exactly with commuting data (many peak hour trips are for other purposes and some commute trips occur in non-peak hours), it is clear that however bad congestion is, it has not had the effect of increasing the average length of time needed to commute to work in the U.S. It is also apparent that if workers had commuted in 1983 only as far, on average, as they had commuted in 1983, they would have saved five minutes on their commute trip in each direction – an amount much larger than the UMR's estimate of congestion-related delays.

The national household travel survey data also underscore a second significant factor: average trip length. Americans spent more time traveling from home to work in 2001 than they did in 1982—about five minutes each way—entirely because of the increasing distances between home and work. The fact that travel distances can and do change over time suggests that at least as much if not more attention should be paid to land use and household location and job markets, as is paid to congestion if we are concerned about understanding urban transportation problems.

If analyzed more closely, the data in the Urban Mobility Report confirm the critical role that increasing trip lengths have had on increasing peak period travel times. Following Bertini and Bigazzi (2008), we can construct estimates of total peak period travel time and average peak period travel speeds for each metropolitan area for the years 1982 through 2007 (See Appendix A for details). Table A-1 shows the change in average peak period travel distances for large metropolitan areas for two time periods: 1982 to 2001 (consistent with the time period shown in Table 7, above) and 2001 to 2007.

From these data, we can trace out trends in peak travel distances. Between 1982 and 2001, average travel distances increased in three-quarters of these metropolitan areas. As a group, mean travel distances increased from about 17.1 miles per peak period traveler per day to 19.3 miles per peak period traveler per day. Although smaller than the increase in travel distances reflected in Table 7, the UMR data confirm that longer travel distances were an important contributor to growing peak period travel times during the 1980s and 1990s. The data for the period 2001 to 2007, however, show that peak period travel distances have been shrinking in most metropolitan areas, and that the average travel distance has declined about 1.0 percent. In some cities, like Portland, shorter travel distances have more than offset the effects of congestion on total travel time (See page 15, above).

It is possible that the Travel Time Index could be affected by a failure of motorists to benefit from improved highway capacity. That is, perhaps the changes in road capacity between 1983 and 2001 were so dramatic that average free flow speeds improved dramatically, and absent congestion, workers would have been able to travel even faster than the 1.7 mile per hour gain they recorded over the 20 years. But this seems implausible, given the observation in the Urban Mobility Report and echoed by Downs (2004), that highway capacity has grown much more slowly than population. Also, it puts a very different face on the impact of congestion to say that its costs are in the form of the failure to obtain even greater increases in travel speed.

3.5.2 Census Journey-to-Work Data

As part of the Decennial Census and now as part of the annual American Community Survey, the Census Bureau asks working persons about their journey to work. They publish, for each metropolitan area, data on mode of travel to work and the respondents' estimated travel time.

For purposes of comparison with the Urban Mobility Report, we choose data from years in which the two data series coincide: 2000 and 2007. (Though referred to as the 2008 Urban Mobility Report, the data in the report are for calendar year 2007.) Data for 2000 are from the Decennial Census, while data for 2007 are from the American Community Survey.

If time lost to congestion is increasing and if UMR is measuring it accurately, then one would expect places that have experienced the biggest increases in congestion also to have experienced the biggest increases in commuting time.

Our analysis compares the change in the length of the average commute trip, according to Census Bureau data, with the change in the number of minutes of delay estimated by the UMR. The Census Bureau asks about journey to work (i.e.., from home to place of work), so this estimate was doubled here, to reflect that workers also travel from place of work to home. For the Urban Mobility Report, we divided their estimate of annual peak period hours of delay by 250 to produce a daily estimate of peak period hours of delay by metropolitan area. For each metropolitan area, we computed the change in minutes of travel between the 2000 and 2007. While the two series measure different populations--the Census Bureau measures all commute trips and the Urban Mobility Report measures peak hour trips—the denominator of the two series is the same: the number of trips taken in an urban area.

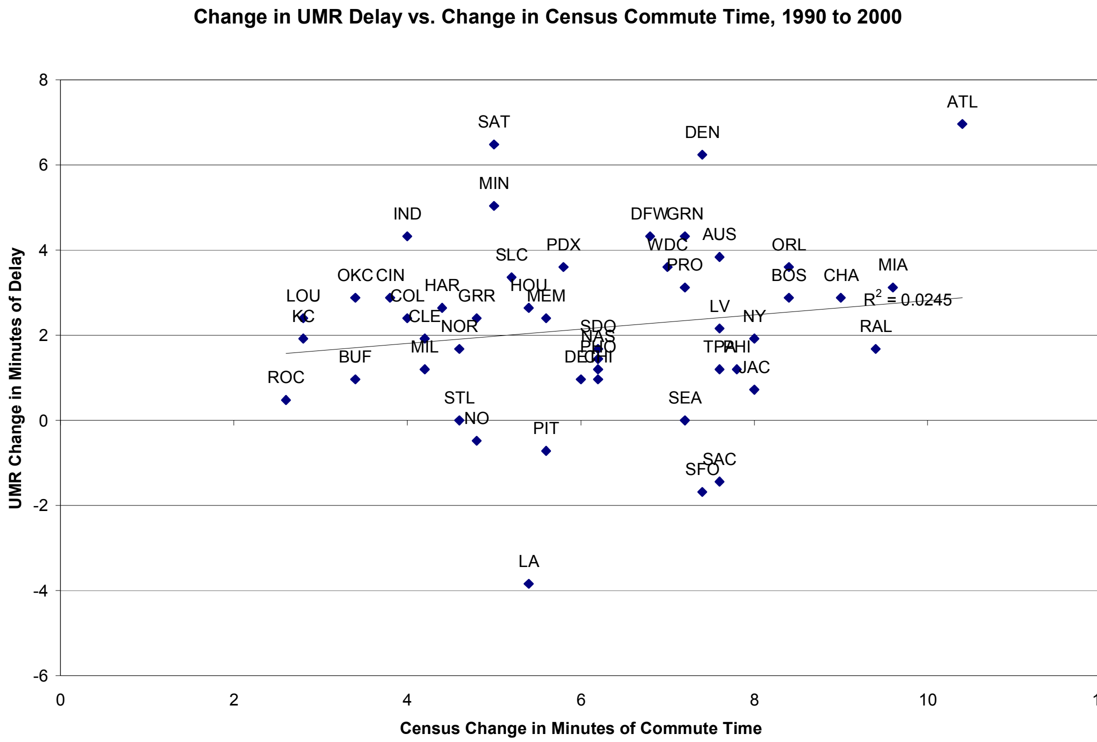
For this analysis we use a slightly different group of metropolitan areas, as these data are taken from tabulations comparing data from the 1990 and 2000 Censuses, based on the metropolitan areas definitions used in tabulating the 2000 Census (McGuckin & Srinivasan, 2003). [8]

Figure 5 shows the relationship between the change in minutes of delay reported by the Urban Mobility Report between 1990 and 2000, and the reported change in average commute times in each metropolitan area reported by the Census over that same time period. According to the Census, during the 1990s, average commute times increased in all these metropolitan areas. (None of the values is negative.) On average in these metropolitan areas, travel times increased about 6 minutes between 1990 and 2000.

A visual inspection shows little relationship between a worsening level of travel delays according to the UMR and increases in commute times reported by the Census. For example, according to the UMR, Atlanta, San Antonio and Denver all had the biggest increases in delay, with each city adding about 6 more minutes per day during the 1990s. But the Census data show very different increases in total commuting times. Atlanta's average delay increased much more than the average (about 10 minutes), but Denver's increase of 8 minutes was just above average, and San Antonio had a below average increase of 5 minutes. At the opposite end of the spectrum, according to the UMR, Seattle, Sacramento and San Francisco all experienced either no change or an actual decrease in congestion-related delay during the 1990s. But the Census Bureau data show that these same three cities reported above average increases in reported commuting times of 7 minutes or more. Statistically, there is almost no correlation between the two series: the R^2 for the relationship is .025. The UMR estimates of increased delay do not explain the pattern of increasing commute times during the 1990s.

[8] This group consists of 49 metropolitan areas, all with 1 million or more population in 2000, based on the MSA definitions used for tabulating Census 2000. Compared to the list contained in Table 2, two metropolitan areas were added: Grand Rapids (GRR), and Greenville (GRN), and three metropolitan areas were dropped: Baltimore, Birmingham, Richmond, Riverside, San Jose, These data are for all modes.

Figure 5: Census and UMR Travel Time Changes



Source: Census & UMR. For key to metropolitan area abbreviations see Table 2.

We have repeated this analysis for the subsequent time period (2000 to 2007), using data from the American Community Survey (data not shown here). As with the earlier time period, there is no statistically significant relationship between changes in the Urban Mobility Report's estimated minutes of delay and reported changes in commuting times.

The lack of any relationship between Census data on changes in average commuting trip lengths and the pattern of changes in traffic delays estimated in the Urban Mobility Report suggests that other factors are at play in changing the amount of time Americans spend in peak hour traffic. As our analysis of the National Household Travel Survey data suggest, one factor is the changing length of average commutes. We examine the role of variations in travel distance on travel time in Section 5.

3.6 Summary

This section showed that there are serious reasons to question the accuracy and validity of the estimates of congestion-related delays presented in the Urban Mobility Report.

The key statistic underpinning the UMR's findings is based on the difference in travel times between peak and non-peak periods, but the study's travel time estimates are based on volume data, not on actually observed travel speeds. As a result, the UMR mechanically translates greater traffic volumes into longer estimated delays.

The model used to convert volume data to estimated speeds was calibrated by "visual inspection" of the data and the line chosen to reflect the data isn't based on statistical analysis; a line fit with a simple quadratic equation would produce much higher estimates of peak hour speeds and consequently lower levels of peak hour delay.

The model relies on daily, rather than hourly (or minute by minute), traffic volumes, meaning that the authors must make heroic assumptions about the distribution of traffic between peak and non-peak hours.

Survey data on self-reported travel times from the Census and National Travel Survey are not consistent with the conclusions of the Urban Mobility Report. Neither the total change in travel time measured nationally nor the pattern of changes in travel time across metropolitan areas is consistent with the estimates of increased delay presented in the Urban Mobility Report.

The Travel Time Index estimated by UMR, using its model and volume data, is 70 percent higher on average for large metropolitan areas than a Travel Time Index computed for the same year based on real time observations of travel speeds computed by Inrix.

4. Congestion and Fuel Consumption

The second key cost associated with congestion, according to the Urban Mobility Report, is excess fuel consumption. According to the Urban Mobility Report, Americans used an additional 2.8 billion gallons of fuel because of traffic congestion. At a rough average price of $3 per gallon, this means that fuel waste associated with congestion would account for about $8.4 billion of the estimated $87 million cost associated with traffic congestion.

The report estimates that peak period travelers lost about 4.2 billion hours and wasted about 2.8 billion gallons of fuel in 2007. This means that on average, each additional hour of time spent traveling due to congestion was equal to about .68 gallons of fuel used. This ratio has changed only slightly since 1982; then it was about .62 gallons of fuel per hour of reported delay.

4.1 Limitations of the Raus Study

The Urban Mobility Report estimates fuel waste due to congestion by calculating the difference in average fuel economy at free flow speeds and average fuel economy at slower congested speeds. The formula used to estimate fuel consumption is listed in the report's appendix and is based on data from a study prepared for the U.S. Department of Transportation, which we will refer to as the Raus study (Raus, 1981).[9] This study examined the fuel use patterns of 1973 to 1976 General Motors vehicles driving on urban arterial streets.

It is questionable whether a study using vehicles that were prevalent in the fleet 30 years ago is an accurate basis for estimating fuel consumption today. There are three major problems with using the UMR's use of its analysis of the Raus data to compute fuel consumption.

First, there have plainly been significant changes in fuel economy since the Raus study. Mid-1970s era GM vehicles bear little resemblance to today's automobile fleet. Since 1976, average fuel economy of new vehicles in the city driving cycle has improved from 12.3 to 20.5 miles per gallon (Environmental Protection Agency, 2007). In addition, there have been technical changes (smaller displacement engines, computer engine control and fuel injection) that have dramatically reduced idle speed fuel consumption, which according to the Raus report is a key determinant of congestion-related fuel consumption. It is not clear from the UMR's methodology whether fuel consumption estimates have been adjusted since 1982 to reflect improvements in vehicle fuel

[9] The Raus study is out of print, and insofar as the author could ascertain was unavailable on the Internet. The author was able to locate a copy of the study on microfiche. The report is rather quaint: it contains an appendix with step by step instructions for computing fuel consumption on an HP programmable calculator. An Adobe Acrobat (PDF) image file of this study is posted on the Internet at: www.ceosforcities.org.

economy; the small but steady increase in estimates of wasted fuel per hour of delay suggests that the UMR makes no adjustment for fuel economy improvements since 1982.

Second, Raus specifically stated that the results of his work were not applicable to traffic traveling at speeds in excess of 35 miles per hour:

> "The above relationship is good only for speeds up to about 35 miles per hour" (Raus, 1981, page 8)

It is clear from the Urban Mobility Report methodology that the fuel consumption estimates are applied to much higher speeds. The study notes that added fuel consumption is calculated based on the difference between average congested speeds and free flow speeds, which for freeways are 60 miles per hour.

Third, the Urban Mobility Report's equation implies that fuel economy increases steadily and without limit with average speeds. There is no evidence that that is true for speeds in excess of 35 miles per hour. And, as the evidence in the following section indicates, it is generally the case that fuel consumption increases at speeds in excess of 50 miles per hour, which is exactly the opposite conclusion one would reach if one applied the UMR's extrapolation of the Raus data to such speeds.

The finding that fuel efficiency steadily improves with speed is due in part to the UMR's decision to fit a linear relationship to the Raus data. Interestingly, this is not the functional form that Raus chose to represent this relationship, even for speeds under 35 miles per hour.

The UMR fuel consumption equation is shown in Figure 6. This formula means that the average fuel consumption of vehicles traveling at 20 miles per hour would be 13.8 miles per gallon: (8.8 * (0.25*20)) = (8.8 + 5) = 13.8 mpg. This equation implies that vehicle fuel economy increased steadily and without limit, as vehicles move faster: at 40 miles per hour, fuel consumption is 18.8 miles per gallon ((8.8 * (0.25*40)) = (8.8 + 10) = 18.8 and at 60 miles per hour it is 23.8 miles per gallon ((8.8 * (0.25*60)) = (8.8 + 15) = 23.8.

Figure 6: The UMR Fuel Consumption Equation

$$\begin{array}{c}\text{Average Fuel}\\ \text{Economy}\\ \text{in Congestion}\end{array} = 8.8 + 0.25\left(\begin{array}{c}\text{Average Peak}\\ \text{Period Congested}\\ \text{System Speed}\end{array}\right)$$

Source: Shrank & Lomax (2009a), Appendix A: page A-18, Equation A-7

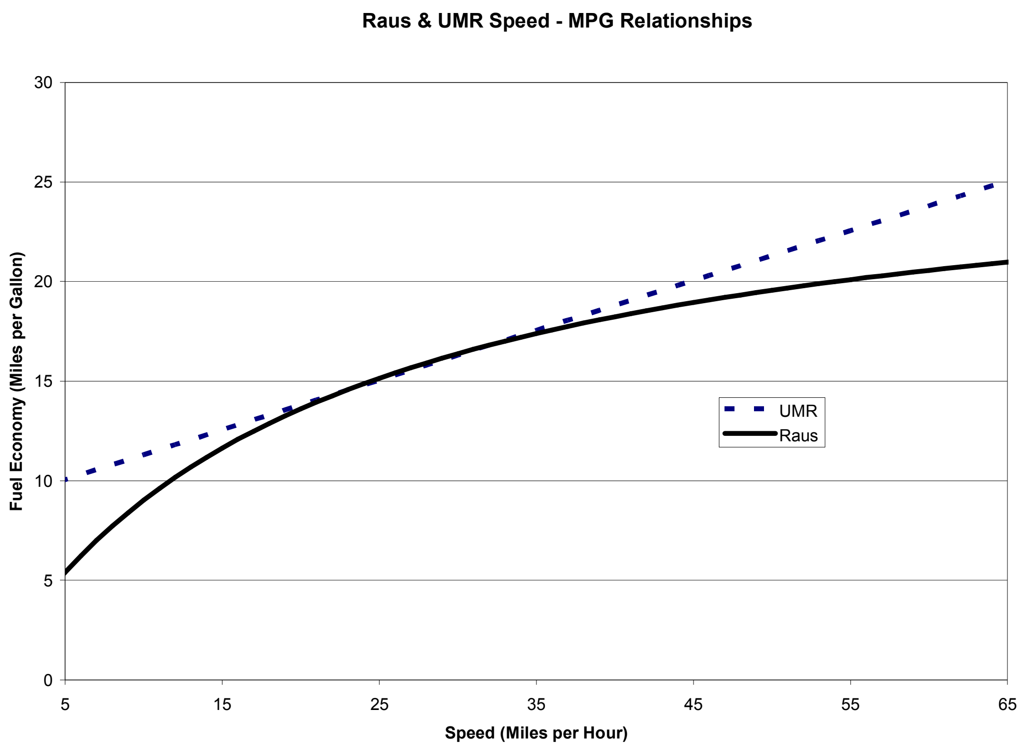
Raus fitted the data to a convex curve, using the following equation.

Average Fuel Economy = 1 / (.0362 + (0.746 / Average Speed))

Source: (Raus 1981)

The functional form used by the Raus equation implies that fuel economy improves with higher speeds but at a diminishing rate as average speeds rise. The curvilinear relationship suggests that any fuel economy advantage from going faster tapers off as speeds increase, which is generally consistent with the evidence from other studies (see next section), which fit even more complex curves to the data. The difference between the UMR's linear equation and the Raus curvilinear equation is shown in Figure 7.

Figure 7: Effect of Different Functional Forms on Fuel Economy Estimates



The decision to use a linear functional form, rather than the curvilinear relationship used by Raus has the effect of producing higher fuel economy estimates at high speeds.

The Raus study seems to be a weak basis for estimating fuel consumption in the 21st Century. It is out-dated, it doesn't apply to speeds in excess of 35 miles per hour, and the UMR's choice to fit a linear relationship to its data biases estimates of fuel consumption.

4.2 Appropriate Models for Fuel Consumption

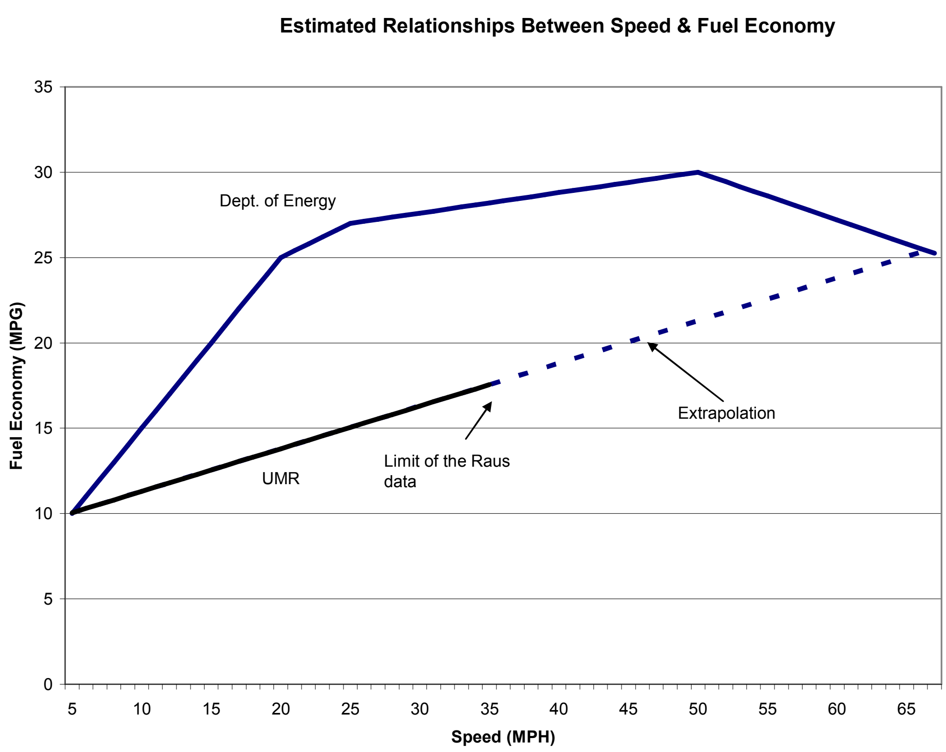
Although a comprehensive review of the literature on the relationship between vehicle speed and fuel economy is beyond the scope of this analysis, the subject has been extensively studied since 1981.

In general, studies find an "inverted U" shaped relationship between travel speed and fuel economy. At very low speeds, under 25 or 30 miles per hour, fuel economy improves as vehicle speeds increase (similar to the Raus study). Between 25 to 30 miles per hour and 45 to 50 miles per hour, fuel economy is essentially static. Above 55 or 60 miles an hour, fuel economy deteriorates.[10] Mathematically, authors usually fit their speed and fuel economy to a polynomial equation, as this allows for the data to have its characteristic "U" shape. In contrast, the UMR employs a simple linear regression, which implies a straight line increase in fuel economy: the faster a car goes, the more efficient it becomes.

The U.S. Department of Energy has published its own estimate of the relationship between vehicle fuel economy and vehicle speed (Department of Energy, 2010). That estimate, based on work by the Oak Ridge National Laboratory, shows the strong inverted U-shaped relationship between speed and fuel economy (West, McGill, Hodgson, Sluder, & Smith, 1999).

Figure 8 shows the fuel consumption speed relationship estimated by the UMR based on its analysis of the Raus data and the fuel consumption speed relationship estimated by the Department of Energy. The dotted portion of the line for the Urban Mobility Report represents the extrapolation of the data beyond the 35 miles per hour limit identified by Raus.

Figure 8: Alternative Fuel Consumption/Speed Estimates



The use of the linear relationship extrapolated from the Raus data makes a huge difference to the estimate of the fuel economy penalty associated with slower travel

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[10] To complicate matters, while most popular descriptions of fuel economy in the United States refer to miles per gallon, most technical studies measure fuel efficiency in terms of fuel consumption per unit of distance, such as liters per 100 kilometers traveled. This is still measuring the same phenomenon, but this produces a U-shaped curve, instead of an inverted U.

speeds. Table 8 compares the estimates one would make as a result of traffic slowing from 60 miles per hour to 30 miles per hour based on the Urban Mobility Report compared to the Department of Energy's estimate of fuel consumption patterns.

Table 8: Sample Calculations of Changes in Miles Per Gallon (MPG) and Fuel Consumption (Gallons per 100 miles), using Urban Mobility Report and Department of Energy Speed/Fuel Consumption Relationships

	Urban Mobility Report		Department of Energy	
Speed	MPG	gal/100mi	MPG	gal/100mi
60 mph	23.8	4.20	27.7	3.61
30 mph	16.3	6.13	27.6	3.62
Change	-7.5	1.93	0.1	0.02
Percent Change		46.0%		0.4%

Source: Author's calculations.

The equation used by the Urban Mobility Report would estimate that as traffic slows from an average speed of 60 miles per hour to 30 miles per hour, average fuel economy falls from 23.8 miles per gallon to 16.3 miles per gallon. This has the effect of increasing fuel consumption by 46 percent, from 4.2 gallons per hundred miles to 6.1 gallons per hundred miles. In contrast, the Department of Energy equation implies that reducing average speeds from 60 to 30 miles per hour has almost no effect (a +0.4 percent increase in fuel consumption) on vehicle fuel economy. The typical vehicle gets a little bit more than 27.5 miles per gallon in either case.

Other studies that address the relationship between average speed and fuel economy produce similar results, controlling for a variety of real world conditions. The New Jersey Department of Transportation prepares its own estimates of the costs of congestion including fuel use (Spasovic, 2008). The original version of its model used a linear relationship similar to the Urban Mobility Report. In a subsequent revision, its model was replaced with a U-shaped, polynomial equation fitted to data on vehicle fuel consumption developed by the California Department of Transportation. This change decreased the estimates of fuel consumption due to congestion by about two-thirds (Dimitrijevic, 2010).

Another study compared the effect on fuel economy of two driving cycles, one with constant speeds and a second with stops and starts. It found the familiar U-shaped relationship for fuel consumption, with the lowest level of fuel consumption for the typical vehicle occurring at an average speed of 50 kilometers per hour (30 miles per hour), and with fuel consumption increasing as speeds increased or decreased from that value (Sivanandan & Rakha, 2003).

Barth and Boriboonsomsin (2008) examined the effect of average travel speeds on Los Angeles freeways on carbon dioxide emissions. Carbon dioxide emissions closely correlated with fuel consumption, so their findings are indicative of the impact of speed on fuel economy. They found that CO_2 emissions increased with average speeds over 55 miles per hour and below 25 miles per hour, a relationship that is strikingly similar to other studies.

While it may seem paradoxical, it is the case that some levels of congestion that reduce speeds without causing stop and go conditions actually save fuel. The U-shaped relationship between fuel consumption and speed means that for speeds in excess of 55 miles per hour, fuel consumption increases substantially. This has been the rationale for highway speed limits. The Department of Energy tells drivers that each five miles an hour above speeds of 60 miles per hour is the same as paying 24 cents more per gallon of gas (Department of Energy, 2010). Other studies confirm that reducing driving speeds from 60 to 50 miles per hour can reduce fuel consumption by 12 percent (HDR Decision Economics, 2009). As a result, because congestion frequently reduces speeds from above 60 miles per hour, to between 45 and 55 miles per hour, congestion actually would be expected to increase, rather than decrease vehicle fuel economy. The Urban Mobility Report makes no calculation of these fuel savings.

Whether congestion has a net positive or net negative effect on fuel consumption depends on the extent to which it reduces travel speeds. If congestion is severe and reduces average travel speeds below 25 miles per hour, it increases fuel consumption. But less severe congestion that reduces speeds from above 60 miles per hour to a slightly lower level would be expected to reduce fuel consumption.

The use of the equation based on the Raus data overestimates the fuel economy penalty associated with slower driving for at least four reasons. First, it is based on 1970s-era vehicles which had much lower overall fuel economy than the current vehicle fleet. Second, it uses a linear rather than a U-shaped relationship to describe the impact of fuel economy on speed; over the relevant range of speeds, the relationship between speed and fuel economy is essentially flat. Third, the Urban Mobility Report inappropriately applies the relationship to speeds in excess of 35 miles per hour, explicitly ignoring the Raus study's caveat that its conclusions only applied to slower speeds. Fourth, the Urban Mobility Report fails to compute the fuel savings that accrue from modest levels of congestion that have the effect of lowering average speeds into the range that actually improves fuel economy.

4.3 Future Trends in Fuel Consumption

There are a variety of technical reasons to believe that, over time, the fuel consumption penalty associated with very slow speeds will decline. Fuel economy standards promise to further increase fuel efficiency.

In the future, technological improvements are likely to reduce slow speed fuel consumption even further. Hybrid vehicles, especially those with regenerative braking systems like the Toyota Prius, actually have better overall fuel economy in the lower speed, stop-and-go city driving cycle than they do in the higher speed highway driving cycle. A number of manufacturers, including Mazda and Subaru, are deploying partial zero emission "start-stop" systems that turn off the engine when the vehicle is stopped.

5. A New View of Urban Transportation

The foregoing portions of this report identified several major problems with the Urban Mobility Report's estimates of congestion-related costs. The Travel Time Index constitutes an unreasonable baseline, it ignores variations in distances traveled among metropolitan areas, and it overestimates the effect of congestion on travel times. The UMR methodology also overestimates fuel use associated with congestion.

Despite its weaknesses, the Urban Mobility Report aims to answer an important set of questions: How well is the nation's urban transportation system working? What are the costs resulting from that system's shortcomings and how are various metropolitan areas performing?

This section considers how our view of urban transportation might change if we adjusted the estimates contained in the Urban Mobility Report to address the weaknesses identified previously. This section re-examines the data contained in the UMR to provide an adjusted estimate of the total cost of congestion-related delays and a comparably calculated cost estimate for the impact of excessive peak period travel distances. While these estimates correct some of the deficiencies identified in the UMR data, they rely on the UMR database as a starting point, and so should be regarded as a preliminary and very rough set of estimates. Even so, the following analysis provides an illustration of what an improved set of performance measures might look like.

5.1 Aggregate Measures of Congestion

The UMR's estimate of an overall cost of $87 billion for congestion hinges directly on its estimates of time lost to congestion, the value of that time, and an estimate of excess fuel consumption due to slower speeds. If we one adjusts the assumptions built into the UMR methodology to incorporate a more realistic baseline, reflect a Travel Time Index based on observed speed data, adopt a lower value of time, and include a more realistic picture of the impact of speed on fuel consumption, the cost of congestion is reduced dramatically.

Selecting an alternative baseline is an inherently subjective task. We have chosen a Travel Time Index of 1.05 as an alternative baseline. This means that peak hour travelers would reasonably expect a peak hour trip to take no more than 5 percent longer than a non-peak hour trip before they regarded the trip as resulting in congestion-related delay. This means, for example, that a trip that could be completed in 20 minutes in free flow conditions could be completed in 21 minutes in peak conditions. For many travelers, the day-to-day variation in travel time is likely to be greater than the calculated amount of congestion related delay (Goodwin, 2004). There is evidence that travelers may be unaware of differences in travel time of this magnitude and that the amounts of time involved are so small that they have no economic value (Bain, 2009). Using this approach, we treat travel time in excess of a TTI value of 1.05 as constituting time lost to congested travel.

As illustrated in Section 2, there are good reasons to believe that the volume/speed model used in the UMR overestimates the Travel Time Index. Our analysis of the data from Inrix suggests that the Travel Time Index calculations used in the UMR overstate the true Travel Time Index in large metropolitan areas by about 70 percent (Section 3). Table 9 shows the Travel Time Index for each of the 51 largest metropolitan areas in the nation, as calculated by Inrix. Overall on a population weighted basis, the values for these metropolitan areas average 1.21, as compared to an average of 1.31 for the UMR.[11] The combined effect of shifting to a more reasonable baseline (Travel Time Index of 1.05 as a threshold for congestion costs) and using the Inrix data is to reduce the Travel Time Index for this overall sample to 1.16, or about a 50 percent reduction from the levels used to calculate delay related time losses in the UMR.[12]

Another key assumption that drives the report is the choice of a value for travel time. There is considerable debate in the literature about the appropriate value to use and the choice is arbitrary in many respects. The UMR assumes that all personal time lost to delay is valued at $15.47. This is higher than the estimate used in many other studies. Travel times have been shown to vary widely across users and across different trip purposes and times of day (Litman, 2010). Many studies find a relationship between average wages and the value of travel time. In their estimate of the nationwide value of time losses to traffic congestion, Winston and Langer settle on 50 percent of the average wage (Winston & Langer, 2006). In 2007 average hourly earnings per worker were $21 (Bureau of Labor Statistics, 2010). Discounted 50 percent this produces a value of time of $10.50. This suggests the average value of travel time is about one-third less than that used in the Urban Mobility Report. [13]

If we adjust the cost estimates used in the Urban Mobility Report for each of these factors—setting the baseline at a minimum 1.05 Travel Time Index, using the Inrix estimates of the Travel Time Index for metropolitan areas, and setting the value of time to

[11] The city-weighted mean values for the Inrix Travel Time Index and the UMR Travel Time Index are 1.14 and 1.24 respectively. The population-weighted mean values are proportionately closer entirely because of a single case, New York City. See note 7.

[12] The UMR delay estimates for these 51 cities are based on a population-weighted Travel Time Index of 1.31. Shifting to the Inrix Travel Time Index data would lower that value to 1.21; adjusting the baseline for computing congestion costs to 1.05 means that for the population-weighted sample, on average the effective Travel Time Index would be about 1.16, or about half of the level reflected in the UMR estimates of hours of delay.

[13] We do not separately analyze the value of time lost for commercial transportation. While the Urban Mobility Report estimates the costs of time lost both for personal transportation and for trucking, it does not separately report these sources of time loss or their values. An analysis of UMR data suggests that about 95 percent of the cost of lost time in metropolitan areas is due to personal transportation (Winston & Langer, 2006).

50 percent of the average wage rate—lowers the total value of the time lost to congestion by about two-thirds.[14]

About 10 percent of the value of losses to congestion is associated with the UMR's estimates of additional fuel consumption. As noted in Section 4, the model used to estimate fuel losses is problematic. An estimate that incorporated the reduction in fuel consumption due to slowing speeds from above 55 or 60 miles an hour to somewhat lower levels might show that there was, on balance, almost no net additional fuel consumption associated with congestion. Given the data presented here, a plausible estimate of the net fuel waste associated with congestion is zero.

This calculation illustrates the importance of key assumptions in the Urban Mobility Report to the magnitude of its findings. The choices of what baseline to use to define congestion, which data to use to measure congestion, and what value to attach to travel time have a major impact on the magnitude of the findings presented in the UMR. Alternative, and in our view, more reasonable assumptions imply that the cost of congestion in monetary terms is perhaps less than 70 percent lower than the figure claimed in the UMR.[15]

Together, this adjustment of data and assumptions suggests that the cost of congestion is much lower than estimated in the Urban Mobility Report. For the 51 metropolitan areas analyzed here, the Urban Mobility Report claims that the total cost of congestion was $71 billion (roughly 81 percent of the national total of $87.2 billion). Adjusting that amount as described above implies that a more realistic estimate of the cost of congestion would be roughly $22 billion.

5.2 Metropolitan Level Measures of Congestion and Travel Distances

Clearly, congestion-related delays are not the only driver of commuting times and commuting distances in U.S. metropolitan areas. Travel distances, particularly the long travel distances in some sprawling metropolitan areas, are a critical factor.

A system for benchmarking the effectiveness of urban transportation systems should address the effects both of congestion-related delays and the effect of travel distance. To illustrate how including measures of travel distance would influence these results, we re-analyze the metropolitan level data presented in the Urban Mobility Report.

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[14] These adjustments to the Travel Time Index lower the cost of delay by roughly 50 percent. The adjustments to the wage rate lower the value of time by 33 percent. The net effect on the UMR's value of time calculation would be (1*.50*.66) or 33%.

[15] The net effect of adjustments to travel time computations is to lower time costs by 66%. Time savings represent 90% of the costs associated with congestion. Approximately 10% of the costs of congestion reflect the estimated cost of wasted fuel. Adjusting the overall estimated costs of congestion by these two factors lowers the total cost by roughly 70% (.90*.33)+(.10*0)

The Urban Mobility Report focuses on the Travel Time Index and publishes its estimates of the hours lost to delay. But using that data and other information contained in the electronic appendix to the report, it is possible to compute several other descriptive variables that are key attributes of metropolitan transportation environments (Bertini & Bigazzi, 2008). (See Appendix A for the derivation of these variables.)

Specifically, we have used the underlying data in the UMR to compute the total amount of peak hour travel time per traveler in each metropolitan area and to compute the total number of peak miles of travel.

Table 9 shows the population, number of peak period travelers, Travel Time Index and the estimated number of hours of travel due to congestion from the UMR. Also shown are the estimates of total peak period travel time (in hours per year), the amount of un-congested travel time,[16] and the average number of miles traveled per peak period trip. Also, for reference, we show the value of the Travel Time Index computed by Inrix for each metropolitan area.

[16] Un-congested travel time refers to the length of time that would be required to complete peak period travel if there were no delays. It is the difference between total travel time, and the amount of additional time that is required to travel because traffic is moving at slower than free-flow speeds.

Table 9: Selected Transportation Indicators

Column	1	2	3	4	5	6	7	8
Metropolitan Area	Population	Peak Travelers	Travel Time Index	Hours of Delay	Total Hours	Un-congested Travel	Miles	Inrix TTI
Atlanta GA	4,440	2,371	1.35	57	220	163	21.6	1.18
Austin TX	1,035	580	1.29	39	173	134	16.2	1.28
Baltimore MD	2,320	1,299	1.31	44	186	142	18.8	1.14
Birmingham AL	715	393	1.15	32	245	213	23.3	1.04
Boston MA-NH-RI	4,200	2,113	1.26	43	208	165	19.8	1.18
Buffalo NY	1,125	540	1.07	11	168	157	16.6	1.04
Charlotte NC-SC	1,070	599	1.25	40	200	160	19.1	1.13
Chicago IL-IN	8,440	4,566	1.43	41	136	95	13.5	1.23
Cincinnati OH-KY-IN	1,670	949	1.18	25	164	139	17.7	1.07
Cleveland OH	1,790	995	1.08	12	162	150	16.3	1.06
Columbus OH	1,225	686	1.18	30	197	167	19.9	1.05
Dallas-Fort Worth TX	4,445	2,645	1.32	53	219	166	20.9	1.15
Denver-Aurora CO	2,180	1,358	1.31	45	190	145	17.0	1.11
Detroit MI	4,050	2,268	1.29	52	231	179	20.9	1.15
Hartford CT	895	489	1.12	21	196	175	19.9	1.10
Houston TX	3,815	2,232	1.33	56	226	170	22.1	1.18
Indianapolis IN	1,070	599	1.21	39	225	186	22.6	1.05
Jacksonville FL	1,040	582	1.23	39	209	170	20.5	1.10
Kansas City MO-KS	1,525	854	1.07	15	229	214	21.6	1.06
Las Vegas NV	1,405	787	1.30	44	191	147	17.6	1.07
Los Angeles-Long Beach CA	12,800	6,976	1.49	70	213	143	21.1	1.29
Louisville KY-IN	915	503	1.20	38	228	190	21.7	1.05
Memphis TN-MS-AR	1,035	580	1.12	25	233	208	20.7	1.06
Miami FL	5,420	3,095	1.37	47	174	127	16.5	1.21
Milwaukee WI	1,465	804	1.13	18	156	138	17.2	1.08
Minneapolis-St. Paul MN	2,525	1,414	1.24	39	202	163	20.1	1.17
Nashville-Davidson TN	995	547	1.15	37	284	247	25.2	1.17
New Haven CT	560	308	1.11	19	192	173	20.3	1.12
New Orleans LA	1,100	579	1.17	20	138	118	12.6	1.10
New York-Newark NY-NJ-CT	18,225	8,602	1.37	44	163	119	18.9	1.45
Oklahoma City OK	875	481	1.12	27	252	225	24.1	1.05
Orlando FL	1,405	787	1.30	53	230	177	20.9	1.08
Philadelphia PA-NJ-DE-MD	5,310	2,947	1.28	38	174	136	17.4	1.14
Phoenix AZ	3,425	1,829	1.30	44	191	147	19.4	1.12
Pittsburgh PA	1,815	1,016	1.09	15	182	167	15.8	1.10
Portland OR-WA	1,800	931	1.29	37	165	128	16.0	1.20
Providence RI-MA	1,245	682	1.17	29	200	171	18.2	1.10
Raleigh-Durham NC	1,025	574	1.17	34	234	200	22.2	1.06
Richmond VA	935	514	1.09	20	242	222	22.5	1.03
Riverside-San Bernardino CA	2,030	1,102	1.36	44	166	122	18.2	1.20
Rochester NY	745	410	1.06	10	177	167	14.9	1.04
Sacramento CA	1,860	1,001	1.32	39	161	122	16.2	1.10
Salt Lake City UT	975	536	1.19	27	169	142	16.0	1.05
San Antonio TX	1,450	812	1.23	38	203	165	20.2	1.09
San Diego CA	2,950	1,652	1.37	52	193	141	19.8	1.24
San Francisco-Oakland CA	4,480	2,339	1.42	55	186	131	19.5	1.31
San Jose CA	1,705	955	1.36	53	200	147	19.0	1.22
Seattle WA	3,100	1,696	1.29	43	191	148	18.8	1.29
St. Louis MO-IL	2,215	1,240	1.13	26	226	200	20.7	1.08
Tampa-St. Petersburg FL	2,320	1,299	1.31	47	199	152	17.8	1.12
Virginia Beach VA	1,545	865	1.18	29	190	161	18.0	1.15
Washington DC-VA-MD	4,330	2,174	1.39	62	221	159	21.5	1.28

Source: Author's calculations.

Notes for Table 9

From Urban Mobility Report
1. Metropolitan population (thousands)
2. Peak period travelers (thousands)
3. Travel Time Index
4. Average hours of delay per traveler (annual)

Computed from Urban Mobility Report
5. Average hours of peak period travel per traveler (annual)
6. Average un-congested travel time per traveler (hours, annual)
7. Average miles of peak period travel per traveler (daily)

From Inrix
8. Travel Time Index

As columns 5 and 7 of Table 9 show, there is considerable variation across metropolitan areas in the total time spent traveling in the peak period and in the length of average peak period trips.

For example, the average peak period traveler in Chicago travels about 14 miles daily and spends 136 hours per year traveling in the peak period. In contrast, the average resident of Charlotte travels 19 miles daily and spends 200 hours per year in peak period travel. According to the UMR, peak period travelers in both cities face almost identical amounts of delay (41 hours per year in Chicago, 40 hours in Charlotte). But Charlotte's travelers spend about 64 hours more per year traveling in the peak hour because their trips are so much longer than those in Chicago. Even if there were no congestion in Charlotte, average peak hour travel times would be 160 hours per year (column 6) longer than in Chicago's trips even with congestion-related delays.

Clearly, variations in travel distance among metropolitan areas are a major reason why travel times and costs are greater in some regions than in others. An objective accounting of the reasons for inter-metropolitan differences in transportation system performance ought to include measures of travel-distance differences, as well as differences in levels of traffic-related delays. Here we attempt to illustrate how such measures can be constructed, using the UMR data as our starting point.

One of the key limitations of the UMR estimates of congestion is its use of an unrealistic baseline for computing delay. We would not suggest using a zero mile trip length as the basis for computing the "costs" associated with variations in travel length among metropolitan areas. (No one expects zero peak period travel.) Instead, we look to estimate "excess" amounts of peak period travel distances: where are average travel distances in metropolitan areas significantly longer than we observe in the best performing (i.e. shortest average peak period travel distance) metropolitan areas.

Somewhat arbitrarily, we choose the 90th percentile performer as our baseline for estimating excessively long peak period travel distances. The logic behind this choice is that the 90th percentile represents the performance that is close to the best that is achieved in practice and that deviations from this level represent transportation "costs" that a city might reasonably said to have incurred from a performance that falls below this level. For our sample of large metropolitan areas, the 90th percentile value is 16 miles, roughly the level observed in practice in Austin, Sacramento and Portland. We classify peak period travel distances in excess of 16 miles per traveler per day as the "excess" travel that is due to more dispersed land uses and extended travel patterns in a metropolitan area.

Table 10 (column 1) shows the annual number of "excess" miles traveled by each peak period traveler in each metropolitan area. These are calculated by subtracting 16 from the actual number of miles traveled per peak period traveler per day and multiplying the result by 250. For example, for Atlanta, the average peak period traveler travels 21.6 miles per day. We subtract 16 from that amount and multiply by 250, giving us roughly 1,400 excess peak period miles per year. The number of excess miles ranges from a high of more than 2,000 miles in Nashville, to several cities with negative excess mileage. Negative numbers indicate places where travelers travel less than 16 miles per peak period.

For each metropolitan area, we then compute how much additional time traveling in peak hours is attributable to the excess distance one needs to travel daily, compared to the 90th percentile metropolitan area. For purposes of this analysis, we assume that the average un-congested travel speed for large metropolitan areas is 30 miles per hour, which is the average implied by the Urban Mobility Report for large metropolitan areas.[17]

For each metropolitan area, our estimate of excess hours of travel is shown in Table 10 (column 2). The number of hours is estimated by dividing the number of excess miles in column 1, by a speed of 30 miles per hour. Excess hours range from 124 hours per peak period traveler per year in Nashville, to negative values for cities with shorter than 90th percentile average peak period travel distances.

Next we estimate the approximate value of the time consumed by excess travel and the value of fuel consumed by such travel. For purposes of this table and comparability with estimates above, we use a value of $10.50 for each hour of travel time. To estimate the amount of fuel used in excess travel, we assume a fleet average fuel economy of 20 miles per gallon. We value fuel at $3.00 per gallon.

The results of these calculations are shown in column 3 of Table 10. The cost of excess travel distance ranges from zero in the best performing metropolitan areas to a high of approximately $1,500 per traveler per year in Nashville.

[17] Un-congested travel time refers to the amount of time that would be required to complete the average peak period trip if there were not delay. It does not refer to the amount of time that travelers experience un-congested travel conditions. For derivation of un-congested travel times, see Appendix A.

Table 10: Estimate of Excess Travel Due to Longer Travel Distances

Column	1	2	3	4
Metropolitan Area	Excess Miles of Travel	Excess Hours of Travel	Cost of Excess Travel	Metro Total
Atlanta GA	1,389	60	695	1,647
Austin TX	45	13	22	13
Baltimore MD	688	26	344	447
Birmingham AL	1,828	85	914	359
Boston MA-NH-RI	960	48	480	1,015
Buffalo NY	143	8	71	39
Charlotte NC-SC	765	40	383	229
Chicago IL-IN	(616)	-24	(308)	-
Cincinnati OH-KY-IN	417	4	208	198
Cleveland OH	80	2	40	40
Columbus OH	978	37	489	336
Dallas-Fort Worth-Arlington TX	1,231	59	615	1,627
Denver-Aurora CO	260	30	130	177
Detroit MI	1,231	71	616	1,396
Hartford CT	985	36	493	241
Houston TX	1,533	66	767	1,711
Indianapolis IN	1,658	65	829	496
Jacksonville FL	1,117	49	558	325
Kansas City MO-KS	1,411	69	706	603
Las Vegas NV	406	31	203	160
Los Angeles-Long Beach-Santa Ana CA	1,281	53	641	4,468
Louisville KY-IN	1,424	68	712	358
Memphis TN-MS-AR	1,167	73	583	338
Miami FL	125	14	63	194
Milwaukee WI	295	-4	148	119
Minneapolis-St. Paul MN	1,020	42	510	721
Nashville-Davidson TN	2,298	124	1,149	629
New Haven CT	1,071	32	535	165
New Orleans LA	(845)	-22	(422)	-
New York-Newark NY-NJ-CT	723	3	361	3,109
Oklahoma City OK	2,030	92	1,015	488
Orlando FL	1,222	70	611	481
Philadelphia PA-NJ-DE-MD	355	14	177	522
Phoenix AZ	859	31	430	786
Pittsburgh PA	(54)	22	(27)	-
Portland OR-WA	(8)	5	(4)	-
Providence RI-MA	538	40	269	184
Raleigh-Durham NC	1,553	74	777	446
Richmond VA	1,629	82	814	419
Riverside-San Bernardino CA	549	6	274	302
Rochester NY	(284)	17	(142)	-
Sacramento CA	57	1	29	29
Salt Lake City UT	(10)	9	(5)	-
San Antonio TX	1,041	43	521	423
San Diego CA	945	33	472	780
San Francisco-Oakland CA	866	26	433	1,012
San Jose CA	761	40	381	363
Seattle WA	689	31	344	584
St. Louis MO-IL	1,186	66	593	735
Tampa-St. Petersburg FL	458	39	229	298
Virginia Beach VA	504	30	252	218
Washington DC-VA-MD	1,386	61	693	1,507

Source: Author's calculations.

Notes for Table 10
1. Excess annual miles of peak period travel distance, per peak period traveler
2. Excess annual hours of peak period travel distance, per peak period traveler
3. Annual cost of excess travel distance, dollars per peak period traveler
4. Total cost of excess peak period travel distance, millions of dollars per year

Note: Costs are computed relative to the 90th percentile. Negative values indicate savings, relative to 90th percentile. Metro areas with total costs of excess peak period travel of zero (column 4) perform in the 90th percentile or higher.

Finally, we multiply the per traveler estimate of the cost of excess travel distance by the number of peak period travelers (from Table 9, column 2) to compute the total annual cost associated with excess travel in each metropolitan area. (For purposes of this calculation, we treat negative values—savings from shorter than 90th percentile trips—as zero. The total value for these 51 metropolitan areas, ignoring negative values, is roughly $31 billion annually.

The re-examination of congestion-related costs presented in the first part of this section and the new estimates of the costs associated with excess travel distances offer a rough idea of the relative contributions of sprawl and congestion to excessive peak period travel times. It appears that the costs associated with congestion-related delay are roughly $22 billion annually, once we make adjustments for its unrealistic baseline, discount the effect of questionable fuel consumption estimates and apply the Travel Time Index data from Inrix.

This suggests that the cost of time and fuel wasted due to excessive travel distances ($31 billion) is nearly fifty percent larger than the cost associated with traffic congestion ($22 billion). For the reasons described throughout this report, one needs to regard such estimates with a good deal of caution. Much more could be done to refine such estimates, but they are indicative of the kind of results one should expect if we broaden our analysis of urban transportation system performance measures to consider the effect of the built environment and travel distances on the cost of commuting.

Conclusion

The Urban Mobility Report tells a distorted and incomplete story about the magnitude and nature of congestion. The chief claims made in the report—that congestion costs the nation $87 billion annually, that it has grown steadily worse since the early 1980s, and that it wastes billions gallons of fuel—cannot be supported by the data presented.

The report's methodology draws questionable inferences from two key pieces of research, one dealing with the relationship between volume-to-capacity ratios and traffic speeds and a second dealing with travel speeds and fuel efficiency which discredit the validity of the report's key findings. The Urban Mobility Report's method for calculating speeds is unreliable and based on a model of debatable statistical validity. Travel time indices computed directly from direct observations of vehicle speeds suggest the UMR overstates the value of the travel time index by 70 percent. The report's fuel consumption model is based on outdated data, is misapplied to higher speeds, and doesn't square with more realistic estimates of the effect of speed on fuel consumption. The report also ignores the fuel savings that would be associated with modest speed reductions found in common urban traffic.

Just as troubling from a policy standpoint is the construction of the "Travel Time Index" as a measure of urban transportation system performance. It sets an unrealistic baseline—that no travel should take place in congested conditions—and its construction, as a ratio measure, penalizes cities with shorter travel distances. And the measure totally obscures from view the effect of land use on travel times and travel costs.

There is little basis for the UMR's claim that the economic cost of congestion has nearly tripled since the early 1980s. The claim that travel times have increased is a product not of actual observations but is an artifact of the structure of the UMR's speed/volume equations, for which there is no independent confirmation. As long as volume increases more than capacity, the UMR model mechanically predicts slower speeds and travel times.

Neither the national nor the cross-sectional pattern of changes in travel times squares with the estimates of increasing travel times estimated in the Urban Mobility Report. At the metropolitan level, there is no correlation between estimates of increased delay in the UMR and reported increases in commute times. Data from the National Household Travel suggest that increasing average trip distances rather than traffic congestion is the chief cause of increasing total peak period travel time. And the UMR completely misdiagnoses some metropolitan areas. In Portland, for example, the report claims traffic got dramatically worse with the TTI going from 1.07 in 1982 to 1.29 in 2007, but in reality, average peak hour travel times declined substantially because trips got shorter.

The UMR's estimates of the economic cost of congestion are significantly over-stated. Using a more reasonable baseline, adjusting for speeds observed in practice, and correctly estimating fuel consumption reduce the estimated cost associated with congestion by two-thirds. Our re-analysis of data from the Urban Mobility Report shows that sprawling land use patterns produce greater travel time costs and more fuel waste than does traffic congestion.

Over time, sprawl has increased the distance people have to travel at the peak hour—a key fact that is obscured by the UMR's methodology. And some cities have seen actual reductions in peak period travel times because they have been able to reduce the distances people travel.

The UMR is a prime example of mobility-based analysis: it implicitly assumes transportation means driving and evaluates transport system performance based on motor vehicle travel speeds, effectively ignoring other factors affecting accessibility such as the quality of alternative modes (particularly walking and grade-separated transit) and land use. It therefore tends to justify mobility-based solutions, such as expanding urban highways, which reduce overall accessibility because they produce a more dispersed set of destinations.

The lesson to policy makers should be clear: look to policies and investments that enable citizens to travel shorter distances, saving time, energy and money. This implies that building communities that are more compact with a better mix of land uses and housing types can play a key role in meeting our transportation challenges.

The wide variation in land use and travel patterns among large metropolitan areas suggests that there is considerable opportunity to implement these changes. There is growing evidence that consumers value dense, walkable, transit-served places that enable them to travel shorter distances and take some trips without driving a car (Cortright, 2009).
Our analysis of city land use and transportation systems would be dramatically improved if we had a comprehensive set of measures of accessibility that valued what people wanted to be able to travel to, rather than focusing exclusively on the speed with which they travel.

The objective of the Urban Mobility Report—to provide a comprehensive system of metrics that enable us to compare the performance of urban transportation systems among cities and over time—is a worthy one. But the current UMR falls well short of what is needed. Specifically, a new set of urban transportation performance measures should be developed, and they should differ in five important ways from the approach taken in the UMR.

First, such measures should emphasize accessibility at least as much as they do mobility. Ultimately, people value the opportunities, experiences and interactions that take place at their destinations. The current UMR essentially focuses only on mobility and largely ignores the value of having many destinations close at hand, enabling shorter and fewer trips.

Second, the metrics included in a future urban transportation performance measurement system need to be much more comprehensive and include measures of land uses and trip distances. We could do much more to develop measures of urban accessibility. Walkscore, a web-based service, computes the relative walkability of all the residential properties in the U.S. And there are promising experiments in combining accessibility indicators with traditional measures of mobility (Grengs, Levine, Shen, & Shen, 2010). Accessibility indicators like these illustrate the potential for a wide range of alternative policies and investments—such as transportation demand management, neighborhood investment, land use planning and location efficient mortgages—to contribute to reducing transportation problems.

Third, improved and more diverse data is needed. There are important weaknesses in the Highway Performance Monitoring System, and much more could be done to improve the quality of this data. In addition, there are promising new sources of data, like the information gleaned from GPS commercial fleets by Inrix and others. Likewise, the Census Bureau's innovative Local Employment Dynamics program provides an extraordinarily detailed set of journey-to-work data that has yet to be fully harnessed.

Fourth, the U. S. Department of Transportation should support a process for designing and selecting the appropriate standards for measuring urban transportation systems that is and multi-disciplinary. It is common in many fields to use an open-source "Request for Comment" process to solicit a wide range of expert opinion to facilitate widely shared consensus about appropriate standards. Such a process will necessarily be a multi-disciplinary challenge that should engage not just highway engineers, but urban planners, economists and others to thoroughly vet the strengths and limitations of different measures.

Fifth, a useful set of measures should do much more than simply draw attention to the apparent magnitude of urban transportation problems, as the UMR currently does. It should also shed light on the nature and causes of these problems and help send clear signals about which policies and investments are likely to have the greatest efficacy in addressing those problems. Ideally, we should have measures that generate policy-relevant information that will let us clearly identify problems, measure progress, and inform decision-making.

In sum, a new and more comprehensive view of urban transportation systems is needed. This new view should serve both to correct the deficiencies in current transportation measures identified here and also to add an explicit consideration of the role that urban form and sprawl play in shaping transportation systems. Such an analysis would provide urban leaders with a much clearer understanding of the nature, extent and causes of urban transportation problems and much more useful direction about how they can be addressed.

Appendix A: Constructed Variables from Urban Mobility Report

This Appendix explains how additional variables were constructed using data from the 2008 Urban Mobility Report.

The Texas Transportation Institute has posted on the Internet a digital copy of the spreadsheet used to show key variables contained in the annual urban mobility report. Based on that data, we have calculated several other supplementary variables that reflect other aspects of the function of urban transportation systems. In general, this follows an approach developed by researchers at Portland State University who developed a similar set of data as part of a report they prepared for Portland (Bertini & Bigazzi, 2008).

Data shown in Tables 5, 9, 10 and A-1 of this report reflect these calculations. The estimates of miles traveled and time spent traveling are consistent with, and mathematically implied by the travel time index and hours of delay reported for each metropolitan area in the UMR. As noted in the text, the UMR methodology likely overstates the share of travel time that is attributable to congestion-related delays because of flaws in its speed volume model. We do not have an independent source of data on the amount of time spent in peak hour travel, so we are unable to determine whether UMR estimates of congestion related delays are neutral with respect to total travel times (i.e. that UMR gets the total amount of travel time correct, but attributes too much to congestion) or whether UMR estimates of congestion-related delays inflate estimates of total travel time (the estimate of the number of un-congested hours of travel is correct, and the over-estimate of hours of delay increases the estimate total of travel time). The data presented here are consistent with the UMR calculation and assume total travel times are correct. An alternative calculation, assuming un-congested travel time estimates were correct would result in lower total hours of travel, but would imply that the proportion of travel time due to longer trip distances in some metropolitan areas was larger than shown here.

These following variables are constructed based directly on the data in Urban Mobility Report spreadsheet (tab is labeled: "ums8207wrci"). Each of these new variables is explained in the tab labeled "variables." The new variables themselves are computed and shown in columns AT through AZ of the tab "ums8207wrci." Note: Except for item 4, all values are for daily periods.

1. Peak Period Vehicle Miles

The Urban Mobility Report spreadsheet gives values for total freeway miles (column I) and total arterial miles (column K). The Urban Mobility Report assumes that 50 percent of all travel occurs during peak periods (Exhibit A-1). Therefore, peak travel distance (total vehicle miles traveled) is 0.5 * the sum of freeway and arterial miles.

2. Peak Period Vehicles

The Urban Mobility Report spreadsheet gives a value for peak period travelers (column H). The estimated vehicle occupancy is 1.25 (Exhibit A-1). Peak period vehicles can be estimated by dividing peak period travelers by 1.25.

3. Peak Period Vehicle Miles per Peak Traveler

If we divide peak period VMT by the number of peak travelers (column H), we get peak period (VMT) per peak traveler.

4. Annual Hours Traveled per Peak Period Traveler

The Urban Mobility Report spreadsheet gives values for the total hours of delay per traveler per year (column AC) and the Travel Time Index (column AF). The Travel Time Index is defined as the ratio of travel time in congested conditions to the travel time in free flow conditions. Total travel time is the sum of free flow or un-congested travel time plus delay per traveler.

Un-congested travel time is delay per traveler per year divided by the Travel Time Index minus 1.

To illustrate the calculation, examine the data for Boston. The Urban Mobility Report says that the average Boston peak period traveler experiences 43 hours of delay per year (Column AC: Annual Hours of Delay per Peak Traveler). Boston has a Travel Time Index of 1.26, (column AF) which means that congestion causes the peak period traveler to take a trip that is 26 percent more time than it would be in free flow conditions.

The Urban Mobility Report spreadsheet does not report total hours of travel, but it is possible to use the Travel Time Index and the reported delay values to compute average free flow hours of peak travel. If the 43 hours of congestion-related delay are equal to 26 percent of un-congested travel time, then free flow travel time is 165 hours.

Un-congested Hours = Annual Hours of Delay / (Travel Time Index -1)

= 43 / 1.26 -1

= 43 / .26

= 165

165 un-congested hours

Because total hours of peak travel per person is the sum of free flow travel time, plus delay, then the peak travel time in Boston, per traveler, was:

43 + 165 = 208

208 total hours of peak period travel per person per year

Algebraically, this formula simplifies as follows:

Travel Hours = TTI/(TTI-1)*Hours of Delay/Travelers

5. Peak Period Vehicle Miles Traveled per Vehicle

From the above, we know the total distance traveled by vehicles (#3) and the total number of vehicles traveling at the peak (#2). If we divide distance traveled by number of vehicles, we get average peak VMT per vehicle.

6. Peak Period Hours Traveled Per Vehicle

Peak period hours traveled per vehicle is calculated by dividing person hours by the number of working days in the year (250) and then by average vehicle occupancy (1.25).

7. Peak Period Average Vehicle Speed

Peak Average vehicle speed is equal to total vehicle miles of travel during the peak (#6) divided by the total vehicle hours of travel during the peak (#5).

Table A-1: Trends in Peak Period Travel Distance by Metropolitan Area

Metropolitan Area	Average Peak Period Travel Distance (miles per day)			Change in Average Peak Period Travel Distance	
	1982	2001	2007	1982-2001	2001-2007
Atlanta GA	20.4	25.1	21.6	23.1%	-14.1%
Austin TX	16.2	16.6	16.2	2.7%	-2.8%
Baltimore MD	15.4	18.6	18.8	20.4%	0.9%
Birmingham AL	16.2	24.3	23.3	50.0%	-4.1%
Boston MA-NH-RI	15.1	19.4	19.8	28.3%	2.5%
Buffalo NY	12.7	15.3	16.6	20.6%	8.2%
Charlotte NC-SC	15.2	18.4	19.1	21.5%	3.5%
Chicago IL-IN	13.9	13.6	13.5	-2.1%	-0.4%
Cincinnati OH-KY-IN	13.4	17.6	17.7	31.9%	0.2%
Cleveland OH	12.3	16.0	16.3	30.2%	1.8%
Columbus OH	14.7	20.6	19.9	40.2%	-3.2%
Dallas-Fort Worth-Arlington TX	21.2	21.5	20.9	1.5%	-2.5%
Denver-Aurora CO	20.1	17.1	17.0	-14.8%	-0.6%
Detroit MI	19.3	21.1	20.9	9.6%	-1.0%
Hartford CT	13.2	19.7	19.9	49.4%	1.2%
Houston TX	18.3	21.7	22.1	18.7%	1.9%
Indianapolis IN	21.4	24.0	22.6	12.1%	-5.7%
Jacksonville FL	22.1	21.0	20.5	-5.0%	-2.7%
Kansas City MO-KS	17.1	23.1	21.6	35.1%	-6.3%
Las Vegas NV	14.9	14.9	17.6	0.0%	18.3%
Los Angeles-Long Beach-Santa Ana CA	23.3	21.7	21.1	-7.0%	-2.5%
Louisville KY-IN	16.2	21.8	21.7	34.6%	-0.3%
Memphis TN-MS-AR	14.6	20.2	20.7	38.1%	2.1%
Miami FL	14.8	16.2	16.5	9.6%	1.9%
Milwaukee WI	14.4	16.9	17.2	17.5%	1.8%
Minneapolis-St. Paul MN	16.8	21.3	20.1	26.9%	-5.8%
Nashville-Davidson TN	21.2	24.9	25.2	17.4%	1.1%
New Orleans LA	15.1	13.8	12.6	-8.8%	-8.2%
New York-Newark NY-NJ-CT	17.1	18.2	18.9	6.2%	4.0%
Oklahoma City OK	21.6	25.1	24.1	16.2%	-3.9%
Orlando FL	17.5	22.4	20.9	28.0%	-6.6%
Philadelphia PA-NJ-DE-MD	17.1	16.4	17.4	-4.5%	6.5%
Phoenix AZ	24.5	19.6	19.4	-19.9%	-0.9%
Pittsburgh PA	16.5	16.6	15.8	0.2%	-4.7%
Portland OR-WA	19.6	16.7	16.0	-14.6%	-4.6%
Providence RI-MA	11.6	17.5	18.2	50.7%	3.9%
Raleigh-Durham NC	19.2	23.4	22.2	21.4%	-4.9%
Richmond VA	14.2	22.3	22.5	56.8%	1.1%
Riverside-San Bernardino CA	20.4	18.8	18.2	-8.0%	-3.2%
Rochester NY	10.2	14.3	14.9	40.7%	3.7%
Sacramento CA	23.3	17.7	16.2	-24.1%	-8.4%
St. Louis MO-IL	16.5	21.9	20.7	32.9%	-5.1%
Salt Lake City UT	13.8	16.2	16.0	17.6%	-1.5%
San Antonio TX	18.0	21.0	20.2	16.5%	-4.1%
San Diego CA	20.2	20.6	19.8	2.2%	-4.1%
San Francisco-Oakland CA	22.1	21.0	19.5	-5.3%	-7.2%
San Jose CA	20.8	20.9	19.0	0.6%	-8.9%
Seattle WA	12.6	13.3	13.2	5.8%	-0.8%
Tampa-St. Petersburg FL	12.5	16.9	17.8	35.1%	5.7%
Virginia Beach VA	18.6	18.4	18.0	-0.7%	-2.3%
Washington DC-VA-MD	15.1	20.9	21.5	38.2%	3.1%

Source: Author's calculations.

Appendix B: Attached Files

These appendices are available at www.ceosforcities.org.

B1: UMR Spreadsheet (umrwrci.xls)

B2: Raus article

B3: Speed/Fuel Consumption Curves

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