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Realistic Analysis of Freeway Expansion and Downsizing

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Executive Summary

Adding urban freeway capacity will induce freeway traffic growth without reducing congestion. Most urban freeway travel is by residents making local trips. Residents will choose freeway routes over street routes until freeway congestion makes the travel times equal across routes. There never will be enough freeway capacity to absorb all the traffic on parallel streets. Therefore, urban freeways will always be congested in peak travel periods, no matter how much capacity is provided.

Benefits of freeway expansion are grossly overstated in alternatives analyses. There are dozens of examples across the U.S. where major expansion projects have failed to reduce travel times as promised. The false promises result from reliance on poor computer models. The conventional models used in these analyses overestimate urban freeway throughput because they lack capacity constraint, and underestimate delay because they do not account for traffic backups.

With advances in computer hardware and software, there is a practical alternative today called *Dynamic Traffic Assignment* (DTA). DTA models properly model bottlenecks and traffic backups.

In case studies of Arkansas River crossings in the Little Rock Arkansas region, the advanced DTA model produces more realistic and useful traffic forecasts than the outdated conventional model for both freeway expansion and downsizing alternatives. DTA should be used for all modeling of urban freeway alternatives.

Fundamental Causes of Urban Freeway Congestion

Freeway congestion is a huge public policy issue in the United States. When Metropolitan Planning Organizations (MPOs) produce long-term regional transportation plans (RTP), the word “congestion” and the closely related term “delay” appear dozens and sometimes hundreds of times. Environmental Impact Statements (EIS) prepared for roadway projects similarly emphasize congestion and delay. The primary performance measures in both RTP and EIS documents are delay and congestion.

Despite this focus on freeway congestion, the fundamental causes of urban freeway congestion are poorly understood – even by many transportation experts. I will illustrate the fundamental causes with an illustration taken from the Little Rock Arkansas region. For travelers from North Little Rock (upper left) to The Clinton Library and Museum in Little Rock (lower right), the choice of routes across the Arkansas River includes two street bridges (Broadway and Main Street) and one Interstate bridge (I-30). The bridges are spaced about one half mile apart.

Figure 1: Equal Travel Times on Street Route and a Freeway Route

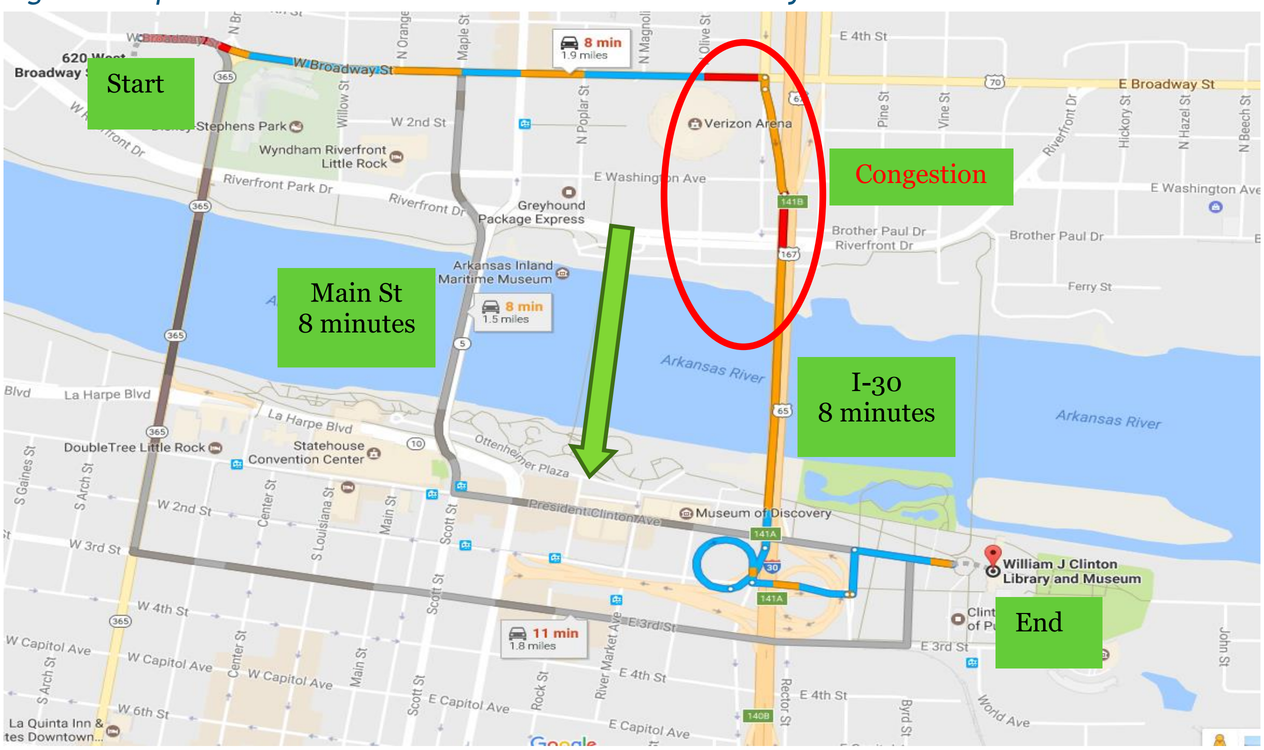


Image from Google Maps

When there is little traffic, I-30 is the fastest route because I-30 has a higher posted speed limit. However, in the weekday morning peak hour, the I-30 southbound route always is congested. in the Google Map image from a Tuesday morning at 8 a.m. in Figure 1, the travel times on the Main Street and I-30 routes are an identical 8 minutes. The higher speeds on I-30 are exactly offset by delays at the approach to the I-30 ramp and at the merge of the I-30 ramp (both areas shown in red), as well as delay across the bridge ahead of the off-ramp (shown in orange).

The pattern is replicated in all U.S. urban areas during peak travel times. Parallel routes, whether freeway or street, have equal travel times because if one route or another were faster, travelers would shift to that route until congestion causes the travel times to be equal.

Route selection is the first and most important factor in the **triple convergence model** set forth by Anthony Downs in *Stuck in Traffic* published 25 years ago in 1992.[1] The other two factors are time and mode convergence. If road capacity is constrained, some travelers schedule their travel to avoid the time of peak congestion. If capacity is increased, some of these travelers will shift back into the peak travel times. In the largest regions, congestion is a powerful motivator to get people out of their cars and onto rail transit. These *triple convergence* components – route, time, and mode – are accompanied by longer-term destination choice and land use changes to collectively form *induced travel*.

> *Most urban freeway travel is by residents making local trips. Residents will choose freeway routes over street routes until freeway congestion makes the travel times equal across routes. There never will be enough freeway capacity to absorb all the traffic on parallel streets. Therefore, urban freeways will always be congested in peak travel periods, no matter how much capacity is provided.*[2]

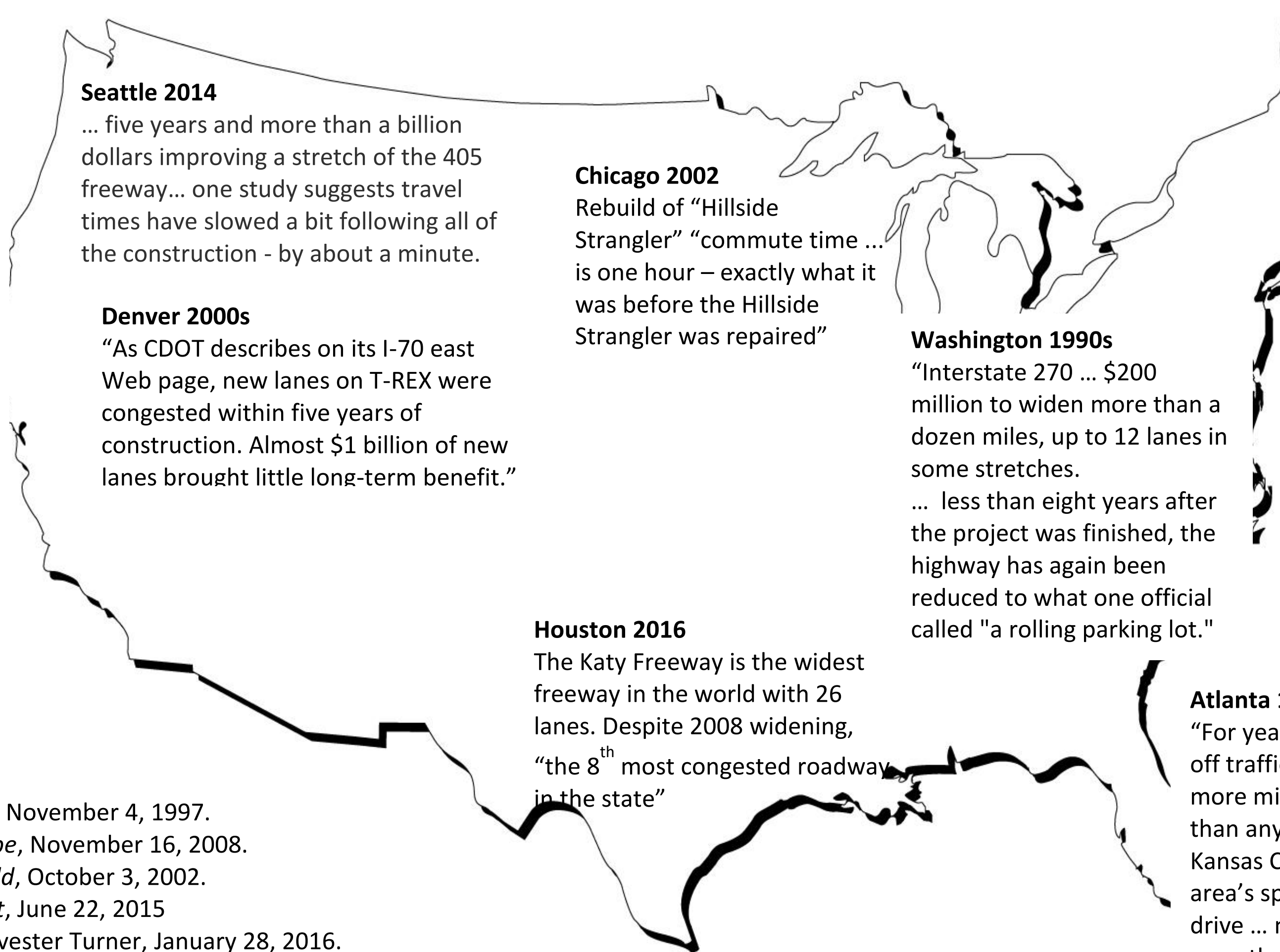
False Claims that Adding Capacity Can Eliminate Congestion

Highway builders have been promising that the next round of urban freeway expansion will solve urban freeway congestion since the beginning of urban freeway construction in the United States 80 years ago. In the 1930s, Robert Moses built a series of freeways in the New York City region. As documented in Robert Caro's *The Power Broker*[3], after each freeway failed to provide the congestion relief promised, Moses promised that the next round of construction would do so. This never worked. Urban freeway expansion has similarly failed to solve urban freeway congestion across the United States in the years since. Figure 2 shows 9 cases where freeway expansion projects have failed to provide the promised congestion relief. There are dozens of other cases.

As discussed below, these false claims always are based on badly outdated computer models. The models promise large reductions in congestion and delay that never materialize.

[1] Downs, Anthony. *Stuck in Traffic: Coping with Peak Hour Traffic Congestion*. Brookings Institution and Lincoln Institute of Land Policy, 1992.
[2] Time-of-day road pricing is effective in reducing or even eliminating congestion on high-speed urban roads. However, this is best done through moderate pricing all high-speed lanes rather than building separate systems of general purpose and managed lanes. A dual system adds a great amount of cost, and only offers a choice between congestion and a high toll.
[3] Caro, Robert. *The Power Broker*, New York: Random House, 1974.

Figure 2: 80 Years of False Claims that Adding Freeway Capacity Can Eliminate Urban Freeway Congestion



San Jose 2004
When the bottleneck on Interstate 880 near Brokaw Road was unplugged two months ago with the addition of a third lane, traffic experts said it would shave 18 minutes off the afternoon southbound commute…
Instead of saving time, commutes have lengthened by perhaps 18 minutes.

Seattle 2014
… five years and more than a billion dollars improving a stretch of the 405 freeway… one study suggests travel times have slowed a bit following all of the construction - by about a minute.

Denver 2000s
“As CDOT describes on its I-70 east Web page, new lanes on T-REX were congested within five years of construction. Almost $1 billion of new lanes brought little long-term benefit.”

Chicago 2002
Rebuild of “Hillside Strangler” “commute time ... is one hour – exactly what it was before the Hillside Strangler was repaired”

Washington 1990s
“Interstate 270 … $200 million to widen more than a dozen miles, up to 12 lanes in some stretches.
… less than eight years after the project was finished, the highway has again been reduced to what one official called "a rolling parking lot."

Boston 2008
Big Dig and $15 billion. The *Globe* documented no apparent overall travel time savings.

New York City 1936
Interborough and Laurelton Parkways: “By God it was as jammed as the Southern State ever was”

Houston 2016
The Katy Freeway is the widest freeway in the world with 26 lanes. Despite 2008 widening, “the 8th most congested roadway in the state”

Atlanta 1990s
“For years, Atlanta tried to ward off traffic problems by building more mile of highways per capita than any other urban area except Kansas City… As a result of the area’s sprawl, Atlantans now drive … more than residents of any other city.”

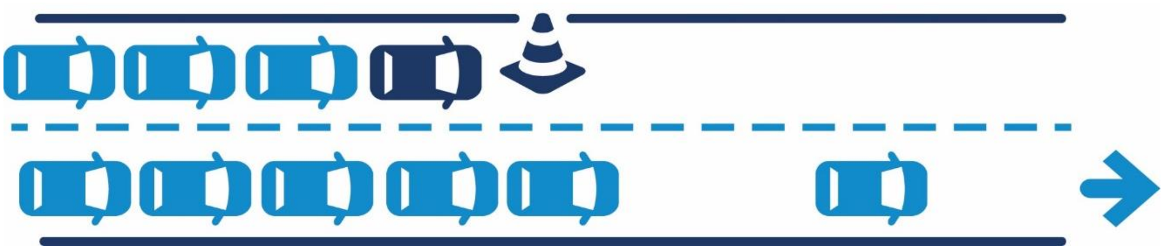
<u>Sources:</u>
Atlanta: *USA Today,* November 4, 1997.
Boston: *Boston Globe*, November 16, 2008.
Chicago: *Daily Herald*, October 3, 2002.
Denver: *Denver Post*, June 22, 2015
Houston: Mayor Sylvester Turner, January 28, 2016.
New York City: Robert Caro, *The Power Broker: Robert Moses and the Fall of New York*, 1975.
San Jose: *San Jose Mercury*, January 23, 2004.
Seattle: *Southern California Public Radio*, October 10, 2014.
Washington: *Washington Post*, January 4, 1999.

Mental Models and Computer Models

Daily travelers in a region have complex mental models of traffic congestion, and select routes after taking into consideration time of day, day of week, season of year, the weather and any special events or other special circumstances. These mental models often consider routes much longer and more complex than those shown in Figure 1.

Urban freeway congestion is not uniformly distributed along the freeways, but is experienced as traffic backups behind a series of bottlenecks. Common bottleneck locations include on-ramps, mainline freeway lanes ahead of off-ramps, sections where some traffic flows are weaving across each other, and lane drops. In the Twin Cities region of Minnesota, one study identified and analyzed hundreds of separate recurring bottleneck locations on the freeway system. Figure 3 shows a schematic diagram of a single bottleneck.

Figure 3: Traffic Backups Behind a Freeway Bottleneck



Although shown as a full lane closure, many bottlenecks reduce throughput capacity by less than one full lane. The important things to notice in Figure 3 are:

1) There are long traffic backups and long delays behind the bottleneck
2) The bottleneck constrains the amount of traffic that can get downstream
3) Traffic is free-flowing downstream of the bottleneck (unless affected by a subsequent bottleneck)

Travelers' mental models include a thorough understanding of bottlenecks and traffic backups – even to the point of thinking about the probability distributions of the likely delay behind each bottleneck.

Traffic forecasts for freeway projects are done using regional computer models. Typically, these models are calibrated to a base year and then used to forecast traffic 20-25 years into the future. Given the complexity of mental models, and the power of modern computers, it is surprising that the computer models used to evaluate freeway expansion and downsizing are much less sophisticated than most people's mental models. The methods used were developed 50-60 years ago for computers that were far less powerful than any smartphone today.

These outdated Static Traffic Assignment (STA) models are used by all state and regional transportation agencies and fail to conform to the three important aspects cited in Figure 3. Instead

1) There are ~~long~~ no traffic backups and no ~~long~~ delays behind the bottleneck
2) The bottleneck does not constrain~~s~~ the amount of traffic that can get downstream
3) Traffic is not free-flowing downstream of the bottleneck

These weaknesses are illustrated in Figure 4. STA models assume that vehicles somehow squeeze through bottlenecks with a short delay, rather than having to wait for space to get through. If you are thinking this doesn't make sense, you are right!

Figure 4: Lack of Capacity Constraint and Traffic Backups in STA Models

STA models overestimate urban freeway throughput because they lack capacity constraint, and underestimate delay because they do not account for traffic backups. The model errors are greater with higher levels of congestion.

I-35 through central Austin Texas is one of the most congested freeways in the U.S. For the northbound weekday afternoon, peak period, the STA model[4] estimates over twice the actual traffic throughput counted, and a speed of 39 mph or almost twice the 20 mph actual average speed.[5] The STA model overestimates traffic throughput because it does not properly constrain traffic at bottlenecks. It underestimates delay because it does not account for traffic backup delays upstream of bottlenecks.

Below I show how these STA model problems translate into false promises of congestion relief, using a case study from the Little Rock region.

I have been commenting on the deficiencies in STA models for many years, but I have found that it is impossible to supplant STA models from the planning process without substituting a better model. Transportation experts who understand the limitations of the STA models often continue to rely on them, in part, because they do not think there is a practical alternative.

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[4] Based on model computer files received from the Capital Area Metropolitan Planning Organization (Austin region).
[5] STA modelers often believe that these problems can be fixed by changing parameters. In fact, the problems are fundamental. There is no set of parameters that can address these deficiencies.

With advances in computer hardware and software, there is a practical alternative today called Dynamic Traffic Assignment (DTA). DTA models properly model bottlenecks and traffic backups.

For more information, see my paper *Realistic Freeway Congestion Metrics Using Regional Dynamic Traffic Assignment*.

Little Rock Freeway Expansion Case Study

The Little Rock region has a total of five road bridges across the Arkansas River (see Figure 5). In addition to the three downtown bridges discussed above, there also are Interstate beltway bridges to west and to the east. The three interstate bridges each has three travel lanes in each direction, and the two street bridges each have two travel lanes in each direction.

Figure 5: Little Rock Region Including Five Roadway Bridges Across Arkansas River

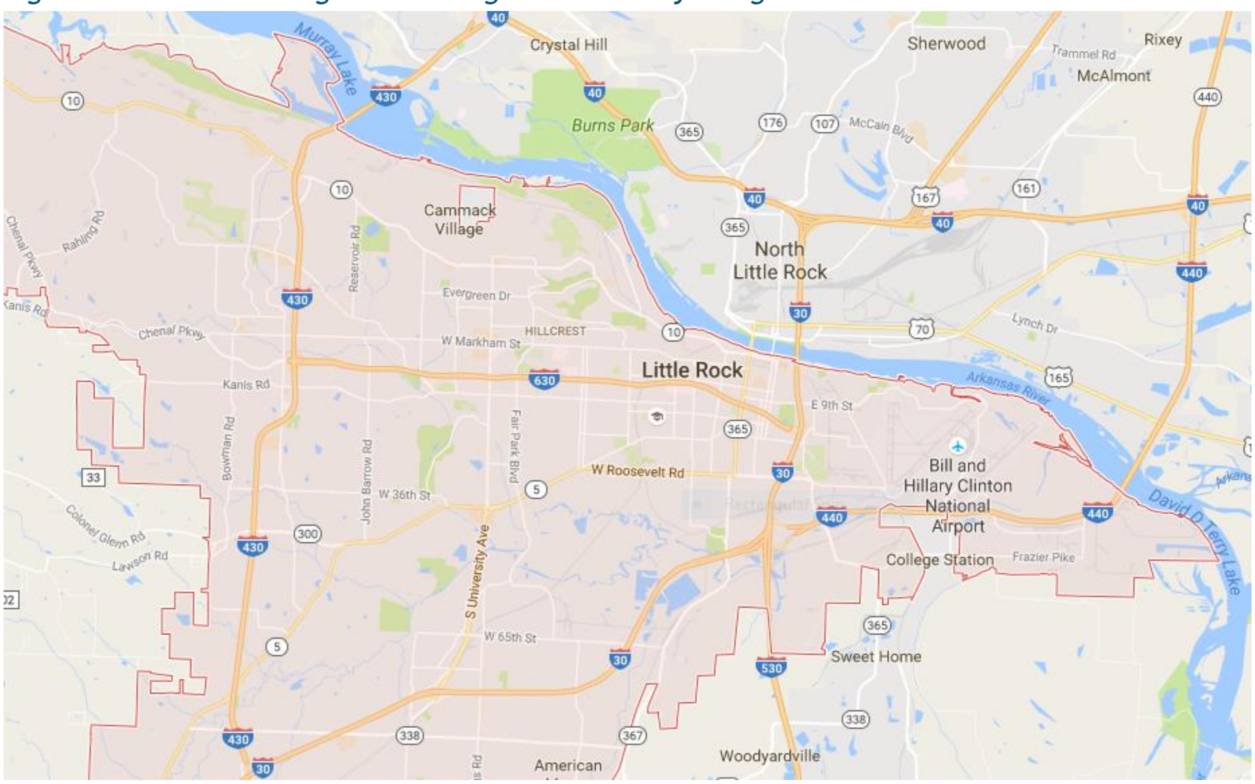
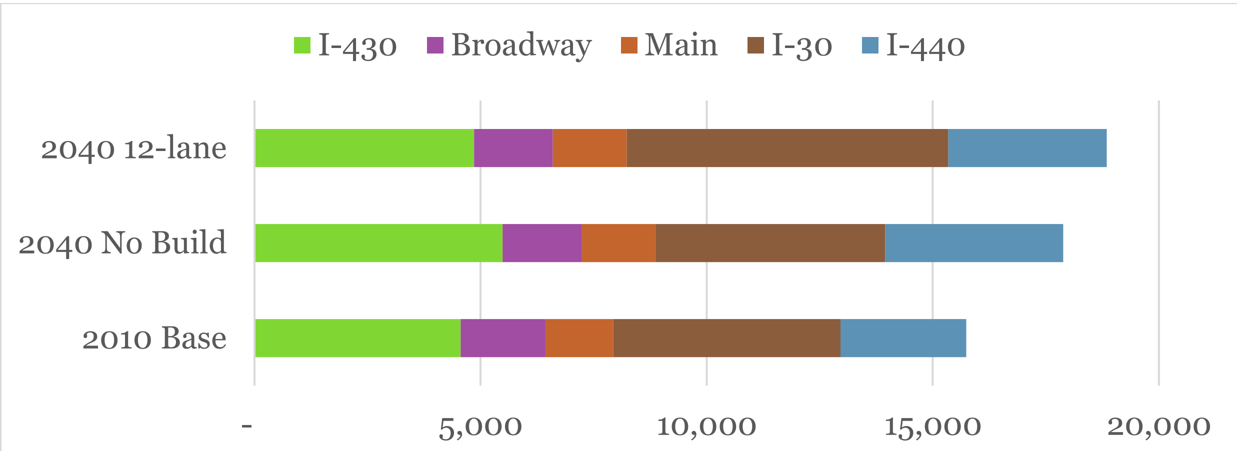


Image from Google Maps

The traffic volume on I-30 at the Arkansas River bridge is at capacity during the weekday morning and afternoon peak hours in the peak direction (southbound in the morning and northbound in the afternoon). The Arkansas Highway and Transportation Department (AHTD) is proposing that the existing I-30 bridge be replaced with a 12-lane bridge. The purpose is to eliminate current and future congestion.

Those readers who have fully absorbed the material presented above may have an accurate mental model of what would happen if this were done. Peak period, peak direction I-30 traffic volume is already at capacity. Therefore, throughput could not increase significantly unless capacity is increased.[6] There likely would be growth in traffic on the other bridges. If I-30 is expanded, it will attract traffic away from the other bridges, but there will be no reduction in regional congestion. This is exactly what DTA modeling shows. Figure 6 shows 2010 and 2040 DTA modeled bridge traffic volumes for the afternoon peak hour northbound (the peak direction).

Figure 6: DTA Modeled Afternoon Peak Hour Northbound Bridge Traffic Volumes



In the 2040 No Build alternative, total afternoon peak hour northbound bridge crossings increase by 14% from 2010, and 97% percent of the increase is on the two beltway bridges (I-430 and I-440). There is only a 1% increase in traffic on I-30 relative to 2010. In the 12-Lane Bridge alternative, afternoon peak hour northbound bridge crossings increase by 20% relative to 2010, and 67% of the increased traffic is on I-30.

In contrast, the STA model shows significant traffic growth in peak direction, peak hour traffic on I-30 whether the bridge is expanded or not, because the STA model fails to constrain traffic volumes so that they do not exceed capacity. This exaggerated traffic throughput in the 2040 No Build alternative translates into extreme congestion in the model. This fantasy congestion can then be mitigated in the model by widening.

STA modeling alone is bad, but the complete analysis done by AHTD is even worse. It takes the increasingly common step of marrying the STA model with a microsimulation model – a highly detailed model that simulates the behavior of individual cars. There is nothing inherently wrong with microsimulation. Like DTA, microsimulation accounts for bottlenecks and traffic backups. Regional microsimulation would provide accurate results. However, microsimulation requires much more data and more computer processing than DTA, and therefore is seldom done for entire regions. Instead, traffic volumes are extracted from the regional STA model and used as inputs to microsimulation. In the I-30 bridge analysis, it was assumed that the 2040 No Build peak direction, peak hour volume on I-30 would

[6] Widespread adoption of autonomous and connected vehicles may significantly increase peak throughput on roadways. However, this will not change the conclusions of this paper that STA is outdated and wrong and that DTA is the correct model used in evaluating urban freeway congestion.

be 20 percent higher than the 2010 traffic volume. As discussed above, this is impossible. When this 20% increase is fed into the microsimulation model, ridiculously long delays are calculated.

The combined STA + microsimulation modeling assumes that extremely long backups would develop on I-30– rather than vehicles simply shifting to one of the other four bridges.

Figure 7 shows regional vehicle hours traveled (VHT) for the three models: DTA, STA and STA + microsimulation. The DTA model forecasts somewhat higher regional VHT with the 12-lane I-30 bridge than for the No Build alternative, because total Vehicle Miles Traveled (VMT) are higher and there is little change in average regional speed. As discussed above, the STA-only and STA + microsimulation models show benefits from widening the bridge because they assume a fantasy level of congestion in the No Build alternative.

Figure 7: 2040 Build vs. No-Build Vehicle Hours Traveled (VHT)
Positive Numbers= Higher VHT, Negative Numbers = Lower VHT

Note: DTA and STA only VHT is for the entire region an entire weekday. STA + microsimulation VHT is only for a small subarea for the morning and afternoon peak hours because the analysis only covers this area and time periods.

The DTA model is preferable because it properly accounts for bottlenecks and traffic backups. It also is most consistent with triple convergence theory, and with experience with urban freeway expansion over the past 80 years. The STA model consistently estimates false benefits for freeway expansion. STA + microsimulation is even less accurate.

DTA should replace STA for all modeling of urban freeway alternatives.

To Reduce Urban Freeway Congestion – Add Street Capacity

All U.S. regions have urban freeway congestion, but the level of congestion is much worse in some regions than others. Data collected from cellphones, GPS and other new data sources are now giving transportation planners a much more accurate picture of congestion than was available in the past. INRIX computes an annual index of congestion across different regions. I combined the INRIX Index with data compiled by the Texas Transportation Institute to study which factors account for the differences in congestion across regions with a statistical regression model.[7]

Some factors that contribute to regional congestion are unavoidable in large and successful regions. These include regional population and regional median income, both of which are strongly correlated with congestion. The primary available policy that reduces congestion is adding non-freeway street capacity, which strongly reduces regional congestion. In sharp contrast, more freeway capacity has no effect on regional congestion. Adding freeway capacity simply shifts local traffic onto freeways without increasing travel speeds. Adding street capacity can reduce congestion on both streets and freeways.

Highways to Boulevards

As discussed above, parallel urban freeways and streets will operate at the same speed during peak periods, i.e. at the speed of the streets. When freeways operate at street speeds, we consider them extremely congested. Therefore, Therefore, urban freeways will always be congested in peak travel periods, no matter how much capacity is provided.

Urban freeway congestion can be eliminated by eliminating the urban freeway.

Several U.S. freeways have been removed and replaced with streets. These projects have been great successes. In some of these cases, the replacement resulted from elevated facilities failing. The lack of major traffic congestion in the aftermath illustrates the triple convergence principal in reverse.

[7] Marshall, Norman L. A Statistical Model of Regional Traffic Congestion in the United States. Presented at the January 2016 Annual Meeting of the Transportation Research Board in Washington D.C.

In his first job assignment, Sam Schwartz was tasked with finding out where the missing traffic went after New York City's West Side Highway collapsed. Where there had been 80,000 vehicles per day traveling the roadway, then there were none. Schwartz was unable to find any evidence of these 80,000 vehicles on other roadways![8]

This same pattern played out when San Francisco's Central Freeway was removed in 1996. As reported in the San Francisco Examiner at the time, Caltrans had warned of the "traffic nightmare of the decade." Instead there were "virtually no traffic jams" and Caltrans could only find 20,000 of the 80,000 vehicles per day that previously used the freeway.[9] DTA modeling would have explained these counterintuitive patterns.

Before and after photos of San Francisco Embarcadero Freeway/Embarcadero area are shown in Figures 8. This area is now an enormous attraction for both residents and visitors.

Figure 8: San Francisco Embarcadero: Before and After Conversion

Images from the Preservation Institute's website

For more information about freeway conversions, see the Congress for the New Urbanism's website: https://www.cnu.org/our-projects/highways-boulevards.

[8] Schwartz, Samuel L. with William Rosen. *Street Smart: The Rise of Cities and the Fall of Cars*, 2015.
[9] *San Francisco Examiner*. Traffic Planners Baffled by Success/No Central Freeway, No Gridlock, and No Explanation, September 13, 1996. http://www.sfgate.com/news/article/PAGE-ONE-Traffic-Planners-Baffled-by-Success-2966258.php

Little Rock Freeway Downsizing Case Study

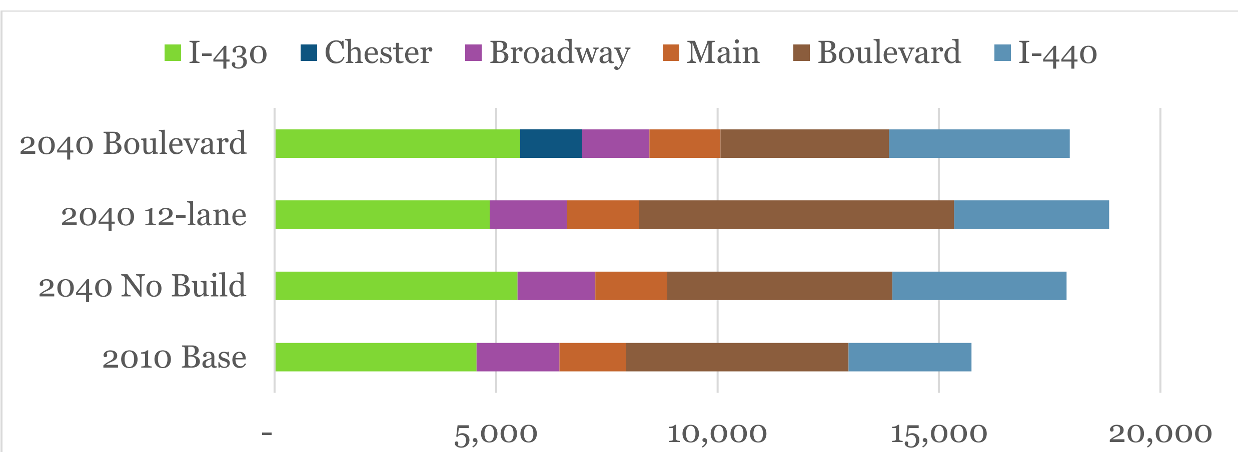
There has long been discussion in the Little Rock region about adding a third street bridge to downtown Little Rock to connect to Chester Street. In addition to adding additional bridge capacity, greater connectivity in the western part of the Little Rock downtown would help economic revitalization in the western part of downtown Little Rock. I have analyzed an alternative with a new Chester Street Bridge along with replacement of I-30 with a 6-lane boulevard (see Figure 9).

Figure 9: Little Rock Proposed Chester Street Bridge & Boulevard Conversion

Image from Google Maps

Figure 10 shows the northbound afternoon peak hour bridge crossings in 2040.

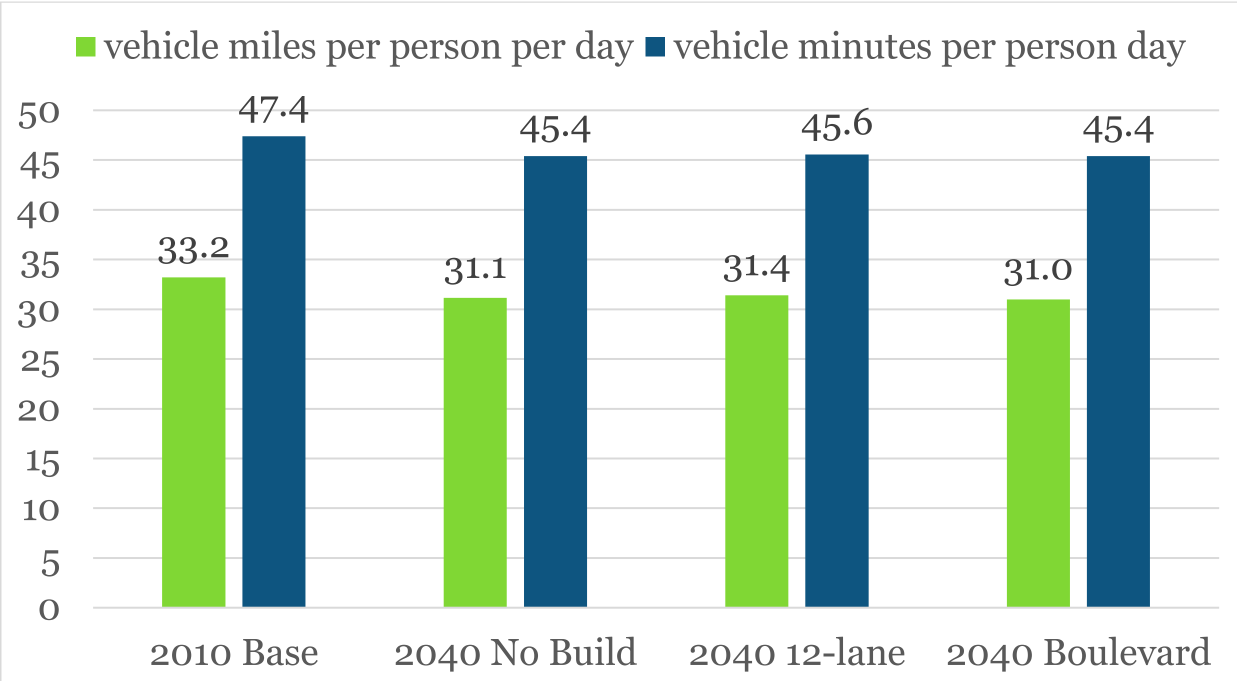
Figure 10: DTA Modeled Afternoon Peak Hour Northbound Bridge Traffic Volumes - Boulevard Alternative



The four street bridges in the Boulevard alternative carry as much traffic as the three bridges (including I-30) do in the No Build alternative.

As shown in Figure 11, this Boulevard alternative (including the Chester Street bridge) performs just as well in the regional DTA model as the 2040 No Build alternative (that maintains the I-30 freeway), and slightly better than the 12-Lane I-30 alternative. In the model, average travel distance per person and average travel time per person are lower in 2040 than in 2010 because regional planners assume land use growth between 2010 and 2040 will be somewhat more concentrated in urban areas than the current land use pattern.

Figure 11: DTA Modeled Regional Performance Measures



STA modeling is incapable of properly evaluating freeway downsizing. When it is attempted, the modelers just run through these steps: 1) future traffic volume will be higher than base year future traffic volume, 2) this future traffic volume cannot be accommodated on the downsized roadway, 3) the downsizing alternative is rejected. As step #1 is invalid, steps #2 and #3 also are invalid.

DTA modeling properly shows that freeway downsizing is a viable alternative.

Conclusions

DTA properly accounts for bottlenecks and traffic backups: Static Traffic Assignment (STA) does not.

DTA properly models triple convergence theory; STA does not.

STA shows false benefits for freeway expansion that have not materialized over 80 years of freeway construction in the United States. DTA does not show these false benefits.

DTA properly accounts for the impacts of freeway downsizing; STA does not.

DTA should be used for all urban freeway capacity analyses. Making this change will result in:

- More accurate planning
- More efficient infrastructure investments
- Less destructive impacts of urban freeways on cities
- Less air and noise pollution in densely-populated areas

About the Author

Norm Marshall is President of Smart Mobility, Inc. in Vermont. He graduated from the Worcester Polytechnic Institute with a B.S. in Mathematics and from Dartmouth College with an M.S. in Engineering Sciences. He has 30 years of transportation modeling experience and has managed projects in over 30 states. He has many peer-reviewed publications. He can be contacted at nmarshall@smartmobility.com.