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16. Abstract

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CONGESTION ON VIRGINIA'S URBAN HIGHWAYS

by

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Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Transportation and the University of Virginia)

In Cooperation with the U.S. Department of Transportation
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ABSTRACT

Congestion on our nation's highways, most commonly found in the urban areas, is a serious problem that is growing steadily worse. While Virginia is predominantly rural, there are few Virginians who have not experienced congestion at some time in their travels throughout the state. The magnitude of this congestion is not known. Accordingly, statewide congestion statistics are needed in order to define and evaluate the problem and to establish the level of effort needed to solve it. Based on a procedure developed by the Federal Highway Administration using Highway Performance Monitoring System data, this report documents statewide recurring congestion on Virginia's interstate roadways. Estimates of nonrecurring congestion, congestion in the year 2000, and congestion on other urban roadways are also provided.

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INTRODUCTION

Congestion on our nation's highways, most predominantly in the urban areas, is a serious problem that is growing steadily worse. It is attracting the attention of transportation engineers, planners, and researchers, as well as local, state, and federal officials. Several national conferences have been held on congestion, and funding is being allocated to national research programs to study the problem. Headline stories on congestion are frequently seen in our urban newspapers.

Being caught in congestion is certainly annoying, often leading to frustration and anger. It is also expensive. Various costs associated with a person's time increase because of delays resulting from congestion. Costs associated with both personal injury and property damage increase as more accidents occur. Fuel and maintenance costs increase as vehicles operate much less efficiently in stop-and-go, reduced-speed situations. The indirect costs associated with air pollution increase as congestion increases the pollutants exhausted into the air.

While Virginia is predominantly rural, i.e., almost 4 of every 5 miles of highway are considered to be rural, there are few Virginians who have not experienced congestion at some time in their travels. There are 10 major urban areas located totally or partially in Virginia, plus an additional 33 areas designated as "small urban." These urban areas, which contain about 20% of the highway system in Virginia, have more than 53% of the travel.

In most urban areas, the interstate routes are among the most congested roadways as they fill up with commuters traveling to and from work in the morning and afternoon rush hours. Interstates account for about 2% of the roadway mileage in Virginia's urban areas; however, they handle about 24% of the annual travel.

Congestion and its impacts are known to exist in Virginia; however, the magnitude statewide is not known. This situation generally parallels the national scene as very few nationwide statistics on congestion are available. Site-specific congestion statistics are often developed when planning for or evaluating specific roadway improvements; however, no general, statewide statistics have been compiled. These statistics are required in order to evaluate the problem and establish the level of effort needed to solve the problems caused by congestion.

DEFINITION OF CONGESTION

The first step in determining statewide congestion statistics is to define congestion in a way that can be measured. This is a difficult task as congestion, like beauty, is in the eye of the beholder. A driver in a queue of five vehicles behind a slow-moving coal truck on a mountainous two-lane road in southwest Virginia will likely be "experiencing" congestion. At the other extreme, a driver who is on I-395 approaching the 14th Street Bridge leading into Washington, who is in a queue that could be several miles long, and who is on a section of roadway carrying more than 170,000 vehicles per day is clearly "experiencing" congestion. When considering congestion statewide, a definition that favors the latter scenario must be used.

Morris J. Rothenberg defines urban highway congestion as "a condition in which the number of vehicles attempting to use a roadway at any given time exceeds the ability of the roadway to carry the load at generally acceptable service levels" (1). The concept of levels of service (LOS) is well established in highway capacity analysis procedures (2). The levels range from LOS A, which represents free-flowing traffic, to LOS F, which represents forced flow or stop-and-go traffic. Urban roadways are typically considered satisfactory if operating at LOS D, which represents high-density but stable flow. Small increases in traffic at this level will often cause operational problems. Flow in the next level, LOS E, is said to be at capacity and on the verge of breaking down. Accordingly, it is generally agreed that congestion begins to occur when traffic is operating at LOS D. Since these levels of service have been quantitatively defined by certain traffic characteristics, although different for different kinds of roadways, the use of LOS D provides a way of measuring congestion.

There are two types of congestion: recurring and nonrecurring. Typically, recurring congestion occurs during the morning and afternoon rush hours as commuters travel to and from work. Nonrecurring congestion is caused by random incidents, most often disabled vehicles and accidents. Recurring congestion is most easily identified as the characteristics of rush hour traffic are well documented. Incidents are random events, and specific patterns and characteristics are not as well defined. Accordingly, estimates of nonrecurring congestion are difficult and not as reliable as estimates of recurring congestion.

PROCEDURE

The traffic characteristics used to define levels of service on interstate highways are the density, average travel speed, volume over capacity ratio (V/C), and maximum service flow. Since these characteristics have a range over which LOS D is designated, it is necessary to set the value of the characteristic at the point congestion is assumed to begin. The average travel speed at the boundary of LOS C and LOS D is approximately 54 mph. If a travel speed of 55 mph is established as the desired speed for an interstate, then speed under 55 mph constitutes delay. Accordingly, this boundary point, often referred to as a "high" LOS D, was chosen as the beginning point of congestion. The V/C at this point is 0.77.

The only statewide data base of traffic characteristics on the highways in Virginia is the Highway Performance Monitoring System (HPMS), which is a federally-required sampling program of functionally classified highways. Approximately 50% of the interstate system has been sampled, providing a reasonably accurate data base from which to develop congestion statistics. (Pertinent statistics from the 1986 HPMS submittal are presented in Appendix A.)

Jeffrey A. Lindley, a researcher with the Federal Highway Administration, has developed a computer program to analyze the HPMS data base for interstate highway congestion (3). His procedure was borrowed and used to calculate congestion in Virginia. Following is a summary of basic assumptions made in the analysis. (A detailed discussion of the methodology is presented in Appendix B.)

1. Congestion occurs when the V/C is equal to or greater than 0.77.
2. Delay occurs when the average speed is less than 55 mph.
3. Fuel is wasted when the average speed is less than 55 mph, as the miles per gallon decrease.
4. Costs are calculated based on $6.25 per vehicle hour of delay and $1.00 per gallon of wasted fuel.

RESULTS OF ANALYSIS

On a typical weekday in 1986, almost 15% of the travel on interstate highways in Virginia's urban areas was congested. More than one third of the interstate mileage experienced congestion some time during the day. As expected, most of the congestion occurred during the commuting periods, broadly defined as 6:00 to 10:00 a.m. and 3:00 to 7:00 p.m. Almost 30% of travel during these rush hours was congested. While these percentages were not very large, and likely not very alarming, the ramifications of congestion were staggering. The 2.5 million vehicle miles of congestion resulted in more than 46,000 vehicle hours of delay and almost 43,000 gallons of wasted fuel daily, at an estimated cost of about $332,000 to motorists. For the year 1986, congestion cost Virginia's drivers more than $86 million, based on more than 12 million vehicle hours of delay and 11 million gallons of wasted fuel. (See Appendix C.)

It is important to note that these figures represent only recurring congestion on the interstate system. The added congestion caused by nonrecurring events, e.g., accidents and disabled vehicles, is not accounted for. The Federal Highway Administration effort (3) found that only about 40% of the total delay and wasted fuel on urban interstates nationwide (including Virginia) is attributable to recurring congestion. If this finding is assumed to be true in Virginia, then the figures for delay and wasted fuel can be multiplied by a factor of 1.5 to derive a conservative estimate of delay and wasted fuel caused by nonrecurring congestion. If the two figures are then added, it can be estimated that recurring and nonrecurring congestion on urban interstates in Virginia resulted in about 30 million vehicle hours of delay and 27.5 million gallons of wasted fuel in 1986. The cost to motorists of this delay and wasted fuel was an estimated $215 million.

Virginia has just entered an era of significant roadway construction, and it is impossible to estimate the positive impacts on congestion that will result from these improvements. For the purpose of discussion, however, recurring congestion was calculated for a typical week day in the year 2000 assuming the same interstate roadway system, a 5% annual growth rate in traffic, and constant dollars. (Since 1980, travel has grown at an average annual rate of 4.8%; the rate over the last three years has averaged 6.6%.) Daily vehicle miles of congestion in Virginia's urban areas will increase almost eight times to 19.4 million. Daily delay will amount to more than 435,000 vehicle hours, and almost 395,000 gallons of fuel will be wasted. Costs to motorists will total $3,114,000. For the year 2000, congestion will cost almost $810 million, based on about 113 million vehicle hours of delay and 103 million gallons of wasted fuel. (See Appendix C.) If nonrecurring congestion is estimated as described previously, then recurring and nonrecurring congestion on urban interstates in the year 2000 will result in 282.5 million vehicle hours of delay and 257.5 gallons of fuel wasted, at an estimated total cost of slightly more than $2 billion. While these estimates are very crude, they do provide an order of magnitude estimate of congestion in the future. The numbers suggest that even with Virginia's ambitious construction program, congestion will continue to have major impacts in the future.

As a final task, the percentage of total urban congestion occurring on the interstate system was estimated. Based on a review of congested peak hour, peak direction vehicle miles of travel in urban areas reported in the HPMS, about 47% of the total urban congestion occurred on the interstate system. Accordingly, the other urban systems combined experienced about the same congestion and resulting impacts as did the interstate system.

SUMMARY AND CONCLUSIONS

In 1986, day-to-day (recurring) congestion on interstate highways in urban areas in Virginia cost motorists more than $86 million. This cost was based on about 12 million vehicle hours of delay and 11 million gallons of wasted fuel and was expended mostly during the morning and afternoon rush hours as commuters traveled to and from work. If the impacts of nonrecurring congestion caused by incidents, most often accidents and disabled vehicles, are estimated and added, then total congestion resulted in about 30 million vehicle hours of delay and 27.5 million gallons of fuel wasted. This increased the cost of congestion to $215 million for delay and wasted fuel.

Based on several simplifying assumptions, it is estimated that recurring congestion alone will cost motorists about $810 million in the year 2000. This figure is based on 113 million vehicle hours of delay and 103 million gallons of wasted fuel. If the impacts of nonrecurring congestion are added, then motorists' total delay will amount to about 282.5 million vehicle hours and fuel waste will be about 257.5 million gallons. The delay and wasted fuel will cost motorists more than $2 billion. While these forecasts are somewhat high because the benefits of Virginia's recently increased highway construction program are not included, the numbers provide order of magnitude estimates.

In conclusion, Virginia's urban interstates currently experience a significant amount of congestion, and it appears that congestion in the future will be considerably worse, even with Virginia's expanded highway construction program. Large amounts of delay and wasted fuel are direct impacts of this congestion, resulting in major costs to Virginia motorists. The data base also suggests that just under 50% of urban congestion occurs on the interstate system. Accordingly, the congestion and impacts thereof can be conservatively estimated at twice the above numbers if other freeways and expressways, principal and minor arterials, and collectors are considered. The resulting costs are overwhelming, and considerable attention should be given to relieving congestion on Virginia's urban roadways.

REFERENCES

1. Rothenberg, Morris J., "Urban Congestion in the United States: What Does the Future Hold?", ITE Journal, Volume 55, Number 7, July 1985, pp. 22-39.

2. "Highway Capacity Manual," Special Report 209, Transportation Research Board, National Research Council, Washington, D.C., 1985.

3. Lindley, Jeffrey A., "Quantification of Urban Freeway Congestion and Analysis of Remedial Measures," Federal Highway Administration, FHWA/RD-87/052, October 1986.

APPENDIX A

SUMMARY OF PERTINENT STATISTICS FROM THE 1986 HPMS SUBMITTAL

EVALUATION OF 1986
PEAK HOUR/PEAK DIRECTION VEHICLE MILES OF TRAVEL IN VIRGINIA

(All statistics in 1,000's unless otherwise noted.)

1. Grand total of 8,873 VMT are distributed as 60% rural, 3% small urban, and 37% urbanized.

2. Define congestion as V/C greater than 0.80.

3. 1,601 VMT, or 18% of grand total, are congested, with 3% rural, 1% small urban, and 14% urbanized.

4. 6% of rural VMT are congested, 23% of small urban are congested, and 38% of urbanized are congested.

5. Of the 1,601 congested VMT, 19% are rural, 3% are small urban, and 78% are urbanized.

6. Of the 1,601 congested VMT:

   a. 50% are interstate (12% rural, 0% small urban, 38% urbanized)
   b. 9% are other freeway/expressway (0% rural, 0% small urban, 9% urbanized)
   c. 20% are other principal arterial (1% rural, 2% small urban, 17% urbanized)
   d. 17% are minor arterial (4% rural, 1% small urban, 12% urbanized)
   e. 4% are collector (2% rural, 0% small urban, 2% urbanized)

7. Of the 1,601 congested VMT:

   a. 31% are in Northern Virginia
   b. 21% are in Norfolk/Portsmouth/Va. Beach area
   c. 12% are in Newport News/Hampton area
   d. 9% are in Richmond
   e. 1% each are in Roanoke, Lynchburg, Tri-Cities, Charlottesville, and Danville
   f. 3% are in small urban areas
   g. 19% are in rural areas

8. Of the 1,296 congested urban VMT:

   a. 39% are in Northern Virginia
   b. 26% are in Norfolk/Portsmouth/Va. Beach area
   c. 11% are in Newport News/Hampton area
   d. 15% are in Richmond
   e. 1% each are in Roanoke, Lynchburg, Tri-Cities, Charlottesville, and Danville
   f. 4% are in small urban areas

9. On average, 38% of the VMT in urbanized areas are congested. The percent congested in each area is:

   a. 47% in Northern Virginia
   b. 44% in Norfolk, Portsmouth/Va. Beach area
   c. 23% in Richmond
   d. 56% in Newport News/Hampton area
   e. 10% in Roanoke
   f. 15% in Lynchburg
   g. 11% in Tri-Cities
   h. 19% in Charlottesville
   i. 46% in Danville

10. Actual peak hour/peak direction vehicle miles of travel having a V/C greater than 0.80 are distributed as follows:

Northern Virginia	502,000
Norfolk/Portsmouth/Va. Beach area	343,000
Newport News/Hampton area	197,000
Richmond	136,000
Roanoke	16,000
Lynchburg	16,000
Danville	16,000
Tri-Cities	9,000
Charlottesville	7,000
Small urban	54,000
Rural	305,000
	1,601,000

11. Congested (V/C greater than 0.80) roadway mileage during peak hour of each day:

    Rural: 161 miles
    Small urban: 60 miles
    Urbanized: 574 miles

APPENDIX B

SUMMARY OF METHODOLOGY USED IN DETERMINING CONGESTION STATISTICS

METHODOLOGY

1. Establish volume profile (24-hour distribution of average annual daily traffic (AADT) by percentage) for each urban interstate by route number and urban area.

   Source: VDOT's 24-hour permanent count stations or field sheets from 12-hour manual counts. (Hourly totals from the field sheets are divided by the AADT reported in VDOT's count book; the difference between the AADT and the 12-hour total is distributed equally by hour in the 7:00 p.m. to 7:00 a.m. time period.)

2. Calculate each HPMS sample section's capacity by:

   C = 2,000 x No. Lanes x f(W) x f(HV)

   where f(W) is the adjustment factor for lane width and lateral clearance, and f(HV) is the adjustment factor for the effect of heavy trucks.

   These factors are "table look-ups" in the software and are based on the Highway Capacity Manual. Lane width is provided in the HPMS data, the percentage of trucks is provided, the HPMS-provided shoulder width is used for lateral clearance, and a general, level terrain is assumed for passenger car equivalency in the truck factor calculation.

3. Calculate annual vehicle miles of travel by:

   VMT = AADT x length of sample section x 365 days/year
   x expansion factor for volume group and functional class.

4. Calculate annual congested vehicle miles of travel, CVMT. Distribute AADT by the appropriate volume profile and calculate V/C for each hour. If V/C is greater than or equal to 0.77, then there is congestion. Therefore,

   CVMT = volume experiencing congestion x length of sample section
   x 260 week days/year x expansion factor for volume group
   and functional class.

5. Calculate annual vehicle hours of delay by:

   Delay = (Ideal travel time/vehicle - actual travel time/vehicle)
   x hourly volume x 260 week days/year
   x expansion factor for volume group and functional class.

   This is performed for each congested hour and summed. Ideal travel time is the time needed to travel the sample section at 55 mph. Actual travel time is the time needed to travel the sample section at the speed determined from Figure 3-4 of the Highway Capacity Manual, which relates average travel speed to the V/C ratio under ideal conditions. If the V/C is greater than 1.00, then a speed of 20 mph is assumed.

6. Calculate excess annual fuel consumption. This is based on the relationship:

   Miles per gallon (mpg) = 8.8 + 0.25 (average speed).

   The mpg at 55 mph minus the mpg at the actual speed determined from Figure 3-4 represents the fuel economy lost. In other words, it takes more gallons per mile (gpm) at speeds lower than 55 mph. The additional gallons required when the speed is less than 55 mph are considered to be wasted. The calculation is as follows:

   Excess fuel consumption = Additional gpm x length of the sample section x hourly volume x 260 week days/year x expansion factor for the volume group and functional class.

   This is performed for each congested hour and summed.

7. Calculate the annual costs to motorists by:

   Costs = \$6.25 x annual vehicle hours of delay + \$1.00 x annual gallons of excess fuel.

   A 1977 AASHTO document quotes a value of time for a work trip having a 5 to 15 minute time savings as \$2.40/traveler hour. If this value is expanded to October 1985 by using the CPI, and an average vehicle occupancy of 1.25 persons/vehicle is assumed, then the value becomes \$6.25. Fuel cost is assumed at \$1.00/gallon.

8. Statistics for the peak period are calculated the same way except only the 6:00 a.m. to 10:00 a.m. and 3:00 p.m. to 7:00 p.m. time periods are used.

9. Statistics for the year 2000 are calculated the same way except that the AADTs are doubled. At the assumed annual growth rate of 5%, travel will approximately double by the year 2000. If the road network is assumed to be held constant, then the AADT must double.

APPENDIX C

TABULAR SUMMARY OF CONGESTION STATISTICS

Table C-1

DAILY INTERSTATE CONGESTION IN VIRGINIA
(1986 Recurring)

Urban Area	Total Miles	Congested Miles	VMT (1,000s)	Congested VMT (1,000s)	Delay (Veh-hrs)	Fuel Waste (Gallons)	Motorist Cost
Northern Va.	71	58	8,210	1,788	37,673	34,445	$ 269,900
Norfolk/Va. Beach	45	27	3,098	641	7,668	7,329	$ 55,260
Newport News/ Hampton	37	8	1,787	69	456	448	$ 3,300
Richmond	62	6	3,034	56	426	431	$ 3,090
Roanoke	21	0	807	0	0	0	0
Petersburg	16	0	469	0	0	0	0
Lynchburg	0	0	0	0	0	0	0
Danville	0	0	0	0	0	0	0
Charlottesville	1	0	29	0	0	0	0
Bristol	10	0	187	0	0	0	0
Small urban	24	0	465	0	0	0	0
Total urban	287	99	18,086	2,554	46,223	42,653	$ 331,550
Annual for total urban	--	--	6,601,390	664,040	12,017,980	11,089,780	$86,203,000

Table C-2

DAILY INTERSTATE CONGESTION IN VIRGINIA
(2000 Recurring)

Urban Area	Total Miles	Congested Miles	VMT (1,000s)	Congested VMT (1,000s)	Delay (Veh-hrs)	Fuel Waste (Gallons)	Motorist Cost
Northern Va.	71	71	16,420	11,818	277,990	251,609	$ 1,989,050
Norfolk/Va. Beach	45	42	6,196	4,411	107,502	96,815	$ 768,700
Newport News/	37	13	3,574	1,150	24,569	22,367	$ 175,920
Richmond	62	60	6,067	1,669	22,615	21,389	$ 162,730
Roanoke	21	8	1,614	208	1,711	1,739	$ 12,430
Petersburg	16	5	938	165	655	721	$ 4,820
Lynchburg	0	0	0	0	0	0	0
Danville	0	0	0	0	0	0	0
Charlottesville	1	0	0	0	0	0	0
Bristol	10	0	0	0	0	0	0
Small urban	24	0	0	0	0	0	0
Total urban	287	199	34,809	19,421	435,042	394,640	$ 3,113,650
Annual for total urban	--	--	12,705,285	5,049,460	113,110,920	102,606,400	$809,549,000

Table C-3

INTERSTATE CONGESTION IN VIRGINIA
(6:00 to 10:00 a.m. and 3:00 to 7:00 p.m., 1986 Recurring)

Urban Area	VMT (1,000s)	Congested VMT (1,000s)	Delay (Veh-hrs)	Fuel Waste (Gallons)	Motorist Cost
Northern Va.	4,125	1,584	33,780	30,858	$ 241,980
Norfolk/Va. Beach	1,596	638	7,657	7,312	$ 55,170
Newport News/Hampton	420	64	446	434	$ 3,220
Richmond	1,494	56	426	431	$ 3,090
Total	7,635	2,342	42,309	39,035	$ 303,460
Annual total	1,985,100	608,920	11,000,340	10,149,100	$78,899,600

Table C-4

INTERSTATE CONGESTION IN VIRGINIA
(6:00 to 10:00 a.m. and 3:00 to 7:00 p.m., 2000 Recurring)

Urban Area	VMT (1,000s)	Congested VMT (1,000s)	Delay (Veh-hrs)	Fuel Waste (Gallons)	Motorist Cost
Northern Va.	8,250	7,214	190,475	170,960	$ 1,361,430
Norfolk/Va. Beach	3,191	2,624	74,490	66,394	$ 531,960
Newport News/Hampton	839	705	16,933	15,260	$ 121,090
Richmond	2,987	1,330	21,115	19,681	$ 151,650
Roanoke	733	208	1,711	1,739	$ 12,430
Petersburg	277	51	216	232	$ 1,580
Total	16,277	12,132	304,940	274,266	$ 2,180,140
Annual total	4,232,020	3,154,320	79,284,400	71,309,160	$566,836,400