

3 ROADWAYS

Approximately 16 million trips are made in the Boston metropolitan region every day. The vast majority of these trips (80 to 85 percent, depending on trip type) involve the use of the roadway network (including trips driving to a transit station and carpools). About 80 million vehicle-miles are logged everyday, over three-quarters of these on the interstate highways and arterials, even though they account for only a fifth of the centerline miles of the roadway network.¹

Reported here are the results of the data collection effort on the CMS network of limited-access highways and arterial roadways. This chapter also describes the performance measures used.

3.1 CMS ROADWAY NETWORK

Travel time information is collected on the regionally significant roadways in the Boston region. These include all roadways that are functionally classified as principal/major arterials and all limited-access highways (often called expressways or freeways), as well as some minor arterials.² This network comprises about 900 centerline miles (or 1,800 miles, bidirectional) of arterial roadways and 377 centerline miles of limited-access highways—over 10 percent of all roadways in the region. Most state-numbered roadways are included in the monitored network, as are most corridors of the National Highway System. In general, volumes on these roadways exceed 10,000 vehicles per day; most of the arterial roadways typically handle over 27,500 vehicles per day on some portion of their length. Volumes on the limited-access highways in the Boston region typically range from 40,000 to 235,000 vehicles per day. The CMS network is dynamic, too, meaning that additional roads may be monitored in any given monitoring effort; other roadways may not get monitored in consecutive monitoring efforts.

Figure 3.1 shows the monitored roadway network and indicates when the monitoring of each roadway took place. A complete list of the monitored roadways, with the year of the most recent travel time data for each route, is provided in Appendix B.

3.2 TRAVEL-TIME-BASED PERFORMANCE MEASURES

3.2.1 Roadway Travel Time Measures

In order to apply performance measures and congestion thresholds, the CMS-monitored roadways are grouped into three general categories: arterial roadways, partially limited-access roadways (which have characteristics of limited-access control, but tend to have midsegment curb cuts and slower speed limits and design speeds), and limited-access highways. Identifying congested areas or locations presenting mobility concerns must be accomplished using slightly different thresholds of level of service (LOS) for the different categories of roadway.

Listed in Table 3.1 are the performance measures and congestion thresholds used for each type of roadway. In general, the CMS identifies congestion on monitored roadway segments by using a combination of the following travel-time-based measures: *average travel speed*, *speed index*, and *delay*. These performance measures are calculated from travel time data collected at peak commute

¹ All values expressed in this paragraph are from the CTPS travel demand model. The region is defined as 164 communities in eastern Massachusetts. The estimates are for 2003, using 1995 as the base model year.

² Limited-access highways were monitored under CTPS project #83205, which used MassHighway SPR funds.

times in typical traffic conditions. The performance measures and congestion thresholds are described in further detail in the following sections.

Table 3.1. Roadway Performance Measures and Congestion Thresholds

Performance Measure	Congestion Threshold (for a specified roadway segment)
<i>Limited-Access Roadways (Freeways/Expressways):</i>	
• Average travel speed (mph)	• Average travel speed < 50 mph
<i>Partially Limited-Access Arterial Roadways (Urban Street Class I/II):</i>	
• Average travel speed (mph)	• Average travel speed ≤ 21 mph
• Speed index (ratio of observed speed to posted speed limit)	• Speed index < 0.70
• Average delay (seconds when speed < 5 mph)	• Average delay ≥ 55 seconds
<i>Arterial Roadways (Urban Street Class III):</i>	
• Average travel speed (mph)	• Average travel speed ≤ 14 mph
• Speed index (ratio of observed speed to posted speed limit)	• Speed index < 0.70
• Average delay (seconds when speed < 5 mph)	• Average delay ≥ 55 seconds

3.2.1.1 Average Observed Travel Speeds

Average observed travel speeds have been used as a measure since the CMS roadway monitoring began (limited-access highways in 1994 and arterial roadways in 1995). Travel speed is a typical measure of performance for a roadway segment; for example, the Highway Capacity Manual (HCM) defines level of service on urban streets (arterial roadways) and freeways in terms of average travel speeds.³

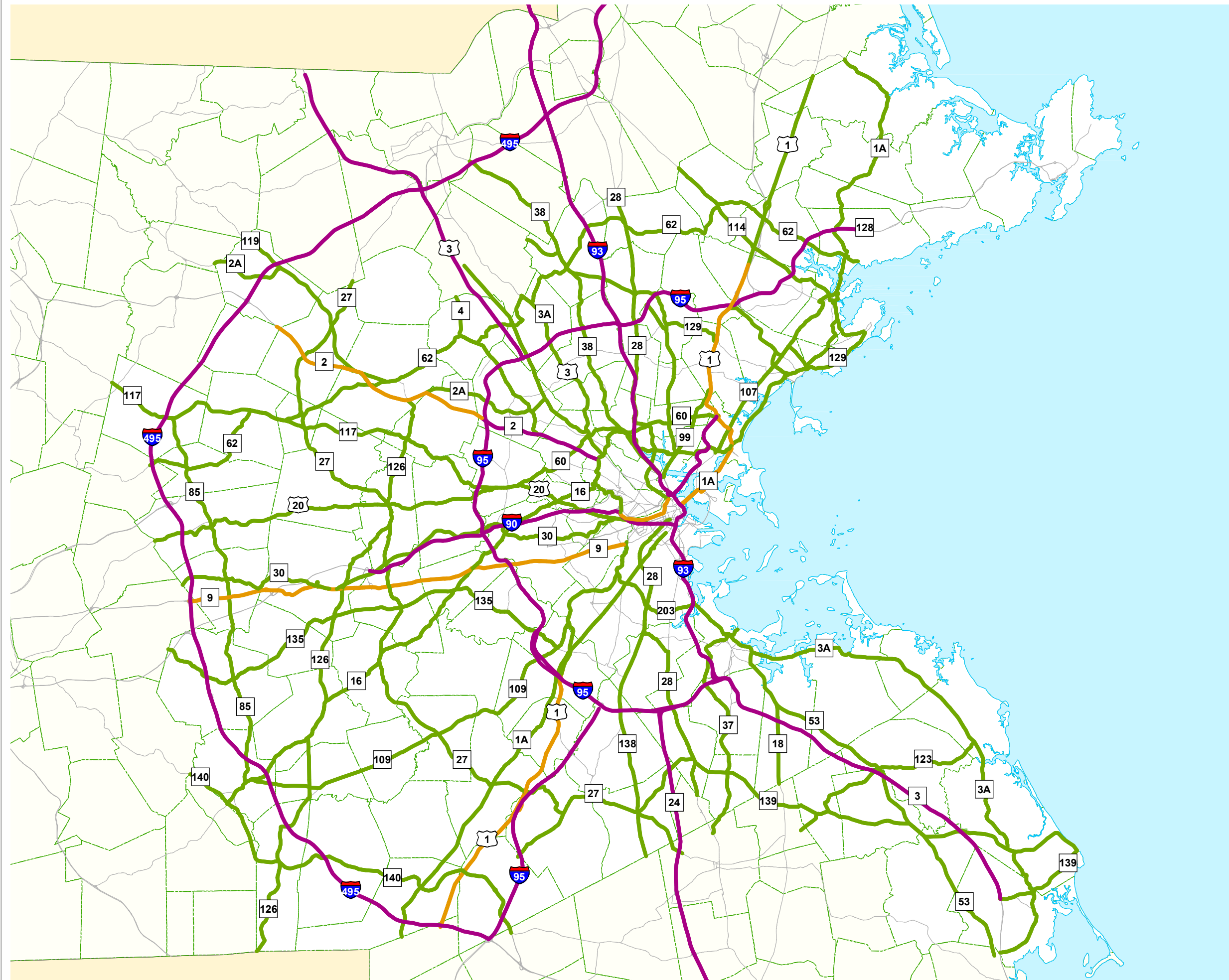
For most of the roadways, travel speed observations were collected during two periods of time. The limited-access highways were monitored in the years 1994–1995 and again in 1999–2000. Arterial roadways were monitored in the periods 1995–1999 and 2001–2003. Therefore, trends can now be investigated.

One of the methods the 2000 HCM uses to establish roadway (that is, urban-street) level of service (LOS) is by analyzing average travel speeds. The LOS corresponding to the average speeds varies, depending on the roadway classification (see Table 3.2).

In order to keep the roadway classifications general and simple, for the CMS analysis the higher-speed arterials (those with some degree of limited access) and partially limited-access highways are classified as Urban Street Class I/II, whereas the remainder of the arterial roadway network is classified as Urban Street Class III. Figure 3.2 depicts the recently monitored roadway network and indicates the CMS roadway classification.

FIGURE 3.2

CMS ROADWAY CLASSIFICATION



-  Expressway:
Fully Limited -
Access Highway
-  Urban Arterial
Class I/II
-  Urban Arterial
Class III

BOSTON MPO
Congestion
Management
System

Table 3.2. Level of Service Based on Average Travel Speed: Arterial Roadways

<i>Urban Street Class I/II</i>		<i>Urban Street Class III</i>	
LOS	Avg. Travel Speed	LOS	Avg. Travel Speed
A	>42	A	>30
B	>34–42	B	>24–30
C	>27–34	C	>18–24
D	>21–27	D	>14–18
E	>16–21	E	>10–14
F	≤ 16	F	≤ 10

Source: 2000 *Highway Capacity Manual*, p. 15-3.

For limited-access highways, LOS is described in the Highway Capacity Manual in terms of the flow of traffic relative to free-flow speeds.³ Levels of service A, B, and C essentially describe conditions equal to or greater than free-flow speeds. LOS D describes conditions where speeds are beginning to decrease, and LOS E describes travel conditions at capacity, but with vehicle speeds that still exceed 49 miles per hour. LOS F describes conditions where traffic flow is congested. Table 3.3 gives the specific speed ranges assigned to each LOS category, based on the HCM descriptions of LOS.

Table 3.3. Level of Service Based on Average Travel Speed: Limited-Access Highways

<i>Limited-Access Highways</i>	
LOS	Average Travel Speed
A, B, C	≥ 60 mph
D	55 mph to <60 mph
E	50 mph to <55 mph
F	<50 mph

Based on the 2000 *Highway Capacity Manual*, pp. 13-8–13-11.

A roadway's average travel speed is not necessarily indicative of a traffic problem or congestion on that segment. In order to appropriately identify a congested segment, the CMS analysis considers not only the average travel speed, but also the posted speed limit and a travel-delay measure. These factors are explained in the following sections.

3.2.1.2 Travel Speed Index

The posted speed limit is one of the factors that influence travel speeds on roadways. Thus, in order to complement the average observed travel speeds, a *speed index* is used to account for the speed limit factor. The speed index is simply a ratio that is calculated by dividing the average observed travel speed by the posted speed limit for that roadway segment. The index helps to determine whether a slow observed speed is caused by congested conditions or simply by a lower posted speed limit.

³ Transportation Research Board of the National Research Council, *Highway Capacity Manual*, 2000, pp. 13-8 through 13-11.

3.2.1.3 Delay

Delay is a performance measure used to describe conditions on the arterial roadway network. For purposes of CMS monitoring, delay is defined as the time a vehicle travels below 5 mph on a roadway segment (including time that the vehicle is stopped, as long as the speed has been lower than 5 mph for at least three consecutive seconds). The observed delay is closely related to “control delay” (for arterial roadways), which is the delay that occurs when a vehicle moves forward in a queue, a slow stop-and-go process. Along most segments, delay can be attributed to intersection controls (for example, traffic signals) at a segment endpoint; however, in a few cases the collected travel-speed data may also include the effect of delays from any midsegment traffic impedances (such as left-turning vehicles, pedestrian crossings, and school bus activity). The division of the monitored routes into segments was done in such a way that this effect was minimized.

Using widely accepted industry practices, an intersection with an average control delay per vehicle of more than 55 seconds is considered to be operating at LOS E. The HCM does not include a definition of a delay threshold for freeways.

The 2000 HCM strongly recommends that any analysis of signalized intersections include both a capacity analysis and an LOS analysis in order to obtain a complete picture of existing intersection operations.⁴ In other words, the CMS analysis should be viewed as a cursory assessment of signalized intersections; further data would need to be collected in order to determine the severity of problems for a specific traffic signal operation.

3.2.2 Travel Time Data Collection Method

Travel time data are collected using a probe vehicle that travels with the flow of traffic according to the “floating car” technique. Each probe vehicle is equipped with a global positioning system (GPS) and with a data collection device (laptop or palmtop computer) that records travel times and distances at one-second intervals. For each segment, a valid sample size of travel time runs is obtained in order to calculate a significant average peak-period measurement. A segment usually begins immediately after a significant intersection and ends immediately after the next significant intersection.

The roadway monitoring captures typical traffic conditions during commute times. Roadways are monitored during weekday morning and evening peak commute periods, primarily between 6:30 AM and 9:00 AM and between 3:30 PM and 6:30 PM. Monitoring does not occur on weekends, Monday mornings, or Friday evenings; nor does monitoring occur during the peak period following or preceding a local, state, or national holiday. Monitoring is conducted during the public school year, in the spring and the fall seasons.

Processing of GPS-based travel speed data using geographic information systems (GIS) allows large databases to be manipulated easily. Furthermore, the integration of the collected information with additional geographic content allows for the production of many of the maps found in this report.

The roadway performance measures of average travel speed and delay are calculated as part of the processing of the individual samples of observed GPS data. Sample sizes are typically 12 travel time runs for each peak period, which is equivalent to approximately one sample per 15-minute time period. The performance measures are summarized for predefined roadway segments. Segments vary in length because of varying distances between significant intersections. Furthermore, in order to understand the roadway characteristics that affect travel speed, the CMS also collected the geographic locations of speed-limit signs, posted school speed-limit zones, pedestrian crossing signals, and other traffic controls along the CMS-monitored network.

⁴ Ibid., p. 16-24.