

Towards an Areawide Service Measure

JOHN D. LEONARD II

MARCELO OLIVEIRA

Georgia Institute of Technology, USA

ABSTRACT

With the introduction of the year 2000 edition, the *Highway Capacity Manual* has taken its first steps towards computing and predicting performance measures for areawide analysis. Chapter 30 of the HCM2000 presents an overview of the general methodology and demonstrates the application of this methodology through several case studies. While Chapter 30 presented several regional measures of performance, it does not suggest nor advocate selection of one of these measures as “the” service measure. This paper describes important characteristics of an areawide service measure, formulates a performance measure that satisfies these characteristics, and presents computational results of this service measure for the Atlanta, Georgia, metropolitan area.

1. BACKGROUND

At present, public and private agencies publish a variety of statistics that describe many aspects of our daily environment including temperature, humidity, heat index, pollen count, Richter scale, and others. Many of these statistics have worked their way into the public vernacular. A typical discussion around the water cooler may include “sheesh, yesterday was really hot! Can you believe it hit 103??!!” [with apologies to those using Celsius!] Further, many “water cooler” conversations eventually turn to a discussion of recent events on the highways and to the severity of recent congestion. Yet, while we have many facility-specific performance measures, the profession has not provided a “number” or “indicator” that can be associated with varying levels of regional, cross-facility traffic congestion.

With the introduction of the year 2000 edition, the *Highway Capacity Manual* has taken its first steps towards computing and predicting performance measures for areawide analysis. Chapter 30 of the HCM2000 presents an overview of the general methodology and demonstrates the application of this methodology through several case studies. Chapter 30 was motivated by a desire to improve the accuracy of capacity and speed estimates used in current regional travel demand forecasting models by replacing their procedures with HCM2000-based procedures. Chapter 30 describes the computation of several performance measures including intensity, duration, extent, variability, and accessibility.

This paper discusses desirable characteristics of an areawide service measure, introduces the HCM2000 definition of “accessibility,” proposes an alternate measure of accessibility, and demonstrates the computation and application of the proposed measure within a real-time environment.

2. DESIRABLE CHARACTERISTICS OF AN AREAWIDE SERVICE MEASURE

A fundamental assumption is that this service measure would be used like “temperature” and be quantifiable in real time. Travellers can then associate their personal experience on the highway with this “value.” As congestion forecasts are broadcast, a traveller familiar with a personal experience with this measure will be able to gauge their upcoming travel experience. The following paragraphs describe desirable characteristics of an areawide service measure.

- Describes the experience of an individual traveller,

By definition a service measure is one that describes a user’s experience with the transportation system. Aggregate measures like vehicle-miles travelled are nice from an operator’s perspective, but don’t reflect what the traveller experiences when travelling. Time-based measures (e.g., speed, travel time, delay time, etc.) are much better indicators of level of service.

- Sensitivity to recurrent and non-recurrent congestion,

The value of the service measure should be sensitive to recurrent and non-recurrent congestion, that is, it should reflect congestion due to accidents or special events, and normal “background” congestion due to the morning or afternoon peak.

- Independent of the size and shape of the region,

The computation of any service measure should be independent of the size and shape of the area under study. This can promote comparison of this service measure across portions of a city, across regions, or between cities.

- Comparable across alternate facilities and modes,

The service measure should be independent of characteristics specific to any mode. In this manner, travellers can make informed choices between alternate routes or alternate modes of travel.

- Comparable across time, and computed in real time,

Using the temperature analogy, we should be able to quantify the value of the service measure in “real time” and build historical records of this travel time. Comparisons of current service measure values with prior values (prior hour, day, day of week, month, year, etc.) would then be possible.

As provision of real-time information becomes more prevalent, and as consumer markets for this information grow larger, there is a need for the transportation engineering community to step forward and define a service measure that can satisfy this demand for information.

3. HCM2000 DEFINITION OF ACCESSIBILITY (MOBILITY)

The follow paragraphs describing “accessibility” are drawn directly from Chapter 30 of the HCM2000 (TRB 2000).

Accessibility can be measured in terms of the number of trip destinations that can be reached within a selected travel time for a designated set of origin locations (such as a residential zone.) The results of each origin zone are tabulated and reported in terms such as: X percent of the homes in the study area can reach Y percent of the jobs within Z minutes.

A mean access time (trip time) for 100 percent of the origins and destinations might also be reported. Accessibility is computed by finding the shortest path travel times from the origin zone to all destination zones in the region. Destination zones that are accessible within the desired travel time are identified and the number of trip destinations represented by these destination zones is tallied to obtain the accessibility performance measure.

Discussions with the author of the HCM definition of accessibility revealed that the author intended to use the words “accessibility” and “mobility” interchangeably. We argue that these terms are distinct, but are in fact two sides of the same coin.

We believe that “accessibility” describes the ease at which a set of origins are served by a single destination (i.e., the shopping mall was very accessible to the region,) while “mobility” describes the ease at which a single origin may travel to a set of multiple destinations.

Based on this argument, the HCM 2000 definitions of accessibility (described above) are in fact measures of mobility.

Further, one difficulty in computing either service measure described above is the requirement that the number of trip origins and destinations are known.

4. PROPOSED DEFINITION OF AN AREAWIDE SERVICE MEASURE

One group of performance measures that satisfies the conditions described in Section 2 includes measures based on speed or “slowness” (slowness being inverse speed, with units of time per unit distance). Adopting a measure of slowness, let the areawide service measure between an origin i and destination j be defined as:

$$T_{ij} = \frac{t_{ij}}{d_{ij}^*} \quad (1)$$

where t_{ij} is the shortest path travel time (seconds) between origin i and destination j , and d_{ij}^* is the Euclidean distance (straight-line or air-line distance, NOT travel distance along the shortest path) between origin i and destination j .

By using Euclidean distance between origin and destination, we use the shortest possible distance between the origin and destination. Any differences in mode, maximum travel

speed, vehicle type, route, etc. will be captured by the differences in travel time. Trips that arrive at the destination quicker will receive a lower value of the service measure, independent of the route or actual distance travelled.

For a single origin i to all destinations j , the areawide service measure is defined as:

$$T_i = \frac{1}{m} \sum_{j=1}^m \frac{t_{ij}}{d_{ij}} \quad (2)$$

where m represents the total number of destinations, and the other variables are described above. This value represents the average slowness from the origin i to all destinations in the region.

Finally, the areawide service measure for all origins (within the entire region) is defined as the average of the individual origin service measures:

$$T = \frac{1}{n \cdot m} \sum_{i=1}^n \sum_{j=1}^m \frac{t_{ij}}{d_{ij}} \quad (3)$$

The proposed service measure represents a measure of travel time between a single origin and destination pair, normalized by the straight-line distance. By dividing by the Euclidean distance, we normalize the trip speed to remove some of the bias introduced by different routes taken by different modes.

The proposed service measure is consistent with performance measures computed from specific facility-based HCM procedures. Travel time aggregates nicely across facilities, and represents one measure that the traveller can directly experience.

5. COMPUTATIONAL EXAMPLE

The service measure described above may be computed using a methodology adopted from the approach described in Chapter 30 of the HCM2000. To compute the service measure described above for an arbitrary region, the engineer must obtain a set of origin and destination locations, a link-node representation of the transportation network, a set of travel times for all links in the network, and a set of delays at each node.

5.1 Basic Implementation

We constructed a directed link-node network of the interstate and other major highways arterials in a 44 km by 52 km region surrounding Atlanta, Georgia, using a GIS database obtained from the Georgia Department of Transportation. Our network included 4389 links. For each link, we obtained the endpoints and their (x,y) coordinates (measured in state-plane meters), the posted speed (in miles per hour), and the estimated travel time (in seconds).

For the same 44x52 km region described above, we arbitrarily defined a 75x75 grid of uniformly spaced 5625 destinations, and recorded their (x,y) locations.

Finally, we selected an arbitrary set of seven major origins within the region. These origins represent major centers of activity and include the Downtown/Georgia Tech area, Atlanta Hartsfield International Airport, and the various connections of the I285 beltway with Interstates 75 and 85.

The figure below shows the seven major origins (as large black dots,) the 5625 destinations (as small dots) and the selected roadway network. The interstate highways are shown with a larger line width and other roads with the smaller line width.

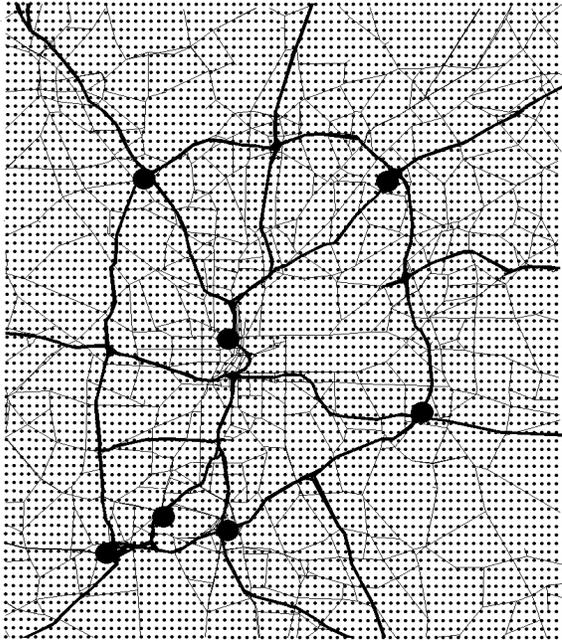


FIGURE 1 Origins, destinations and roadway network.

Using these data, the shortest path travel times between any single origin-destination pair may be computed using any one of many well-known shortest-path algorithms. [We used an object pascal implementation of Dijkstra's (1959) algorithm.] The airline distance between origin and destination may also be computed (directly from the node coordinates). Using these results, the service measure for one node to all destinations is then computed.

To simplify the network and speed computation we included only the interstates and primary highways. Since most destinations are not directly connected to the roadway network, we determined the nearest neighbour node and assigned an access time proportional to a background speed of 10 mph.

5.2 Real-Time Implementation

We implemented the computation methodology described above within a real-time environment. In the tested implementation we estimated (see below) the individual link travel times for selected links every 5 minutes. The shortest path travel times for the seven major origins to all 5625 destinations are then recomputed.

Updated travel times are estimated using data gathered from Atlanta's Transportation Management Center (TMC), the Georgia NaviGator. At 330 locations along sections of

Interstates 75, 85, and 285, the Georgia NaviGator gathers point speeds of all vehicles in all travel lanes, then posts the current averages to a web site every five minutes. We have written script that automatically gathers these speeds and uses them to estimate link travel times for the surveyed interstate links. All other link travel time data in the network remain static over time. We plan on relaxing this restriction in a future implementation.

For the given roadway network, seven origins and 5625 destinations, the software implementation requires about 1.5 minutes to compute the shortest-path travel times on a dual-processor Pentium Pro server. An additional minute is required to create JPEG images (refer to Section 6). Note that this combined computation time is about one-half of the real time cycle time (5 minutes). The computation results and associated JPEG images are also posted and archived to on the internet and form the basis of a demonstration traveller information web site.

5.3 Software Description

As implemented, the software requires no special hardware or software. The computation engine and web server both reside the same dual processor, 200 MHz Pentium Pro desktop computer. The only specialized hardware consists of a high-capacity hard disk implementing a Level 5 RAID technology.

The server is running Microsoft Windows NT 4.0, Microsoft Internet Information Server (IIS) 4.0, ActiveState Perl, and Mathworks MATLAB.

The software implementation is very modular. Shortest path computations are performed using a pascal program written in Borland Delphi (object pascal). JPEG images are created using Mathwork's MATLAB. All programs are "glued" together using the platform-independent scripting language, perl. The software should be relatively portable across platforms and easily deployable in different cities and regions around the world.

6. THEMATIC REPRESENTATION OF AREAWIDE SERVICE MEASURE

The travel times from a single origin to all destinations [as defined in Equation (2) above] may be presented graphically using a travel time contour diagram (Figure 2). Each color band on the travel time contour represents an isochrone — a line of constant travel time. In the diagram below, the origin of is shown as a large light-color dot. Edges between color boundaries represent the distance traveled in 10-minute increments.

Figure 2 graphically presents mobility from the Georgia Tech area to all other destinations within the region for an uncongested time of day. Note the color bands that extend link fingers along the interstate. Travel speeds along the interstate average around 65 mph

(108 kph), while surface street speeds are set around 30 mph (50 kph), resulting in further travel distances within the fixed 10-minute contour increment.

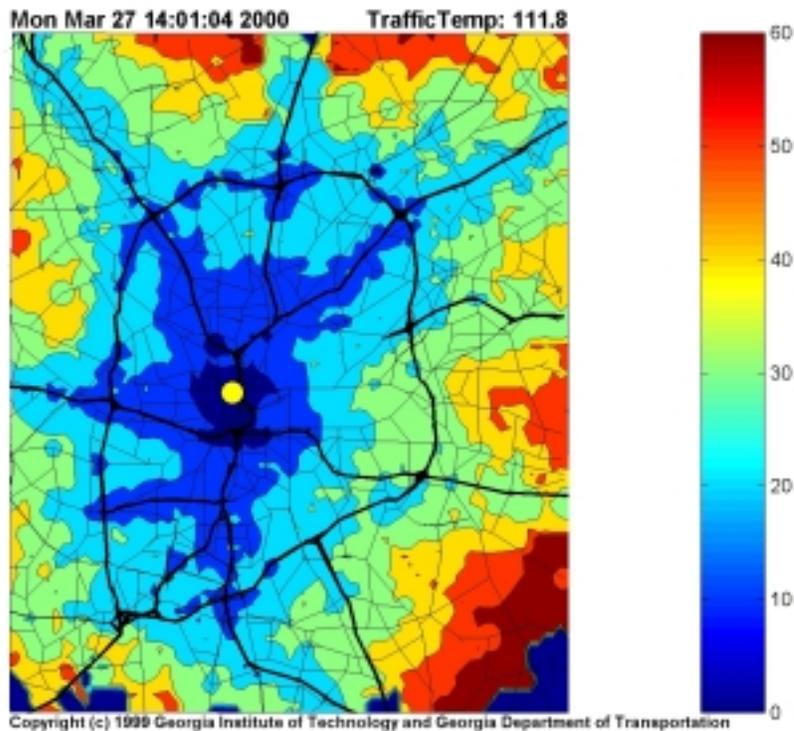


FIGURE 2 Real-time travel time contour under uncongested conditions.

Figure 3 presents the same network under congested conditions. For this figure, we reduced the speeds on all interstate links by one-half, and regenerated the JPEG image. Note that the fingers that extended along the interstates in Figure 2 contract, demonstrating that less distance can be covered during the 10-minute contour interval.

The proposed service measure described in Equation (2) offers a single value representation for the travel time contour show above, and represents the average mobility for the origin to all destinations in the region.

A travel time contour diagram is one excellent form of traveller information. Travellers can determine their travel times to any destination by counting the number of color boundaries crossed between origin and destination.

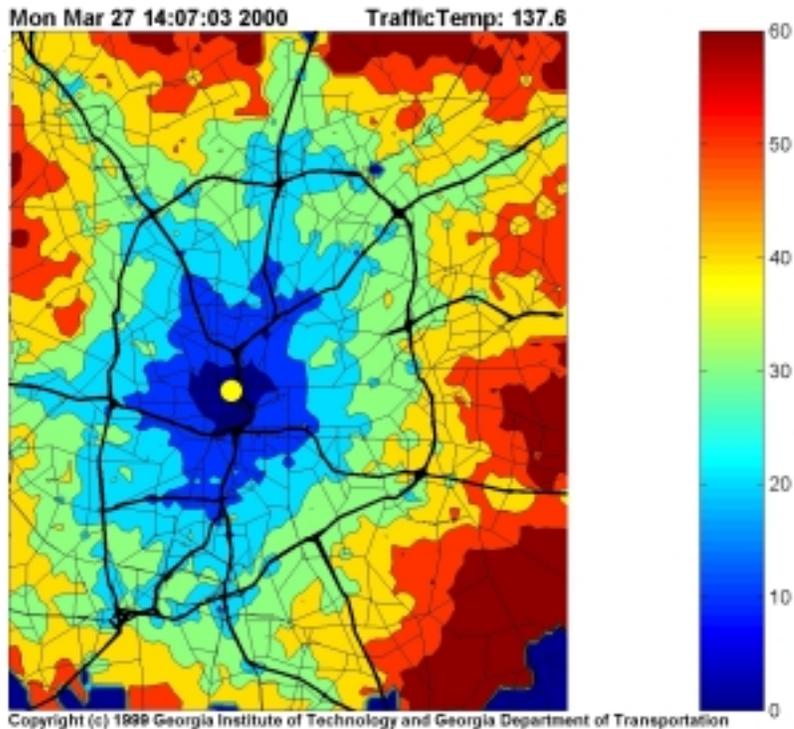


FIGURE 3 Travel time contour under congestion conditions.

7. FUTURE DIRECTIONS

This research was initiated before final publication of the HCM2000. As such, we didn't have many details regarding Chapter 30 procedures. We are currently modifying the procedures to include additional node delay components (varying by time of day) at all signalized intersections. We are currently increasing the scope of the roadway network to include all 14 counties of the Atlanta metropolitan planning region and investigating the possibility of providing contour maps for a greater number of origins.

The proposed service measure and associated real-time computation methodology offers interesting opportunities as a "real-time performance measure." Results suggest that the measure is sensitive to congestion and incidents, as well as demand changes across days. By computing these values in real time, it becomes possible to "watch" the impacts of specific control scenarios and their impact on the transportation system.

As new surveillance technologies are deployed, the additional data gathered can be directly "plugged" into the computation engine, enhancing the sensitivity of the performance indicator.

REFERENCES

*-, (2000) ActiveState perl, <http://www.activestate.com>.

Areawide Analysis. In *Special Report 209: Highway Capacity Manual 2000*, TRB, National Research Council, Washington D.C., 2000, Chapt. 30.

*-, (2000) MATLAB, Mathworks, <http://www.mathworks.com>.

*-, (1998) Internet Information Server, Microsoft, <http://www.microsoft.com>.

*-, (1998) Windows NT, Microsoft, <http://www.microsoft.com>.

Dijkstra, E.W. A Note on Two Problems in Connection with Graphs. *Numerische Mathematik*, Vol. 1, 1959, 269–271.