Chapter 10
The Impact of Traffic Congestion on Mobility

10.1 Defining Mobility

Mobility is the ability of people and goods to travel easily, safely, quickly and reliably. Trip mobility varies with the speed of travel, and it may be defined as the number of trips taken and their distance (trip-miles) within the traveler's daily travel time and cost budgets. Therefore, lower speeds resulting from traffic congestion reduce mobility.

This chapter has two basic objectives: (1) to define and quantify traveler mobility, and (2) to determine how mobility is impacted by traffic congestion.

10.2 Factors Influencing Mobility

Mobility depends on three key factors: (1) the type of transportation modes available to the traveler (e.g., walk, bicycle, bus, rail, private vehicle); (2) traveler's requirements and needs that influence mode selection (e.g., travel time budget, physical ability in using a given mode, affordability, trips purpose, and the license to drive); and (3) the operational characteristics of the travel modes (e.g., speed, reliability, cost, safety, comfort/convenience, and the absence of physical barriers to using the mode). Figure 10.1 shows how these factors interact in determining a traveler's mobility.

10.2.1 Traveler Requirements/Needs

Traveler requirements/needs include:

Travel Time Budget: the time one allocates daily to travel. Daily travel time budgets have remained relatively stable over time and across metropolitan areas

J.C. Falcocchio and H.S. Levinson, *Road Traffic Congestion: A Concise Guide*,
Springer Tracts on Transportation and Traffic 7,
DOI 10.1007/978-3-319-15165-6_10

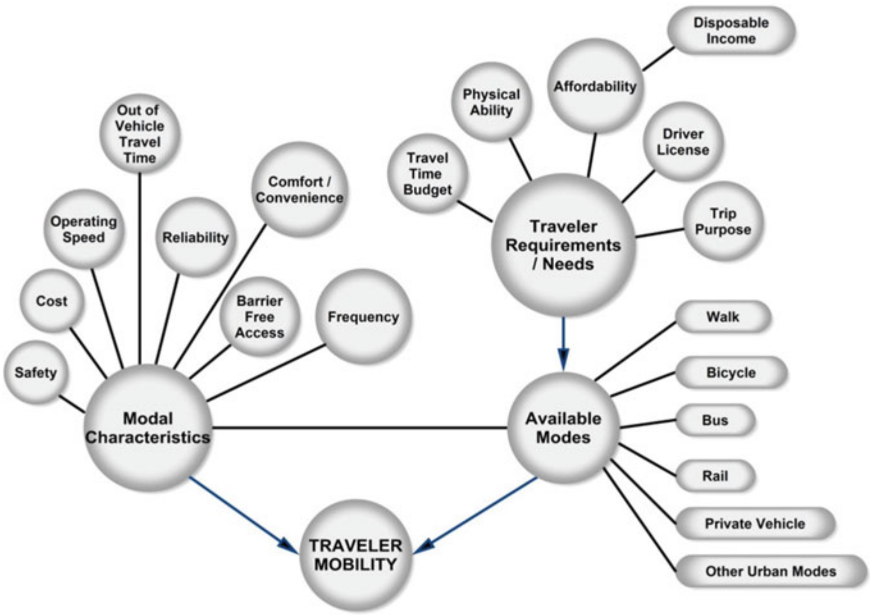

Fig. 10.1 Factors impacting traveler mobility

[1–6]. Time is a finite resource, and it is allocated to various activities in finite amounts in accordance with the individual's physiological, social, educational, and economic needs.

- Zahavi [1] in his pioneering study of travel by car, found that average daily auto travel time is stable in all urban areas, with a slight tendency to increase with the size of the urban area
- Reno et al. [2], found that the average time spent by persons who drove private vehicles on their travel day was within a very narrow range (69–74 min) and it was independent of the size of urban area (see Fig. 10.1)
- In the New York Metropolitan area [3], the average time spent in travel was reported as 77 min/day
- Hanson and Giuliano [4] report the results of a study by Hupkes [6] who found that the time spent for travel by all modes of transportation is nearly constant over time—from decade to decade. It was reported that "although shifts occur over time in the modes used (walking, biking, busing, driving), a remarkable stability in the overall number of trips and in total hours devoted to travel was documented"
- Within these aggregated values, however, not all travelers have the same travel time budgets. Garrison and Levinson [5] reported that for the Washington, DC metropolitan area, adults (age 18–65) have higher travel time budgets, and employed adults spend more time traveling than those who are not employed. And women spend less time traveling than men

- There is also variability in the time allocated for different travel activities (trip purposes). For example, more time is spent for work trips than non-work travel. In the New York Metro area work trip took an average of 33 min and non-work trips 20 min [3].

Trip Purpose: some trips (e.g., work) tend to use a larger share of the travel time budgets than other trips (e.g., convenience shopping).

Physical Ability: to enter, ride, and exit the vehicle/mode.

Affordability: the choice of mode is often based on its trip cost. Affordability is related to the disposable income of the traveler.

Driver's License: only those of legal age are allowed to obtain a driver's license. Those who cannot drive can only use private vehicles as passengers.

10.2.2 Availability of Travel Modes

Many modes of travel are usually available to people living in metropolitan areas. They include walking, bicycles, private vehicles, taxis, schedule-based public transit (including: buses, street cars, light rail, bus and rail rapid transit, commuter rail and ferry). The modes chosen are among those that will satisfy travelers' requirements/need. However, in specific neighborhoods all modes might not be available. Transit coverage is limited in many suburban areas. Rapid transit lines are sometimes too far from where people live, and some households do not own automobiles.

10.2.3 Modal Characteristics

Key modal characteristics that influence the choice of private and public transport include frequency, operating speed, reliability, out-of-vehicle travel time, door-to-door travel time, trip cost, perceived safety, barrier-free access, and comfort/convenience.

Frequency: how often the service is available during a particular time of day. It is an indicator of waiting time and travel mode convenience.

Operating Speed: faster modes provide greater trip mobility than slower ones.

Reliability: modes/routes with stable speeds are preferred to those which experience variability in speed.

Out-of-Vehicle Travel Time: this is the time spent walking to/from vehicles and waiting for vehicles, while on the trip. Travelers value *excess travel time* from 2 to 2.5 times the value of line-haul travel time. Thus an excess trip time of 10 min is equivalent to a line-haul travel time of 20–25 min.

Trip Cost:

- out-of-pocket trip costs: fare, toll charges, parking charges, fuel, etc.
- vehicle ownership costs: purchase/lease, maintenance, insurance, etc.,

Safety: Travelers prefer modes that they perceive to be safe, and avoid those that they perceive to be unsafe.

The perceived safety of using the mode reflects:

- probability of personal injury,
- probability of fatality,
- risk to personal security.

Barrier-Free Access: vehicle entry/exit that allows access to the physically disabled.

Comfort/Convenience—Includes the following variables:

- Walking distance
- Number of transfers
- Frequency of service
- Waiting time for vehicle ("it's not just how long you wait; it's how you spend the time waiting")
- Physical comfort: cleanliness, temperature and humidity, cleanliness, ride quality, space per passenger, weather protection
- Psychological comfort: sense of being in control, availability of real-time information
- Availability of vehicle parking
- Availability/dependability of travel mode
- Ability to carry packages, tools, etc. when needed.

10.2.3.1 Door-to-Door Travel Time and Speed

The door-to-door trip speed of each travel mode is a key measure of modal mobility, and it depends on the door-to-door trip distance and trip time. It is expressed as follows:

$$\begin{aligned} Door\text{−to−Door Travel Speed} = & (Door\text{−to−Door Trip Distance}) \\ & /(Door\text{−to−Door Travel Time}) \end{aligned} \tag{10.1}$$

Door-to-door trip time is typically the sum of (1) vehicle riding/driving time, and (2) "out-of-vehicle" or excess time. Excess time represents the time spent outside the vehicle. It includes the walk time from the trip origin to the vehicle location, waiting time for the vehicle, transfer time from one vehicle to another for trips involving multiple vehicles, and walk time from one leaves the vehicle to the trip destination.

This distinction in travel time components is important because travelers value the out-of-vehicle time 2–2.5 times the time spent riding the vehicle. The exception is across the platform transfer at rapid transit stations.

Fig. 10.2 Door-to-door trip components

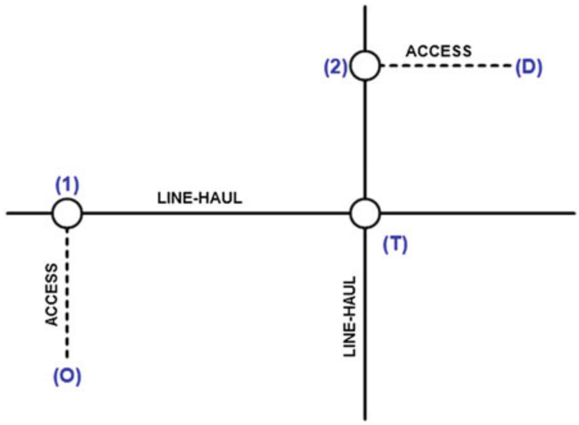

Figure 10.2 illustrates a trip distance from origin [O] to destination [D] using two line-haul transit lines, with access at [1], requiring a transfer at [T], and an egress at [2] for access to a destination at [D].

The travel time components for this trip are shown in Fig. 10.2 and summarized in Table 10.1.

In-vehicle Travel Time

This time is calculated by dividing the distance traveled in a vehicle by the average vehicle speed:

The average private vehicle speed is a function land use density, road design speed and traffic volume. For public transportation vehicles, the average speed is also affected by service patterns, bus stop/station frequency, dwell times and rights-of-way.

Typical average modal speeds in a large urban area are shown in Table 10.2. Operating speeds of rapid transit and commuter-rail lines range between about 20–30 miles/h.

Table 10.1 Time components of the door-to-door trip in Fig. 10.2

Trip components	Out-of-vehicle travel time	In-vehicle travel time
Access to or from line-haul vehicle: • [O]–[1] • [2]–[D]	• Walk time • Wait time	Time in auto, bus, or bicycle to [1] or from [2], if distance to/from line-haul is beyond walk distance
Line-haul vehicle • [1]–[T] • [T]–[2]	For multivehicle trips: • Transfer walk time • Transfer waiting time	Time riding the main line vehicle (transit or auto)
Total	Out-of-vehicle time	In-vehicle time

Source Fig. 10.2

Table 10.2 Typical average line-haul speed of on-street travel modes in a large metropolitan area

Mode	Urban (mph)	Suburban (mph)
Walk	3	3
Bicycle	8	12
Bus (mixed traffic)	10–12	12–15
Automobile	15–20	25–30

Source Estimated

Illustrative Example

Table 10.3 shows an example of typical average speeds and excess travel times for selected urban travel modes that do not require transfers. Values for specific cases, however, would depend on actual transit schedules or service areas, route structures, and the number of transfers required to complete the trip.

Notes for Table 10.3:

(1) Actual average mode speed is typically determined by the volume of traffic in the road network, the roadway's design speed and capacity, and the operational characteristics of the mode (e.g., local or express bus; on local or arterial road, freeway, etc.).
(2) Access to and from the bus mode assumes an average walk distance of 0.25 miles for each trip segment.
(3) Waiting time is assumed ½ the vehicle headway.
(4) In addition to the above components of excess travel time, travelers also consider the travel time reliability of the individual travel modes. When using a mode that is subject to random but significant delays, excess travel time would be larger than what is shown in the table.

The travel time of an urban trip made by bicycle or by a private motor vehicle typically does not include significant "excess time components." But the excess time components of urban trips by transit can be typically a significant share of door-to-door travel time.

Table 10.3 Typical average speed and excess travel time for line-haul modes

Line-haul mode		Average speed of line-haul mode (mph)	Excess travel time (min)			
			Vehicle access	Waiting time	Destination access	Total
Walk		3	–	–	–	0
Bike			–	–	–	
• Urban		8				0
• Suburban		12				0
Bus local/surface	Urban	12	5	3	5	13
	Suburban	15	5	8	5	18
Auto	Urban	20	1	2	3	6
	Suburban	30	1	1	1	3

Source Estimated

10.3 Measuring Mobility

Traveler mobility is defined as the distance traveled with a chosen mode within an acceptable travel time. The time acceptable or budgeted for a trip is related to trip purpose (e.g., the time acceptable for a work trip is likely to be greater than that for a shopping trip), and the size of the metro area: for example, in a small urban area an acceptable trip to work is 20 min long, but in a metro area of over 5 million people an acceptable trip time to work is 45 min.

The distance traveled is calculated as follows:

$$\begin{aligned} \textit{Traveler Mobility} &= \textit{Distance Traveled} \\ &= \{[\textit{speed of line by haul mode}] \\ &\quad \times [(\textit{time budgeted for the trip} - (\textit{excess travel time})]\} \\ &\quad + \textit{Distance from the origin to line} - \textit{haul vehicle} \\ &\quad + \textit{Distance from line} - \textit{haul vehicle to trip destination} \end{aligned} \tag{10.2}$$

Using Eq. 10.2, traveler mobility provided by each of the four travel modes shown in Table 10.2, is plotted in Fig. 10.3 for trip times up to 60 min.

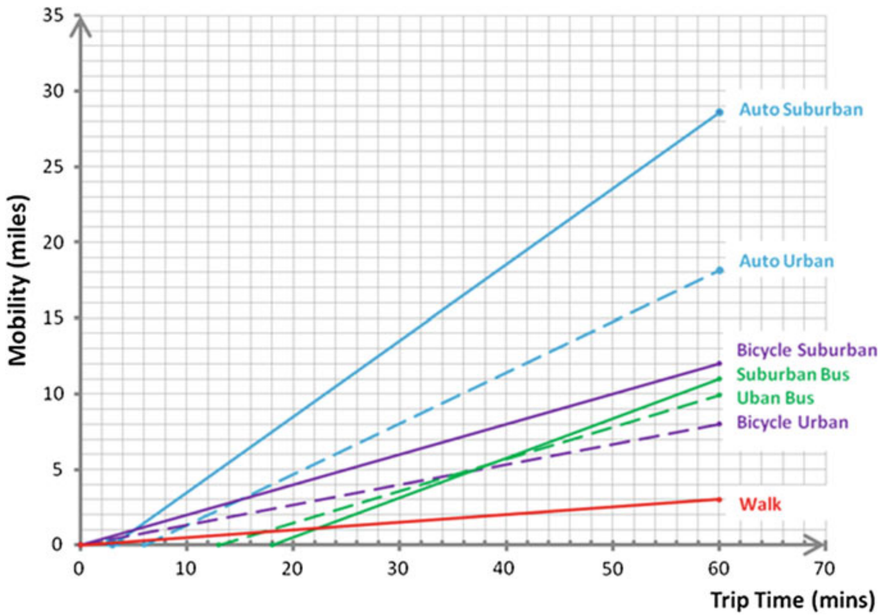

Fig. 10.3 Trip mobility of selected modes and trip time

Thus if one is willing to allocate 20 min to a shopping trip, the trip mobility of to a shopping destination would be: 1.0 mile if by walking, 1.5 miles if by bus, 2.5 miles if by bicycle, and 4.8 miles if by auto.

This example shows that the mode's operating speed is not always an indicator of mobility. From the viewpoint of travelers what is important is distance traveled within an acceptable door-to-door travel time. For example, the mobility advantage of the bicycle over the bus for trips less than 30 min points to the need for implementing bicycle networks in urban areas.

The above comparisons do not include rail rapid transit lines operating on grade-separated or private guide—ways, whose line haul speeds are usually at least double those of surface transit. Long established US rapid transit lines in New York City, Chicago, Philadelphia, and Boston have typical line-haul speeds of 20–25 miles/h; newer regional lines have speeds in excess of 30 miles/h. Commuter rail have line haul average speeds that can reach 40 miles/h. Rail modes were excluded in Table 10.3, however, to simplify the discussion.

Actual modal speeds will vary both within and among urban areas. Communities interested in measuring modal mobility could develop curves similar to Fig. 10.3 to reflect local conditions (e.g., area size, travel barriers, availability of freeways, or public transportation operating on exclusive right-of-way).

10.4 Congestion Impacts on Mobility

Because congestion adds trip time to cover the same distance, travelers will reduce their mobility as congestion increases.

10.4.1 An Illustrative Example: Measuring Freeway Congestion in a Large Urban Area and Its Impact on Trip Time and Trip Mobility

The following example considers an urban freeway used for a trip 10 miles long., and assumes that 70 % of the trip distance uses the freeway, and 30 % uses roads connecting to the freeway.

Typically the rest of the road network connecting drivers' origin to their destinations is less congested than the freeway segment of the trip—especially in suburban areas. In addition, each trip experiences out-of-vehicle time involved with walking and waiting for the vehicle. Therefore, these factors greatly shape how freeway congestion impacts on trip time.

Table 10.4 Trip components for a trip distance of 10 mile

Trip segment	Distance (miles)	Speed (mph)	Time (min)	% Trip time	% Trip distance
Other roads	2.9	**20**	8.7	32.6[a] 27.6[b]	29
Uncongested freeway	7.0	35	12.0	44.9[a]	70
Congested freeway	7.0	25	16.8	53.3[b]	70
Out of vehicle travel time (walking, waiting)	0.1	3.0	6.0	22.5[a] 19.1[b]	1
Total—(uncongested freeway)	10.0	22.5	26.7	100[a]	100
Total—(congested freeway)	10.0	19.0	31.5	100[b]	100

[a] No congestion on freeway
[b] Freeway congested

Other assumptions are:

- Acceptable peak period average freeway speed = 35 mph (see Table 8.6, Chap. 8)
- Congested freeway speed = 25 mph.
- Average speed of the roads connecting to the freeway = 20 mph.
- Out-of-vehicle time for the trip = 6 min (includes walking to and from the vehicle and waiting for the vehicle).

The questions are:

I. What is the impact of peak period freeway congestion on trip time?
II. What is the impact of peak period freeway congestion on mobility?

Table 10.4 lays out the assumed values of the trip components under congested and uncongested trip conditions for the 10 mile trip.

10.4.1.1 Findings

Key findings are as follows:

Impact of Freeway Congestion on Trip Time

In this example, an increase in freeway congestion of 40 %, (4.8/12) increases trip time by only 18 % (4.8/26.7). This means that one cannot estimate the trip time lost to congestion by only measuring the freeway delay rate because the time spent on the congested freeway segment comprises only a fraction of the total trip time [7].

Considering that over 65 % of urban trips is shorter than 5 miles [8], and that trips shorter than 5 miles are unlikely to be freeway users [9], measuring the impact of traffic congestion on trip time using data only from freeways and other principal arterials, is likely to overestimate average trip congestion delay.

Therefore, to accurately evaluate the impact of traffic congestion on trip time, all segments of the trip (as shown in Table 10.4) must be considered in the analysis.

Impact of Freeway Congestion on Trip Mobility

As shown in Fig. 10.4, a traveler's response to increased freeway congestion would be either to reduce trip mobility by over 15 % (from 10 to 8.46 miles)—for a constant trip time—or to increase trip time by 18 % (from 26.7 to 31.5 min) in order to maintain the same level of trip mobility (10 miles).

Data on traveler responses to an increase in travel speed shows that travelers generally have used the travel time reductions to increase the trip distance instead of reducing their trip times [10]. So it may be inferred that the converse is true: when congestion increases travel time, trips distance (mobility) would decrease.

Comments

The example uses 35 mph freeway speed to represent acceptable peak hour speed conditions—a realistic assumption for many freeways in large metropolitan areas. This value (35 mph) is considerably less than the freeway free-flow speed (e.g.,

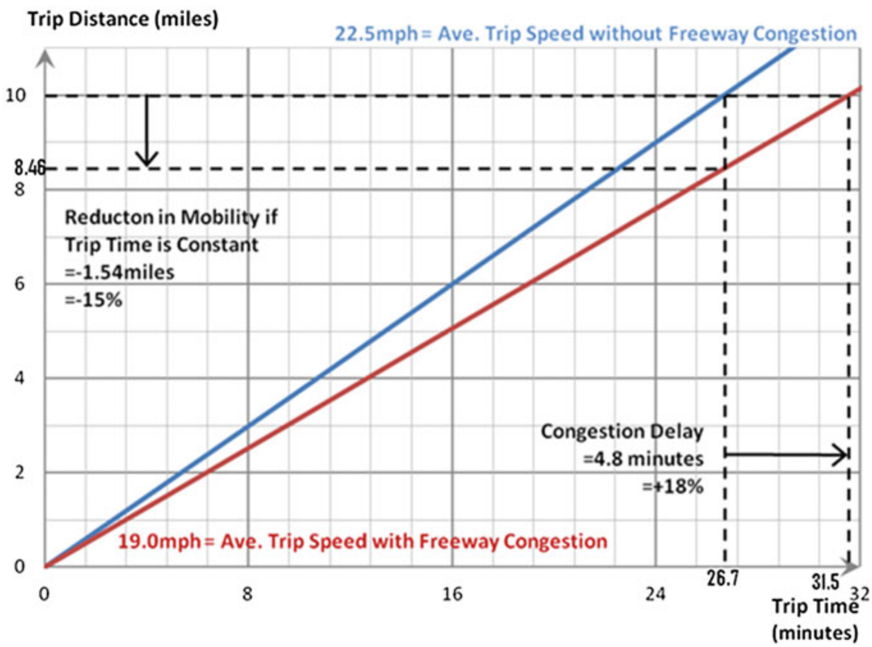

Fig. 10.4 Congestion impacts on mobility and trip time for a trip 10 miles long

60 mph) used as the basis in measuring the Travel Time Index. In practice each urban area should set its own congestion threshold criterion (Chap. 8).

10.4.2 Not All Travelers are Impacted by Traffic Congestion

Some travelers see their mobility increase even as roadway traffic congestion increases. They include those who move from the city to the suburbs and switch from transit and walking to driving, and those who get their driving license as they become of age.

10.4.3 Impacts of Traffic Congestion on the Mobility of Transit Riders, Pedestrians, and Bicycle Users

10.4.3.1 Transit Riders

Because the out-of-vehicle travel time for transit riders is a large component of door-to-door travel time (see Table 10.3), network traffic congestion which affects primarily in-vehicle-travel time, tends to have a smaller impact on the mobility of transit users than it has on that of automobile users.

10.4.3.2 Traffic Congestion Impact on the Mobility of Pedestrians and Bicycle Users

Pedestrian and bicycle trips tend to be shorter than vehicle trips. Therefore traffic congestion tends to have a smaller impact on pedestrian/bicycle trip times than it has on motorized vehicle trips.

10.5 Trends in Traffic Congestion and Traveler Mobility

The Texas Transportation Institute (TTI) annual metropolitan traffic congestion reports [11] indicate that traffic congestion has been steadily increasing since 1980—except for the years of economic slowdown (see Chap. 6). The news media and elected/appointed officials rely on these annual reports to inform the public about the increasing cost of traffic congestion [12].

But according to the National Household Travel Survey [13] and reported by Pisarski and Alan [14] increasing freeway/expressway traffic congestion does not seem to have reduced average traveler mobility (Table 10.5).

Table 10.5 Trip mobility and trip time trends—1980 to 2000

Commuter trips	1980	1900	% change (from 1980)	2000	% change (from 1990)
Trip length[a]	8.54 miles	10.65 miles	+24.0	12.41	+13.7
Trip time[b]	21.7 min	22.4 min	+3.2	25.5 min	+13.8
Average speed	23.6 mph	28.5 mph	+20.7	28.5 mph	0
All trips					
Trip length	8.68 miles	9.47 miles	+9.1	10.03 miles	+5.9
Trip time	21.7 min	23.4 min	+7.8	25.5 min	+9.0
Average speed	24.0 mph	24.3 mph	+1.3	23.6 min	−2.9

[a] *Source* [13 p 51]
[b] *Source* [13 p 101]

10.5.1 All Trips

- 1980–1990: Trip mobility increased more (+9.1 %) than trip time (+7.8 %). Reflecting higher trip speed and an small increase travel time budge.
- 1990–2000: Trip mobility continued to increase (but at a slower rate—+5.9 %) however, trip time increased more (+9.0 %)—indicating that the travel time budget increased more than trip mobility.

10.5.2 Commuter Trips

For commuter trips the findings are even more dramatic:

- 1980–1990: Trip mobility increased eight times more than trip time (24 % vs. 3.2 %)—reflecting a relatively stable trip time budget, and big gains in mobility due to higher travel speed (+20.7 %).
- 1990–2000: Trip mobility and trip time kept increasing but at a slower pace (+13.75 % and +13.8 %, respectively).

Possible explanations for the discrepancy between network speed trends and trip speed trends are as follows:

(1) Network speed is not synonymous to door-to-door trip speed. Network speed reflects the performance of the system under observation. It does not measure the performance of all trip components that affect door-to-door trip speed.
(2) Freeways and other principal arterials are the most congested roads in large metropolitan areas. However, because they serve only a fraction of the metro area's traffic, their speed performance cannot be the sole indicator traffic congestion of the entire roadway network that includes collectors and local streets.
(3) Typically, traffic speed on city streets is lower than traffic speed on suburban roads. Greater population and job growth in suburban areas has increased the growth of vehicle trips in low density areas where traffic speeds are higher,

and has decreased the growth in the number of trips within the city where traffic speeds are lower. In addition, many of the trips that in the city were made by walking and transit (slower travel modes), in suburban areas they are substituted by the auto—a higher speed mode.

References

1. Y Zahavi (1974) Traveltime budgets and mobility in urban areas. s.l. Technical report, Federal Highway Administration
2. Reno A, Kuzmyak R, Douglas B (2002) Characteristics of urban travel demand. TRCP report 73
3. Schaller Consulting (2000) Travel in the New York-New Jersey metropolitan area. s.l. prepared for New York metropolitan transportation council and North Jersey transportation planning authority
4. Hanson S, Giuliano G (2004) The geography of urban transportation, 3rd edn. s.l. The Guilford Press, New York
5. Garrison WL, Levinson DM (2006) The transportation experience—policy, planning, and deployment. s.l. Oxford University Press, Oxford
6. Hupkes G (1982) The law of constant travel time and trip rates. s.l. Futures 14:38–46
7. Taylor B (2002) Rethinking traffic congestion. Access Mag1:21
8. New York Metropolitan Transportation Council (2000) Council contact—household interview survey
9. Levinson HS (1979) Characteristics of urban transportation demand—appendix. Department of Transportation, Mass Transportation Administration, Washington, DC
10. Reno AT (1988) Personal mobility in the United States: a look ahead—year 2020, Special Report 220. s.l. Transportation Research Board, National Research Council
11. Shrank D, Lomax T, Turner S (2011) 2010 Urban mobility report—powered by INRIX data. s. l. Texas Transportation Institute
12. La Hood R (2011) Statement of the honorable ray la hood, secretary of transportation. Senate Committee on Banking, Housing, and Urban Affairs, Washington, DC
13. NHTS (2004) Summary of travel trends-2001 national household travel survey. s.l. US Department of Transportation, Federal Highway Administration. National Technical Information Service
14. Alan PE (2006) Commuting in America III: the third national report on commuting patterns and trends. NCHRP report 550 and TCRP report 110