Chapter 2
How Transportation Technology Has Shaped Urban Travel Patterns

2.1 Introduction

The primary functions of transportation are to facilitate the movement of people and goods and to provide access to land use activities located within the service area.

This chapter shows how advances in transportation technology have helped to determine the size, shape and density of urban areas and associated traffic congestion patterns. It provides a brief historical review—from ancient times to the present—of how transportation technology has shaped the size of urban areas over time, and highlights the connection between transportation technology and land use. Each advance in transportation technology (e.g., electric streetcars, subways, automobiles) has produced higher travel speeds; and each time travel speed has increased, the amount of land used for urban growth has increased and population density has decreased. The resulting travel patterns followed the population and employment gradients.

This transition in living conditions from high population density (where activities are located very close to one another) to low population density (where activities are located far from each other) has changed how people travel to work, shop, and pursuit of other endeavors—from a high dependence on walking and transit in high density cities, to an almost exclusive reliance on cars in low-density suburbs.

The underlying theme is that traffic congestion is a product of vibrant urban areas and that people with the means to do so have tried to escape congestion when technological advances provided the opportunity to do so.

It took the transportation advances of the Industrial Revolution (electric streetcars and subways) to enable people to act on their desire to escape the congested industrial city. The automobile accelerated and sustained this desire especially since the end of WWII.

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However, just as city streets before the car era were crowded and congested, the popularity of the suburbs has attracted many people and jobs over time creating traffic congestion on many freeways and arterial roadways.

Understanding how transportation technology influences the character of land development is fundamental to establishing policies aimed at sustaining desirable levels of mobility and accessibility in light of increasing travel growth and traffic congestion. Addressing these concerns is a major challenge especially in the US where the zoning of land use is typically controlled by local governments whose decisions are often made separately from decisions that States make about major transportation investments.

This chapter sets forth some key issues that should be considered when formulating policies and programs addressing urban and suburban traffic congestion, and it shows that traffic congestion has usually followed urban development.

2.2 Transportation Technology, Urbanization, and Travel

The predominant type of transportation available at a particular time in history (non-motorized, fixed route transit, or motor vehicles) has influenced the location and density of residential and non-residential activities.

Transportation and land use are two interconnected elements of the urban system and structure. The locations of activities reflect the daily need for access to jobs, shopping, educational or social needs of the population. Access to these people-oriented activities is determined by the prevailing transportation technology, and by the time people budget for travel.

Traveler and goods mobility was provided by walking and animal power for thousands of years until the dawn of the industrial revolution.

Land travel was by foot (2–3 mph) or by the use of animal power (horse speed of 4–6 mph). At these travel speeds the distance one could cover within acceptable travel times was very short and for this reason land use activities were located close together.

With the introduction of mechanized travel, speeds increased substantially allowing people to travel farther within the same travel time budgets. This increased mobility encouraged the separation of various activities, expanded the amount of urbanized land, and reduced population density in central areas.

The transition from high density urban developments to lower density ones is closely related to the transportation technology prevailing at various times in history.

Lay [1] in his remarkable book "The Ways of the World" provides many examples of how transportation technology influenced the character of cities and urban development. Salient highlights are as follows.

2.2.1 Ancient Time

Ancient cities were compact places with buildings located close to one another and connected by narrow streets. Most people lived within a 15 min walk of their work places, and their streets were predominantly used for pedestrian movement as well as for many commercial and social activities.

Population Densities [1]

Examples of ancient population densities are:

(1) Babylon and Rome with peak populations of over ½ million, were contained within an area of 14 Km^2. or less, and had an effective radius under 2 km.
(2) The population of Baghdad in about 900 AD, was 900,000—the largest that could be practically accommodated within a walking city. Its population density peaking at 600 persons per hectare (243 per acre, or 155,500 persons per square mile).

Ancient cities suffered from street congestion. In Rome, 'Julius Caesar found it necessary to issue an order prohibiting the passage of wagons through the central district for 10 h after sunset' [1]—a more stringent regulation than is found in any modern city.

Mobility in medieval cities—hemmed in by their defensive walls—was provided by walking on narrow and crooked lanes/alleys unsuitable for wheeled traffic.

2.2.2 The Industrial Revolution (ca. 1825–1900)

In the years of the Industrial Revolution, land development in cities continued to locate around the walking mode. During this period cities had high population density; streets were narrow, congested, and often polluted with horse manure and dead animals.

The growth of cities around the beginning of the 20th century was made possible by the steel-framed building construction that allowed taller buildings at the city center, and by electric traction that provided speeds of 8–12 miles per hour. At the same time, mechanization of agriculture enabled many people on the farms to migrate to the cities—a trend that continued through the 20th century.

The rise and spread of cities has paralleled the growth and speed of transportation. Improved transportation has played a crucial role in the transition from a rural to and urban society.

People looking for employment and a more promising economic future migrated from the countryside to the industrial city contributing to its extremely crowded living and travel conditions. By 1900, "population densities in London and Paris peaked at over 700 people/ha. (283 per acre, or 181,000 per square mile), and in New York City they reached 1,350/ha" (546 per acre, or 350,000 per square mile in several neighborhoods) [2]. Overcrowded living conditions became a major social and environmental concern in New York City.

The appearance of streetcars, subways, elevated rail, and commuter rail lines, with their higher operating speeds, replaced the horse drawn cars by extending the distance that people could travel within acceptable travel times. This technological development reduced population densities and increased employment densities in city centers and it transformed the urban landscape by enabling settlements to expand into new territories previously inaccessible by the slower modes of transportation.

New rail transit lines were laid out to connect the population to jobs and shopping locations in the central business district (CBD)—which became the most accessible place in the city.

The steam railroads that appeared in the latter half of the 19th century improved access between cities. Over the years, many small communities that had access to train stations, became suburbs of nearby cities.

The commuter railroad operating at higher speeds (30–35 mph), enabled commuters to work in the city and live farther out from the city limits (away from the dirty air) where living space was more affordable, and the environment more desirable for raising a family. With an average commuter rail speed of 30 mph, one could cover a door-to-door distance of approximately 12 miles in 45 min.[1] This rail-based urban expansion, created new towns and villages whose residential and other land use activities were located within walking distance of the transit stations.

The rail lines allowed (1) increased employment concentration in city centers, and (2) fostered residential developments in outlying areas.

2.2.3 The Private Motor Vehicle Era (1925–Present)

With the coming of the motor vehicle, the land between rail lines and beyond became accessible for development and the distance between land use activities was no longer limited by the rail lines and the walking distance to their stops or stations.

The technology of the automobile provides people with access to one almost total freedom to travel <u>when</u> and where they want. Its use is not constrained by service routes or schedules. It offers reliable door-to-door transportation without the need to change travel modes. It operates at high door-to-door travel speeds relative to most urban travel modes. It ensures seating and privacy as well as weather protection. And, last but not least, it offers pride of ownership.

Its higher operating speed (up to 30–40 mph) makes possible traveling longer distances within acceptable commuting times. Consider a 45 min trip from home to a job location: if the trip is by car one can reach a job located 30 miles away; if the

[1] (45 min) − (20 min spent to reach vehicle, wait, and reach destination) = 25 min riding time; 25 min/(60 min/hr) × (30 mph) = 12.5 miles.

trip is by commuter rail, however, only jobs within 12 miles can be reached. Thus the higher door-to-door travel speed of the automobile and its unlimited choice of destination opportunities, make it possible for a commuter to expand her/his area of residential location and job choices.

The motor vehicle allowed urban activities to spread-out by removing the need to locate buildings within walking distance of rail stations, and reduced the reliance on transit for accessing more distant destination opportunities. In the US, the superior mobility provided by the automobile was quickly recognized and its popularity steadily increased. In 1916 there were over 2 million automobiles owned and that increased to 8 million in 1920—a fourfold increase in 4 years. Before the beginning of WWII (1940), there were 32.45 million motor vehicles in the US.

After WWII, the private motor vehicle further accelerated the urbanization of agricultural and developable land beyond the city's limits. This was made possible by the convergence of a number of factors. The construction of high-speed (65 mph) limited access highways made possible by a vast federal road building program that peaked with the Federal-Aid Highway act of 1956 authorizing 41,000 miles of high speed freeways and expressways which by 1972, were to link 90 % of the cities with population of 50,000 population or greater, along with many smaller cities and towns [3]. When combined with affordable prices of automobiles, cheap gasoline, an abundance of FHA low-cost housing mortgages, and a favorable tax code for home owners, these events set in motion a large suburban expansion of the population into low-density housing developments that could only be served by car, and were followed by the spreading of jobs from center cities into suburban areas [4]. Schools, retail stores, industries also became more numerous in suburban settings.

The popularity of the car as a mobility provider enabled vast number of families to escape the city—with its crowded housing, poor public schools, high crime, and racial problems of the 1960s—by moving to the open spaces and affordable larger living quarters offered by the suburbs made accessible by new highways connecting the new residential developments to the jobs in center cities. Modes of Travel in US Metropolitan Areas.

Tables 2.1 and 2.2 show commuter trips within the US metropolitan areas and the major travel modes used in commuting to and from work.

The significance of Tables 2.1 and 2.2 can be summarized as follows:

(1) In the suburbs, where 64 % of metro area commuters live and about 54 % work (Table 2.3), the car is used for 94 % of suburban trip destinations that originate in center cities; 91 % of suburban trip destinations originating in the suburbs; and 93 % of center city destinations originating in the suburbs.
(2) In center cities, where 36 % of commuters live and approximately 46 % of the commuters work, transit is used for 15 % of center city trip destinations originating in center city; 6 % of center city trip destinations originating in the suburbs; and 5 % of suburban trip destinations originating in center cities.

Table 2.1 Intra metropolitan origin/destination of commuter travel, 2,000 (million of trips)

	Central city employment destinations	Suburban employment destinations	Total trip origins
Commuter trips originating in central city	24.5 27.40 %	7.5 8.40 %	32 35.80 %
Commuter trips originating in the suburbs	16.6 18.50 %	40.9 45.70 %	57.5 64.20 %
Total trip destinations	41.1 45.90 %	48.4 54.10 %	89.5 100 %

Source Reference [4], p 49, Fig. 3.3, 2,000 data

Table 2.2 Mode share of metropolitan commuters (2,000)

	Destined to central city (%)		Destined to suburbs (%)	
Trips originating in central city	Drive alone	62	Drive alone	76
	Carpool	12	Carpool	18
	Subtotal car	**74**	**Subtotal car**	**94**
	Transit	**15**	**Transit**	**5**
	Bike	1	Bike	0
	Walk	5	Walk	0
	Work at home	3	Work at home	na
	Other	2	Other	1
Trips originating in the suburbs	Drive alone	82	Drive alone	79
	Carpool	11	Carpool	12
	Subtotal car	**93**	**Subtotal car**	**91**
	Transit	**6**	**Transit**	**1**
	Bike	0	Bike	0
	Walk	0	Walk	3
	Work at home	na	Work at home	5
	Other	1	Other	1

Source Reference [4], p 81, Fig. 3.40 and 3.42, 2,000 data

It should be noted, however, that the above values are averages for all metropolitan areas—from the largest to the smallest. There is a large difference, however, in transit share between the largest and smallest metro areas, as shown in Table 2.3.

The transit share of downtown trips of the 15 metro areas in Table 2.3, ranges from 76.5 % for New York with a downtown worker density of over 351,000 commuters per square mile, to 3.8 % for Austin with a downtown density of 80,000 commuters per square mile.

Table 2.3 Transit commuting to downtowns (as defined)

Area	Total commutes to entire metro area, 2,000	Total commuters to central city	Total transit commuters to central city	Transit share to central city (%)	Total downtown commuters 2,000	Total transit commuters to downtown, 2,000	Downtown land area (square miles)	Transit share of downtown commuters (%)	Worker density (commuters per square mile)
New York	9,429,080	4,545,645	2,065,120	45.43	379,380	290,390	1.08	76.5	351,277.78
Chicago	4,263,430	1,686,150	420,975	24.97	341,014	210,490	1.13	61.7	301,782.30
San Fran cisco	3,523,465	1,809,120	273,430	15.11	320,170	156,764	2.55	49.0	125,556.86
Washington, DC	3,876,675	1,296,840	269,685	20.80	409,505	154,658	3.99	37.8	102,632.83
Boston	2,977,665	1,143,960	222,500	19.45	270,315	137,701	2.32	50.9	116,515.09
Philadelphia	2,790,705	875,785	190,310	21.73	230,358	105,387	2.40	45.7	95,982.50
Seattle	1,785,935	841,560	100,500	11.94	147,905	54,435	2.99	36.8	49,466.56
Los Angeles	6,744,860	2,776,585	185,515	6.68	215,340	43,656	3.78	20.3	56,968.25
Portland	1,107,080	549,160	49,940	9.09	104,810	28,839	2.11	27.5	49,672.99
Houston	2,078,465	1,354,610	62,665	4.63	155,050	25,874	1.68	16.7	92,291.67
Dallas	2,569,405	1,430,395	37,475	2.62	91,786	12,493	0.85	13.6	107,983.53
San Diego	1,293,940	801,530	29,830	3.72	75,850	8,675	2.16	11.4	35,115.74
Sacramento	802,455	308,235	14,855	4.82	64,830	7,959	1.26	12.3	51,452.38
San Antonio	708,445	582,675	18,045	3.10	53,440	3,842	1.15	7.2	46,469.57
Austin	657,455	506,750	15,514	3.06	76,150	2,913	0.95	3.8	80,157.89

Source Adopted from Reference [4], p 94, Table 3.42

Table 2.4 Transport mode and urban form

Item	Type of city		
	Pedestrian	Electric transit	Automobile
Population	3,000,000	3,000,000	3,000,000
Area (square mile)	30	200	500±
Density (persons/sq.mi)	100,000	15,000	6,000
Jobs in city center	200,000	300,000	150,000
Development pattern	Compact	Radial with major corridor	Dispersed
Example	Paris pre 1900	Chicago 1930	Dallas 1990

Assuming an average of 225 square feet of floor space per commuter, the office floor space needed to hold New York's downtown commuters would amount to approximately 79 million square feet, and to accommodate Austin's downtown commuters, 18 million square feet.

2.3 Conclusion

Urban development and congestion patterns reflect the available transportation technologies. Each advance in the speed of travel has increased mobility, influenced land development, the form of cities, and patterns of congestion.

- Walking limited the radius of cities to the distance one could cover in 30–40 min (an average of about 2 miles).
- The electric street car extended the radius of the city, focused development along street car lines, reduced residential density in city centers and spread congestion outward. Large cities such as Boston and Philadelphia placed their street car lines underground to avoid congestion in city centers.
- A handful of cities built rapid transit lines that complemented suburban rail lines in improving mobility. These facilities had the dual effects of further concentrating development in the city center and extending urban development outward along the rapid transit lines. In a few cases, parallel rapid transit lines were built to accommodate the increased demand.
- Automobiles and the roadways that were built to serve them further decentralized development and traffic congestion.
- The changes in transport technology progressively flattened the population density gradient—the decline in population density with increasing distances from the city center. These changes are illustrated in Table 2.4 that gives illustrative population and employment densities for pedestrian, electric transit and automobile cities [5].

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