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HISTORY AND ROLE OF PUBLIC TRANSPORTATION IN URBAN DEVELOPMENT[1]

The founding, shaping, and growth of human agglomerations throughout history have been products of complex interactions of many forces. One major force has always been transportation. A review of historic developments will show how long-distance transportation had a major role in determining the *locations* of cities; how their *size* has been influenced by both long-distance as well as local, intraurban travel and transportation systems; and how the latter have affected the *urban form* (shape of urban area and its basic transportation network) and *urban structure* (distribution of land uses and population densities).

1.1 EARLY DEVELOPMENT OF CITIES

A brief description and analysis of urban development through history, focusing particularly on periods when relationships among different influences were relatively simple, is helpful in understanding the impacts of various technological and organizational changes that have taken place in modern times. Consequently, such an understanding may be helpful in selecting the transportation policies that have an impact on the creation of desirable urban development patterns. In particular, the role of public transportation in cities is better understood with the perspective that such a background provides.

1.1.1 Transportation and Locations of Cities

It is considered that the first significant civilian transportation began with exchange of goods. The exchange started when either a surplus of production was created, allowing producers to trade their surplus commodities for other goods, or when there was deficiency of some resources that existed at other locations. With intensification of exchange, it became possible to introduce specialization of work, which led to increased productivity, a greater surplus of goods, and a further increase of exchange. The process thus developed and accelerated itself.

The intensification of goods exchange led to the formation of trading routes and markets. At locations along the routes where tradesmen or caravans exchanged supplies or stayed overnight, stores, inns, and other services began to develop. Most frequently, these locations were at the points where goods had to be transloaded from one transportation mode to another or where trading routes intersected. Crossings of natural obstacles, such as rivers or hills, also created clustering of facilities and services.

1.1.1.1 Transloading Points and Route Crossings. Typically, ports and harbors on seacoasts and lakes or along rivers became the most common deter-

[1] Substantial parts of this chapter were written by Mark Horn as a part of the requirements for the author's graduate course, Urban Public Transportation, at the University of Pennsylvania in 1977.

minants of locations of cities. This is obvious from the present distribution of cities throughout the world. Istanbul, Naples, Lisbon, Rotterdam, Hamburg, and Oslo are harbor cities. The Atlantic Coast of the United States—with Boston, New York, Philadelphia, Baltimore, and many other ports—represents the largest concentration of cities and population in the country. Seattle, San Francisco, Los Angeles, and San Diego are prime harbor locations on the Pacific Coast. Regensburg, capital of the Holy Roman Empire of the German nation, Vienna, Budapest, Novi Sad, Belgrade (originally the Roman city of Singidunum), and a number of smaller cities are located along the Danube, the largest waterway in that part of Europe. Zürich, Chicago, Detroit, and Toronto are harbor cities on lakes, and so on.

Although for some cities—such as Berlin, Paris, and Moscow—it is difficult to discover today any special geographic reason for the choice of their particular locations, it is considered that route intersections and river crossings caused their initial development. Thus transloading points and route intersections were in most cases determining factors in the selection of city locations. Other factors that influenced urban locations can be grouped into the following four categories.

1.1.1.2 Mining Locations. Construction of a mine usually caused development of service industries and other components of future cities. Typical examples of cities that grew around mines are the densely developed areas of the Ruhr in Germany and the Midlands region in England; both represent agglomerations consisting of a number of large cities.

1.1.1.3 Strategic Considerations. In contrast to cities located along transportation routes (i.e., at accessible points), some cities were founded at locations that were easy to defend. Often, they were built close to transportation routes, where topography or water bodies provided good defense lines on one or more sides. Although some of these cities declined or were even abandoned (particularly those developed on hilltops), others—such as Copenhagen, Heidelberg, and Belgrade—were later opened up and grew into modern cities. Most towns that developed far from transportation routes could not prosper for long periods.

1.1.1.4 Resorts. Natural beauty, a pleasant climate, hot springs, and seacoasts attracting tourists, often represent a major force in the founding and growth of cities. With increasing affluence, these factors have become particularly important. Honolulu, Acapulco, Odessa, Nice, Innsbruck, and many Swiss cities owe much of their growth and prosperity to their natural attractions.

1.1.1.5 Political or "Representative" Reasons. Some cities have been founded at certain locations by a government decision. The reasons have usually been economic or political: to stimulate development of a particular part of the country, to utilize remote resources, to provide a representative capital. Good examples are Washington, DC (1780s), Ankara and Canberra (1920s), Brasilia (1950s), and Islamabad (1990s).

Only the first of the five major factors influencing the locations of cities—transloading and route-crossing points—is a direct function of transportation, but it is by far the most prevalent. Moreover, cities at mine locations were indirectly influenced by transportation: to reduce transport of bulky ores, extractive industries were developed in the vicinities of mines. It can therefore be said that transportation has had a major role in the determination of urban locations, although it did not always continue to be a dominant activity in later stages of a city's development. In all large cities, the growth of supporting services led to diversification of activities and eventually to the strong development of the tertiary sector (administrative, cultural, financial activities, etc.), which is not directly dependent on transloading of freight. Consequently, even closings of major transloading facilities that took place in some cities (e.g., relocation of most port activities from New York to New Jersey and from San Francisco to Oakland) had negative but not fatal effects on the city.

1.1.2 Transportation and City Size

Transportation technology and organization have in many periods of history had a major impact on the size of city and its population. Having influenced the locations of many cities, transportation continued to stimulate growth of cities that had easy access from many areas and by different modes. Good mobility within cities also influenced their growth. This was the case in many cities when construction of a bridge or tunnel resulted in the development of new areas with commercial, industrial, and residential activities, leading to economic growth and population increases in the entire urban area.

However, transportation has sometimes also acted as a constraint on urban growth in two ways, particularly prior to the invention of mechanized vehicles. First, the capacity of the system to supply the city with food and other material needs was limited. The transportation of supplies was slow, expensive, and often physically impossible beyond certain volumes and distances. Theorizing about the maximum possible size of cities, British statistician Petty stated in 1686 that all supplies for a city must be produced within a radius of 50 km. He computed that the production from an area of that size could support at most 600,000 houses and concluded that the maximum population of a city (in his study, London) would be 5 million. The second constraint was personal travel. When internal passenger circulation was slow, it was not possible to develop a city that would operate coherently over a large area. All major activities involving contacts among people had to be located within distances that permitted walking or the use of horses.

In addition to transportation, urban growth has always been influenced by other forces. In his monumental study of the development and growth of cities, A. F. Weber (1899) estimates that several ancient cities—among them Thebes, Memphis, Babylon, and Nineveh—had populations probably well in excess of 100,000; that Carthage probably had as many as 700,000, that Alexandria was somewhat smaller, and that Rome was somewhat larger (800,000 to 1 million). On the other hand, it is conjectured that in the Middle Ages, probably only Constantinople reached a population of 1 million (data from both periods are not very reliable). Western cities (London and Paris being most notable) did not reach the figure of 1 million until early in the nineteenth century. Since transportation technology in ancient times was not significantly different from that in the Middle Ages, Weber concludes that economic, political, and social factors in the two periods were different and they, acting collectively with transportation, caused different rates of growth and sizes of cities.

Schaffer and Sclar (1980) describe interaction of cities and transportation at a further level: they show how the basic mode of travel—such as walking, use of public transit, and driving a car—influences the size and type of life in cities.

1.1.3 Form and Structure of Cities

The ancient city of Miletus in Asia Minor is often mentioned as one of the first systematically planned cities (about 450 B.C.). It had a regular grid pattern of streets, indicating the attention given to transportation within the city. In the Middle Ages, the dominant role of market activities in the creation of the city influenced the formation of its core; typically, markets remained the central places, and the church, city hall, and other religious and secular central facilities were located immediately around them. The fact that internal circulation was performed mostly by walking and the requirement that the city be surrounded by massive defense walls dictated that cities be built with a very compact structure, like the example in Photo 1.1; this resulted in high population densities. Such cities typically had irregular street patterns because the basic modes of transportation (walking, riding, using animal-drawn carts) did not require any special roadway geometry.

With the passing of the Middle Ages, the need for defense walls gradually decreased and new patterns of urban development appeared. Political, functional, and often aesthetic factors began to influence urban form and street patterns. For example, the cities of Karlsruhe in Germany and Versailles in France were laid out with distinct radial/circumferential (section of a ring) street networks. Moscow has a ring and radial network. Royal palaces and government seats were usually focal points in cities with radial networks.

A grid pattern of streets, although used in several ancient cities (e.g., Miletus) and in some European ones (Mannheim is a good example), became extremely popular in North American cities. William Penn's plan for Philadelphia, founded in 1682, and

Photo 1.1 *A typical European city laid out in the Middle Ages: narrow streets and protective wall.*

street layouts in all five boroughs of New York City as well as in Chicago, Toronto, San Francisco (two grids with different block sizes and geometric orientations), and most other cities in North America utilized this pattern. Examples of cities with different street patterns are given in Table 1.1.

Consequently, the role of transportation in determining street networks has varied with times and conditions. Transportation had little influence on the layout of the irregular streets in medieval cities, but it has been a major factor in the designs of most regular networks. Grid street patterns provide for regular-size lots and easy travel along their two axes, although they are poorly suited to diagonal and radial travel toward areas with concentrations of offices, commercial and other activities, which are major traffic generators. To facilitate diagonal travel as well as to achieve aesthetic effects, L'Enfant designed Washington as a grid with

Table 1.1 Examples of street network patterns

Grid	*Radial / Circumferential*	*Combinations*	*Irregular*
Philadelphia	Moscow	Mexico, Milan (grid-irregular)	Boston
Chicago	Cologne		Lisbon
Mannheim	Copenhagen	Paris, St. Petersburg (diagonal-radial-irregular)	Bremen
New York	Karlsruhe		London
San Francisco	Amsterdam	Washington (grid and diagonal)	Manchester
Toronto	Versailles		Regensburg

superimposed diagonal arterials. These broke up the monotony of the grid but created many extremely complex intersections. The boulevards of Paris, built by Haussmann mostly for other reasons (to control civil disorders), also had a major impact on the city's transportation.

Public transportation has usually been given inadequate attention in street network designs. In cities with farsighted planning, central medians were provided for separate streetcar rights-of-way, which had increasing importance when street congestion intensified. In most cities, however, transit vehicles, especially buses, were considered as one of the user categories on regular streets; no special facilities were provided for them. Metro systems did get better treatment in most cities: their stations were used as focal points for street networks and for feeder transit convergence. Various commercial and office complexes and other intensive land uses have often been built around metro stations.

1.1.4 The Industrial Revolution, Urbanization, and the Growth of Cities

Cities have always been centers of human activity. In addition to being seats of government, they have been central locations for manufacturing, trade, educational, cultural, and other activities. However, before the development of large-scale industrial processes, most people resided in rural areas and were employed in the agricultural sector of the economy. This pattern was completely changed by the industrial revolution, which was initiated and sustained by many institutional, economic, and technological developments in the course of the eighteenth and nineteenth centuries.

The invention of the steam engine by James Watt around 1765 is often mentioned as symbolizing the beginning of the industrial era. Although that invention was by no means the single cause of the far-reaching economic and social developments that subsequently occurred, it did represent a significant technological breakthrough: it created a practical means of obtaining mechanical energy for application in mining, manufacturing, and, somewhat later, in transportation.

With an energy source many times more powerful than those available earlier and the introduction of the division of labor in industrial processes, labor productivity grew rapidly. Increased industrial production created a much greater surplus of goods than had been available previously. Trade intensified and locally autonomous economies were gradually replaced by economies based on distant supplies of resources and wide distribution of products. Agricultural and manufacturing production were reorganized toward an increased volume of production and consumption. The impact of these changes upon urban patterns was first evident in the rapid growth of the centers of international trade and commerce that began at the end of the eighteenth century. These centers—London, Paris, Berlin, New York, and others—grew throughout the century, and in most countries this growth has continued to the present.

New jobs in cities offered employment opportunities and attracted the rural population with the prospect of higher wages. The major shift proceeded from the primary sector of the economy (agriculture) to the secondary (manufacturing industry) and tertiary (government, administration, banking, trade, education, culture, etc.) sectors. While it is estimated that during the Middle Ages in European countries over 80% of the population was in the primary sector, with the secondary and tertiary sectors having some 10% each, these ratios have drastically changed since the industrial revolution. In highly developed countries, the primary sector now employs the smallest segment of the population.

The employment shifts that occurred during the process of industrialization are shown schematically in Figure 1.1: the curves showing the shift of population among the three sectors are typical for most countries, but the time periods in which they occurred and exact percentages vary with local conditions. Table 1.2, which gives estimates of present population distributions among the three sectors in several countries, shows that the tertiary sector is now predominant in the developed countries. It is therefore sometimes said that these countries have "tertiary economies."

Because the secondary and tertiary sectors are concentrated primarily in towns and cities, these employ-

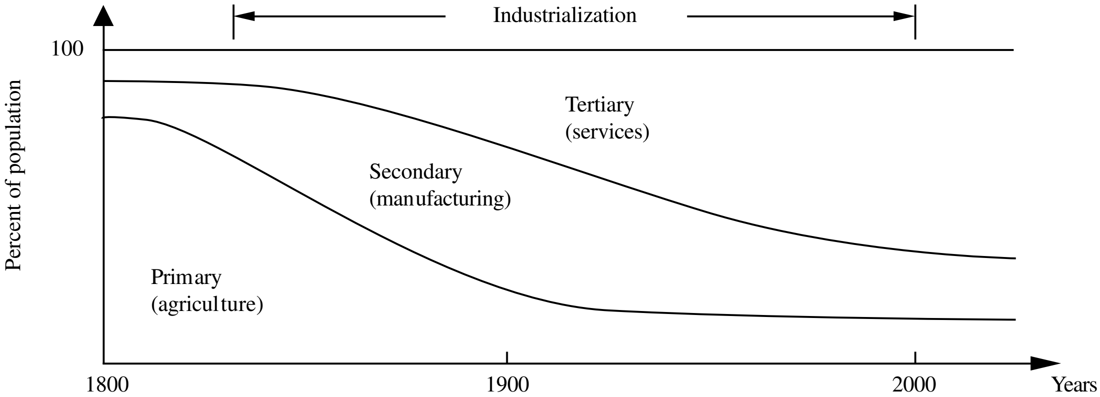

Figure 1.1 *Population shifts among sectors of the economy in the United States*

ment shifts among the sectors were accompanied by a massive movement of population from rural to urban areas, the process called *urbanization.* The scale of this process can be measured by changes in the proportions of the population living in urban areas on the one hand and in rural areas on the other. Before the nineteenth century, rural population was dominant, amounting typically to some 70% to 90% of the total population; following the period of intensive urbanization, which in most countries is still continuing, this share has now fallen to approximately 30%. The approximate trend of urbanization in the United States is shown in Figure 1.2; the estimated present distribution of population between rural and urban areas in different countries is given in Table 1.3.

Table 1.2 Estimated population distribution (%) among the three economic sectors for selected countries (1990)

	Economic Sector		
Country	*Primary*	*Secondary*	*Tertiary*
United States	2.8	26.0	71.2
United Kingdom	2.2	29.1	68.7
The Netherlands	4.6	25.6	69.8
Norway	6.3	25.3	68.4
France	5.5	28.8	65.7
Japan	7.3	34.2	58.5
Germany	4.0	38.1	57.9
Italy	8.6	31.4	60.0

Source: ILO, *Economically Active Population 1950–2010,* 4th edition, Geneva 1997.

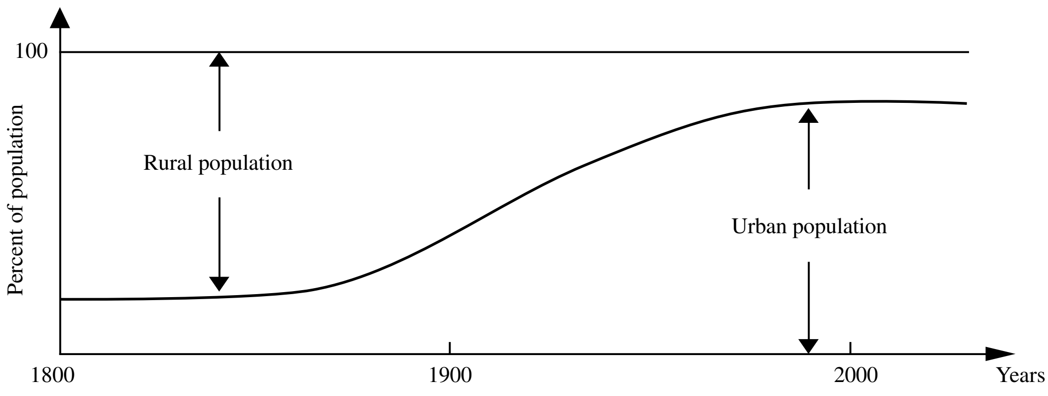

Figure 1.2 *The trend of urbanization in the United States*

Table 1.3 Changes in shares of urban population in different countries due to the urbanization process[a]

	Percent of Population in Urban Areas[b]				
Country	*1800*	*1850*	*1890*	*1970*	*2003*[e]
Germany[c]	7.3	10.6	30.0	79.6	88.1
The Netherlands	29.5	29.0	43.0	55.9	65.8
England/Wales	21.3	39.5	61.7	(U.K.)77.1	(U.K.)89.1
Canada	—	8.5	17.1	75.6	80.4
United States	3.8	12.0	27.6	73.6	80.1
France	9.5	14.4	25.9	71.1	76.3
Belgium	13.5(1820)	20.8	34.8	93.8	97.2
Russia	3.7	5.3	9.3	62.5	73.3
Brazil	6.7	7.4	10.2	55.8	83.1
Mexico	5.8	5.9	13.0	59.0	75.5
Japan	—	—	13.1	53.2	65.4
Italy	4.4[d]	6.0[d]	20.6	64.3	67.4

[a] The data for 1800, 1850, and 1890 are from Weber (1899), Table CXII; they include cities with populations greater than 10,000. For 1970 from the United Nations, Common Database (UN Population Division).
[b] Data are for the closest census to the quoted years.
[c] The first two columns refer to Prussia, the third to Germany, the fourth to West Germany, and the fifth to present-day Germany.
[d] Includes only cities with populations greater than 100,000.
[e] *Urban and Rural Area 2003,* Population Division, United Nations.

Table 1.4 Number of cities with population over 100,000 by continent[a]

	Year							
Continent	*1700*	*1800*	*1850*	*1900*	*1930*	*1950*	*1970*	*2002*
Europe	10	23	48	147	245	348	567[b]	796
Asia	30	40	55	90	172	290	702[b]	1962
Africa	1	1	2	7	16	39	123	322
Americas	—	1	9	51	142	192	440	919
Australasia	—	—	—	4	10	10	15	27
Total	41	65	114	199	585	879	1847	4026

[a] The data are from Weber, A. F. (1899), Lehner F. (1969); and the United Nations, *Demographic Yearbook,* 1972 and 2002. Considerable variations exist in definitions of cities and reporting dates among sources and countries.
[b] An estimated 238 USSR cities were distributed as follows: 167 to Europe and 71 to Asia, based on approximate shares of the country's population between the two continents (7:3). The two numbers are therefore approximate.

Coincident with the industrial revolution, food production also intensified and its supplies increased. Eventually, general living conditions improved and medical care progressed. These developments were major causes of the rapid population growth that has occurred since the eighteenth century. It is estimated that for many centuries world population fluctuated at a level between 300 and 500 million. This figure began to increase in about 1800 and grew to 1.2 billion in 1850, 1.6 billion in 1900, 2.5 billion in 1950, 3.6 billion in 1970, and 6.3 billion in 2003.

The process of urbanization, compounded by the population increases, resulted in explosive increases in urban populations. This phenomenon has been worldwide, as can be seen from the rapidly rising number of cities with populations over 100,000 on each continent since 1700, given in Table 1.4.

A particular event in transportation played a significant role in making the growth of cities possible. The invention of the first railway by George Stephenson (1781–1848) in England in 1825 represented a major milestone in the development of transportation, which accelerated the industrial era and stimulated the growth of cities. This new mode of transportation possessed speed, capacity, comfort, and reliability many times greater than those provided by any mode previously known. The improved quality and decreased cost of the transportation by rail resulted in increased travel, intensified communications, and a broadening of markets for low-value (bulk) resource materials and products for which transportation costs had previously been prohibitive. Thus the limit on city size imposed by the capacity of transportation systems to supply materials and goods was virtually eliminated. The benefits from railroads were so great that, following their introduction in the western countries around 1830 to 1840, construction of their networks proceeded rapidly; by the end of the nineteenth century, virtually all European and North American cities depended on railroad services for their economic functioning and growth.

1.2 BEGINNINGS OF PUBLIC TRANSPORTATION

With one limitation on city size (supplies) removed, the pressure for resolving the other (internal travel) became increasingly important for the growing cities and led to many efforts toward inventing new urban passenger transport modes. Numerous attempts failed, but the successful ones had direct and very significant impacts on cities. Before proceeding to these new modes, however, it will be useful to briefly review their somewhat scattered antecedents.

1.2.1 Public Transportation before the Nineteenth Century[2]

The Greek myth of Chiron, ferryman of the Styx, attests to the ancient provenance of the *boat* as a public conveyance. *Ferries* were again used extensively in late-medieval commercial centers such as Venice and London. Several organized forms of interurban public transportation appeared during the sixteenth century. Under the *posting* system, horses and horse-drawn post chaises were hired out for travel between posting points along major roads and highways. *Stage wagons,* used primarily for the transportation of goods, were operated on fixed routes to regular schedules from the beginning of the sixteenth century; faster *stagecoach* services, carrying only mail and passengers, appeared soon afterward.

During the seventeenth century, these methods of transport organization were adapted to intraurban conditions. Three of the new urban modes deserve special mention.

1. *Coaches,* hired out for intraurban trips, first appeared in London around 1600. In 1634, the proprietors of these hackney coaches obtained permission to ply the streets for hire, and by 1694 there were 700 licensed hackney coaches in London. This form of transport, the ancestor of the modern taxicab, was introduced in Paris as the *fiacre* in 1612.
2. The *sedan chair,* mounted on wooden poles and carried through the streets by a pair of "chairmen," was a significant form of urban public transportation in large European cities during the seventeenth and eighteenth centuries. Public-hire sedan chairs first appeared in Paris in 1617. They were introduced in London in 1634 and were still being used there as late as 1821.
3. In 1662, a *public coach* service operating on fixed routes was introduced in Paris. Blaise Pascal was one of the instigators of the scheme. Each vehicle had seating for eight passengers and services were provided on five routes. This early predecessor of modern forms of urban transit continued in operation for approximately 20 years.

These modes, however, were "public" only in the narrow sense of the word. Only the wealthy could afford them; their character is well illustrated by the official regulation, which excluded all but "bourgeoisie and people of merit" from Pascal's coaches. Conditions that would favor the development of large-scale

[2] The principal sources for this section are Causse (1972), Hart (1962), and Pratt (1912).

public transport systems available to large sections of the public did not arise until the nineteenth century.

1.2.2 Horse-Drawn Omnibuses[3]

The horse-drawn omnibus was, in effect, a long box on wheels, distinguished from its immediate antecedent, the stagecoach, by its higher passenger capacity. Such vehicles (known as ''long stagecoaches'') were operating around London as early as 1798, but it was in France that they acquired the name by which they were to become generally known, and it was in France that they were first used in inner-city areas. Stanislaus Baudry established the first ''omnibus'' service in Nantes in 1826; omnibuses appeared in Bordeaux in 1827; and in 1828 Baudry obtained official permission to run 100 of the new vehicles on 10 fixed routes in Paris.

In 1829, George Shillibeer introduced an omnibus service in London. His vehicles were larger than those operating in Paris, carrying 20 passengers as against 14 in Paris, and drawn by three horses instead of two. Initially, Shillibeer was not permitted to stop for passengers in the inner streets of London, where the hackney coaches had a monopoly and his omnibuses were in direct competition with the ''short stages,'' which had capacities of only four or six seats. In his advertising he emphasized the speed and punctuality of the service, which was well patronized from the start and soon imitated by other entrepreneurs. The lifting of the London hackney coach monopoly in 1832 enabled the omnibus proprietors to run the high-capacity mode of operation for which their vehicles were best suited.

The first omnibus type of service in the United States was in New York City, where in 1827 Abraham Brower commenced operation on Broadway with a 12-passenger open-sided vehicle called *The Accommodation.* Within eight years the city had more than 100 omnibuses. In New York, as in London at the same time, rivalry between competing omnibus proprietors was fierce, and recklessly driven omnibuses were a notorious hazard to pedestrians.

Within 20 years there were regular omnibus services in the other leading ports of the eastern seaboard: Philadelphia (omnibus introduced in 1831), Boston (1835), and Baltimore (1844) as well as in many European cities, such as Prague (1829), Liverpool (1831), Budapest (1832), Birmingham (1834), St. Petersburg (1835), Lyon (1837), and Leeds (1839). The omnibuses arrived somewhat later in Germany than in other parts of Europe: for example, in Berlin (1837), Dresden (1838), Hannover (1852), Leipzig (1860), and Munich (1861). Photo 1.2 shows several omnibuses from that era in Paris.

The great strength of the omnibus was its operating flexibility, and this—combined with gradual improvement in the condition of city streets—gave it a commanding position in urban transit during the middle third of the nineteenth century. Indeed, omnibuses continued to operate successfully in some European cities in the face of competition from rail modes of higher performance until they were finally superseded by motor buses in the first decade of the twentieth century.

Omnibus design varied considerably from place to place. The London omnibus in its final form was the model for its successor, the well-known double-decker motorbus; its evolution on London's narrow streets is therefore of special interest. The first omnibuses in London were very cramped inside, as small as 4 ft 6 in. (1.40 m) high and 4 ft 6 in. wide, with wooden seats running down the side walls and entrance through a door at the rear. During the 1830s some passengers began to sit beside the driver on his seat, and after changes were made to the licensing provisions, they began to sit behind the driver on the roof. By 1847, ''knifeboard'' seating had been introduced; with this system the ''outside'' passengers sat back-to-back along the main axis of the roof. In 1856, ceiling heights were raised, ventilation was improved, and steps were added to give better access to the roof. In 1880, a new bus design incorporated lateral ''garden seats'' in place of the longitudinal knifeboard; other improvements included a swiveling front axle and upholstered seats inside the vehicle. But it appears that no roofing for the upper deck was provided until after

[3] The principal sources for this section are Barker (1963), Carter (1973), Miller (1941), and Risch (1957).

Photo 1.2 *Horse-drawn omnibuses in Paris* (*Courtesy of RATP, Paris*)

the conversion to mechanical traction, in the early years of the twentieth century.

1.2.3 Horse-Drawn Tramways[4]

In its earliest form, the horse tram, or horsecar (as it was called in the United States),[5] was simply an omnibus running on rails. Here the technology of rail guidance found its first specifically urban application. The horsecar's low rolling resistance gave it several marked advantages over the omnibus: more efficient use of horsepower, higher passenger capacity, and improved comfort. Moreover, since the horsecar ran on smooth rails instead of irregular cobblestones, the size of the wheels had little effect on the vehicle's riding characteristics, and with small wheels the car body could be built conveniently low and wide. These basic vehicle characteristics were carried over in the mechanized rail modes which superseded the horsecar toward the end of the nineteenth century.

The first horse-drawn ''street railway'' opened in New York in 1832. This first use of rail vehicles for urban transit was a line that ran from Harlem to lower Manhattan and was intended as a feeder to the proposed Harlem-Albany railroad. The vehicles initially used were like oversized stagecoaches. They had three

[4] In addition to the sources for the preceding section, material in this section is also based on Klapper (1961) and McKay (1976).

[5] The terms ''horse-drawn trams,'' ''horse trams,'' and ''horsecars'' all refer to rail vehicles towed by horses. ''Horse tramway'' or ''horse-drawn street railway'' refers to the lines served by these vehicles. These terms are used here interchangeably, according to the local terminology in the country or area under discussion.

compartments, each seating 10 passengers, plus 30 more on the roof.

The New York line flourished, and a horsecar line was built in New Orleans during the 1830s, but it was not until the 1850s that horsecars began to appear in other American cities: in Boston in 1856, and (within the next four years) in Baltimore, Chicago, Cincinnati, Philadelphia, and Pittsburgh. Probably an important reason for the widespread acceptance of horsecars in America at that time was the introduction of grooved rails, laid flush with the surface of the street, instead of step rails, which protruded above the pavement and so presented a hindrance to street traffic. Alphonse Loubat, a French engineer, built the first grooved-rail horsecar line in 1852 in New York.

In 1853, Loubat opened a horse tramway in Paris; but this line, *Le Chemin de Fer Americain,* the first of its kind in Europe, was so conditioned by official restrictions that it can hardly have been a fair demonstration for the new mode. Horse tramway development in Europe did not really get under way until the late 1860s. The first tramway in St. Petersburg opened in 1863, followed by Berlin (1865), Vienna (1865), and Budapest (1866). By 1869, tramways had been introduced in Hamburg, Stuttgart, Brussels, Geneva, and Copenhagen.

In Great Britain, the institutional factors that initially delayed the development of horse tramways were particularly severe. An engineer named William Curtis built the first horse tramway in Britain, at Liverpool in 1860; and George Francis Train, an American entrepreneur, built a line at Birkenhead in 1860. Train built two lines in London, in 1861 and 1862, but local residents forced their closure soon afterward, and permanent tramway services were not established in London until 1870. Subsequent legislation banned horse tramways from central London and gave local authorities the right to acquire tramways after 20 years of private operation. These regulations inhibited private tramway construction and established an institutional environment that would foster the ‘‘municipalization movement’’ some 25 years later. Tramway legislation in other European countries was more favorable to private entrepreneurs: for example, concessions were usually granted for periods of 40 to 50 years.

Horse tramway development in Europe proceeded very rapidly during the 1870s; for example, tramway networks were built in more than 16 German cities during that period. Because of their higher efficiency, the tramways could sustain lower fare schedules than the omnibuses, so that they supplanted omnibus services in some middle-class neighborhoods. They also attracted many working-class people who previously could not afford any kind of urban transportation. Two double-decker horse tramways in Paris are shown in Photo 1.3.

Nevertheless, the impact of the horse tramways on city life was more pronounced in the United States than in Europe. American cities, large and small, had tramway lines on all their major streets, and at least in the North, the tramways were a significant element of the post–Civil War boom in suburban housing. Tramway development was subject to fewer official restrictions in America than in Europe, and there were also important differences in physical conditions. In Europe, trams and omnibuses could complement each other, for in most of the old European cities there was a roughly two-level hierarchy of streets: narrow, winding medieval streets, where the omnibuses had the upper hand, and broad boulevards, built in the eighteenth and nineteenth centuries, where the trams had the advantage. On the other hand, the regular grid of broad, straight streets characteristic of American cities tended to minimize the omnibuses' competitive advantage, and for this reason trams tended to replace rather than complement omnibuses in the United States.

1.2.4 Mechanized Street Transit Technologies before 1880[6]

Omnibus and street railway operations were severely restricted in scope as long as they depended on horses for traction. The costs involved in purchasing, feeding, and stabling horses were large and constituted a large proportion of the overall cost of transit operations. Horses were quickly worn out by street work, and their

[6] The primary sources for this section are Barker (1963), Hilton (1982), Klapper (1961), McKay (1976), and Miller (1941).

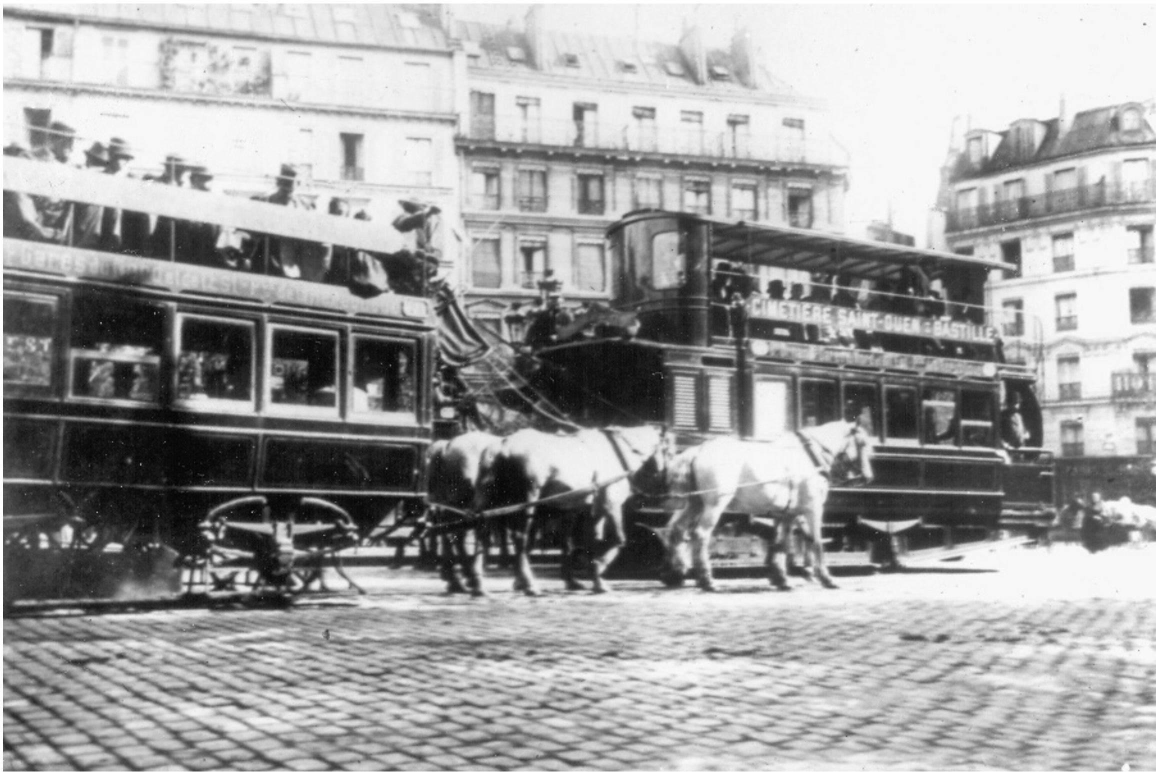

Photo 1.3 *Horse-drawn tramways* (*Courtesy of RATP, Paris*)

vulnerability to disease was demonstrated dramatically in 1872, when thousands of horses in the eastern United States died in the Great Epizootic, an equine influenza epidemic.

The search for a mechanical replacement for horses was concentrated initially upon the proven source of power, the steam engine. Between 1821 and 1840 a number of steam carriages were built in England. These vehicles were heavy, slow, noisy, and cumbersome; of the few that developed beyond the stage of technical experiment, none achieved sufficient success to attract further investment. For example, between 1833 and 1836, Walter Hancock operated regular services with 14- and 22-seat *steam-driven omnibuses* in London, but the vehicles attracted few passengers from the horse-drawn omnibuses working the same route, and the venture was a commercial failure. Improvements in steam engine technology later in the century led to renewed interest in steam as a source of power for street vehicles, and during the 1870s several models of steam trams went into commercial production. In some cases a small rail-guided steam locomotive drew an ordinary unpowered tram; otherwise, the engine was incorporated in the passenger vehicle itself. It has been estimated that at various times there may have been as many as 2500 steam trams on the Continent, 700 in the United States, and 500 in Great Britain, but only a fraction of them were used as transit vehicles (most were operated as "light railways" in sparsely populated rural areas). The steam trams were noisy and dirty and were therefore unpopular with the public and with municipal authorities. Devices fitted to reduce noise and smoke emission to acceptable levels rendered the vehicles too heavy for use on tracks laid for horsecars and less profitable than horsecars.

An ingenious solution to these problems was found in the *fireless steam engine,* which used pressurized steam generated in a stationary boiler at a central depot. No boiler was required for the locomotive itself; smoke, sparks, and cinders were eliminated; the dead weight of the locomotive was reduced; and the onboard fireman was dispensed with. This system was first tried in New Orleans in 1873 and was perfected by Leon Francq, a French engineer. Francq's fireless locomotives were adopted on several lines in the Paris suburbs and in a number of French provincial cities during the late 1870s and early 1880s; they were hauling tramways in Lyon until as late as 1905. But they were beset with one major problem: their ordinary operating range (15 km) could be sharply reduced by unusual events such as street congestion or blockage of tracks, leaving them stranded without steam anywhere along the line.

The Mekarski *compressed-air* system, developed in the same period, was similar in principle to the fireless steam engine and had similar weaknesses. Mekarski's tramcars were equipped with piston motors; the motors were driven by air compressed at a central plant and stored on board. They first gained official approval in Nantes (France), where they were in regular service from 1878 until 1913; as late as 1910, there were six compressed-air tramway lines in Paris. But the system was rather unreliable—one of the Paris lines was known popularly as *Reste en Panne* (“breakdown”)—and the stationary air compressors consumed inordinately large quantities of fuel. Tests of compressed-air locomotives carried out in England in 1880 showed a rate of coal consumption five times that of ordinary steam locomotives. Several compressed-air trams were tried in British cities during the 1880s, but none went into permanent operation.

The investigation of *electric traction* for rail-guided vehicles commenced during the 1830s, soon after Faraday's invention of a rudimentary electric motor (1831). Thomas Davenport, a blacksmith of Green Mountain, Massachusetts, exhibited a miniature electric railway in 1837, and in the following year an engineer named Robert Davidson ran a locomotive powered by electric batteries on the Scottish railway lines, achieving speeds of over 6 km/h. Various experiments of a similar nature were carried out during the 1840s and 1856s, but they all depended on storage batteries for electricity supply, and none offered a serious challenge to the established modes of traction. Power supplied by electric batteries was “fully 20 times as costly as equivalent power supplied by a steam engine,” and economical methods of supplying large quantities of electricity did not become available until the late 1870s (see Section 1.3).

Tests were also made with trams powered by *large springs* wound by stationary steam engines (London, 1875; Philadelphia, 1876); during the 1890s *oil and gas motors* seemed to offer some promise of success. Actually, trams driven by town gas fired in Crossley-Holt gas engines were running on a few English lines until as late as 1920.

The *cable car* was the first mechanized mixed-traffic mode to attain widespread commercial success and public approval. Its main mechanical features can be traced to a system of ropes, pulleys, and stationary steam engines developed during the eighteenth century for the hauling of rail-guided wagons on steep inclines in the British mines. Cable traction was used on a suburban railway line in London during the 1840s and on New York's first elevated railway, opened in 1868; but in both cases the cable system was found to be unsatisfactory and was replaced by conventional steam locomotion. The world's first cable-operated street tramway opened in 1873 on San Francisco's Clay Street Hill. Andrew Hallidie, a manufacturer of ropes and cables for the California gold fields, was the inventor and instigator of the project. The system comprised an endless wire-hemp cable driven by a stationary steam engine, a cable car running on rails with a gripping device mounted on board, and a driver or “gripman.” By operating the “grip,” the gripman could attach the car to the moving cable; to stop, he would release the grip and apply a wheel brake. The cable, guided by rollers and pulleys, ran in a slotted conduit built into the pavement between the rails; in the engine house there was a movable counterbalanced pulley system to maintain cable tension.

In several respects Hallidie's system was clearly superior to the horse tramway: it was clean, running costs were very low, and high running speeds (up to 15 km/h) could be reached even with full passenger loading. Steep hills could be negotiated without difficulty and actually more safely than in most other traction technologies: gripping the cable, the car would travel uphill or downhill at a constant speed without the possibility of skidding or running away. An interesting feature of the system is that the cars traveling downhill when attached to the cable assist the traction of other cars—a simple and effective method of energy regeneration.

These advantages seemed to justify the large capital investments involved, and during the 1880s cable tramways were installed on many high-volume city routes, especially in the United States. By 1893, there were approximately 800 km of cable tramway in 16 American cities; the largest network was in Chicago, with 135 km of track, 496 grip cars, and perhaps 1000 trailer cars. Cable car systems were also built in large cities in England, Scotland, France, Portugal, Australia, and New Zealand. The first in Europe was London's High Gate Hill line, opened in 1884; the largest network in the world was in Melbourne: 153 km of track, built between 1884 and 1891.

But by 1890 the electric tramway (trolley) system already offered a cheap and practical alternative to cable traction. The simplicity of the trolley system offered a means of avoiding the imperfections and dangers of cable haulage. For example, negotiation of the giant pulleys installed at line crossings and bends often involved safety problems, and when the grip snagged in a frayed strand or loose cable, the cable car would be dragged along city streets, out of control until the depot engineers were notified and the driving engines halted. Consequently, most cable car systems were converted to electric traction or abandoned by 1905.

Nevertheless, on very steep gradients, cable traction has certain advantages over other modes, even today. Cable cars still provide effective service on steep hills in San Francisco. Other technologies with cable traction, such as *funiculars* (inclines) and *aerial tramways,* remain in extensive use in mountainous terrains and in many cities with special geographic conditions (e.g., Pittsburgh, Hong Kong, Salzburg, and New York's Roosevelt Island), as discussed in Chapter 9.

1.3 INVENTION OF ELECTRIC STREETCARS/TRAMWAYS[7]

The development of the dynamo and electric motor during the 1870s, through the inventions of Werner von Siemens (1816–1892), Z. T. Gramme, C. F. Brush, Pacinotti, and others formed the basis of a new industry associated with the generation and distribution of electricity for arc lighting and (after 1879) incandescent lighting. As early as 1855, several European inventors had conceived the idea of using continuous conductors to convey centrally produced electricity to rail-guided vehicles, and the new electrical industry provided the means for the realization of such a scheme.

In 1879, Siemens' firm, Siemens & Halske, built a demonstration electric railway for the Berlin Trade Fair, and two years later the world's first electric streetcar line, developed by the same firm, opened at Lichterfelde near Berlin. For both lines the running rails were used as positive and negative conductors; a similar railway opened at Brighton (England) in 1883.

The use of exposed conductors on a public street was obviously unsatisfactory, and it was clear that fencing off the line for safety (as was done at Lichterfelde) would severely restrict the range of places in which the new invention might be put to work. Electrification of tramway lines therefore proceeded very hesitantly at first, with much effort being spent in the search for a safe and reliable method of current collection. Siemens & Halske took a leading part in this work. For the Paris Exposition of 1880, they equipped a line with an overhead copper-wire conductor, which was set inside a slotted pipe. Current was collected by

[7] The principal sources for this ection are Cudahy (1982, 1990), Hering (1892), Klapper (1961), Singer (1960), McKay (1976), Risch (1957), and Sprague (1931–32).

lugs running inside the pipe, taken down to the motor via a cable, and returned to the generator along the running rails. In the same year Siemens & Halske tried small contact carriages running on grooved wheels along a pair of overhead wires on an experimental line at Charlottenburg. But it was in America that the really fruitful technical development—the ‘‘breakthrough’’ in streetcar technology—was to occur.

1.3.1 Beginnings of Electric Streetcars in the United States

Thomas Edison built an experimental rail conductor tramway at his Menlo Park factory in 1880. The first regular electric streetcar service in the United States commenced operation in Cleveland in 1884; for this line its designers, Bentley and Knight, used a small ‘‘plough’’ to draw current from a pair of copper wires, which were laid in a slotted underground conduit between the rails. This system was found to be unreliable, and service on the Cleveland line was discontinued in 1885. Systems employing overhead wires and overrunning ‘‘trollers’’ (similar to those used by Siemens at Charlottenburg) appeared in several American cities during the middle 1880s. The underrunning spring-loaded trolley pole was first used in Montgomery (Alabama) in 1886, but Charles Van Depoele, the author of this scheme, went back to trollers in his subsequent electrification projects. All the electric lines built during this period encountered serious technical problems and few continued in operation for more than a few years.

While Siemens, with his inventions, made the first operational streetcar in Germany, another genius of electric traction in the United States made numerous inventions that eliminated the initial problems and made the streetcar a practical and efficient vehicle. Frank Sprague (1857–1934), a former officer in the American Navy who had worked with Edison on some of his electric railway experiments, set up the Sprague Electric Railway and Motor Company in 1884. In May 1887, he was awarded his first major contract, for the supply of electrical equipment and vehicles on 19 km of line in Richmond (Virginia). This was larger than any other electric tramway network in the world and twice as large as any then built in the United States. Steep hills and poorly laid track presented a severe test to the performance and durability of Sprague’s equipment; but through a process of ‘‘patient experimentation, hard work, and attention to detail’’ (Klapper 1961), Sprague and his assistants found satisfactory solutions to most of the problems confronting them. They designed a power generation and distribution system that could meet peak demand conditions, and they perfected the underrunning trolley pole. To drive the streetcars, they used Sprague’s heavy-duty motors, which were capable of withstanding sudden surges of current; to minimize wear and tear on the drive gears, the motors were hung in ‘‘wheelbarrow fashion’’ between axle and sprung frame; speed control was by series/parallel switching and heavy-duty rheostats. This work established a sound technical basis for the streetcar industry in America.

The Richmond network opened in February 1888 and immediately attracted the attention of American street railway officials. Because operation by electricity was very much less costly than horse traction, street railway proprietors were able to reduce fares and so attract more passengers; with a larger market, they were able to build streetcar lines on routes that would have been unprofitable with horse traction. The dramatic impact of this technology can be seen from several statistical figures. It is estimated that in 1880 the total length of ‘‘street railway’’ networks (line lengths) in U.S. cities was 3300 km (2050 mi), virtually all of it with horse traction. By 1890 the length had increased to 9305 km (5783 mi), of which approximately 800 km was with cable and 1900 km with electric traction. San Francisco’s Market Street already had four tracks at that time (Photo 1.4). By 1902, virtually all of the total length of 26,782 km (16,645 mi) of lines was equipped with electric traction, and by 1912 the total length of lines had increased to 48,975 km (30,438 mi). Intensive streetcar traffic in Philadelphia around 1900 can be seen in Photo 1.5.

This development was closely linked with the rapid growth of urban population, which was evident both in the expanding industrial metropolises of the Northeast and in the booming farm produce and railroad

Photo 1.4 *Cable car with trailer of the Clay Street Hill Railroad Co., San Francisco, ca. 1878* (*Courtesy of San Francisco Cable Car Museum*)

capitals of the Midwest. By virtue of their range and speed, the electric streetcars greatly increased the capacity of urban centers to accommodate population growth.

The introduction of cable and then electric streetcars was interrelated with some important changes in transit organizations. The original horsecar services were typically provided by many different operators, some of whom had only a single line. Coordination among them was poor, causing serious inconvenience to the public. For trips involving travel on more than one route, passengers had inconvenient transfers and paid double fares. Since cable, and particularly electric traction, required substantial investment, its introduction accelerated the trend toward mergers of many small operators into larger companies. These consolidations led to greater efficiencies of operations and to improved transit service for the public through better schedules and information, integrated fares, and easier transfers. Increased ridership, attracted through better service, generated additional revenue.

The rapid growth of cities and industries resulted in increasing demand for travel in cities. Transit companies, facing rapid expansion and foreseeing the likelihood of imminent replacement of thousands of horses by mechanical traction, were interested to work on technical inventions as well as organizational improvements. It was thus logical that an initiative of H. H. Littell, of St. Louis, to form a national association of transit companies was widely accepted. At the meeting in Boston in 1882, the American Street Railway Association, predecessor of the present American Public Transportation Association (APTA), was founded. At that time, there were 415 street railway companies operating 18,000 streetcars and 100,000 horses. Cudahy

Photo 1.5 *Streetcar terminal on Market Street at Delaware Avenue in Philadelphia, 1900*

(1982, 1990) presents an extremely detailed and lively description of that event as well as the history of transit development since that time.

International development of transit systems led to the founding of the Union Internationale des Transports Publics (UITP) in Brussels in 1885. That organization, the International Association of Public Transport, continues today to be the world's leading organization of urban public transport.

In some U.S. cities, few official restrictions hindered street railway development during this period. Many municipalities granted perpetual franchises to streetcar entrepreneurs. The entrepreneurs were able to plan their routes to ensure the profitability of their investments, often without much concern for community and environmental impacts. For example, overhead wiring and supporting structures were erected with little or no consideration of their visual quality, a major concern in many European cities during the same period. The fact that the entrepreneurs' activities generally happened to be beneficial to the general public was in such cases of secondary importance in the minds of urban politicians steeped in the ideology of "free enterprise" and material progress. However, in the older, established cities—such as Boston, New York, Philadelphia, and Washington—awareness of the possible impacts of transportation facilities on the environment was much greater. As in Europe, city authorities often demanded the construction of tunnels instead of elevated steel structures. Regulation was sometimes excessive. In Washington and some parts of New York, transit companies had to provide an underground power supply for streetcars instead of overhead wires, while the transit company in Philadelphia had to maintain the entire pavement on all the streets on which its streetcars ran.

1.3.2 Introduction of Electric Tramways in Europe

In Europe, governments and influential sections of the public tended to regard the planning of tramway services as a public responsibility. This attitude, combined with systems of stringent government regulations established for the horse tramways, had substantial effects upon the development of electric tramways in Europe.

In 1890, the total length of electric tramway lines in Europe was only 96 km. Tramway electrification proceeded more slowly than in the United States until the last few years of the nineteenth century. This initial delay was due largely to the importance attached to aesthetic aspects of urban development in European city politics. Influential members of European city governments felt that streets and squares should not be wrapped in an untidy web of overhead wires and believed that further technical work would yield a feasible and visually unobtrusive alternative to the American overhead trolley system. Consequently, manufacturers of electrical equipment were forced to devote much effort to the search for safe, reliable, and efficient systems of power distribution and power pickup that would not require overhead wires. Three main alternatives were explored: battery traction, continuous-contact conductors in underground conduit, and surface contact systems.

Battery propulsion entailed the use of large storage batteries, charged at a central power station and carried on board the tramways. The chief advantages of this method were safety, low infrastructure costs, and freedom from the technical problems associated with continuous conductors. Battery-powered streetcars were given extensive trials in France, Belgium, Germany, and Britain during the 1880s and 1890s, but with very limited success. The problems encountered with battery traction were quite similar to those associated with traction by fireless steam engines and compressed air: running costs were high, and the battery cars lacked reserves to meet the demands of peak traffic loadings. In addition, the batteries were expensive to purchase, and they added about 2½ tons to the weight of each car.

Conduit and surface-contact systems were based on the use of continuous underground conductors. In the former systems, power was picked up by means of a plough moving in an underground slotted conduit.[8] With the surface-contact systems, power was provided

[8] A similar system was used on the streetcar system in Washington until its closure in 1962.

by contact between a long skate mounted under the tramway and iron plates or studs set between the running rails at intervals somewhat less than the length of the skate; each plate was connected to the underground conductor through a switch activated by the skate, so that the plates would be "live" only when a tramway was passing over them. These systems were used quite extensively in a number of European cities between 1890 and 1910, notably the surface-contact system in Paris and the conduit system in Budapest. But both systems were expensive to install and both were unreliable in operation: underground conduits easily became clogged with mud, and surface-contact plates remaining "live" on the open streets presented a lethal hazard to iron-shod horses.

The pace of tramway electrification in the industrial nations of central Europe quickened after 1895: successfully constructed networks served to demonstrate the merits of the new technology and to break down official resistance. Strong competition among tramway promoters placed municipalities in a favorable bargaining position, enabling them to make the best of the available systems. The range of choice encompassed the three nonoverhead systems described above, plus the overhead conductor system, for which power pickup was either by Sprague's underrunning trolley or by the *Bügel* or "bow" (first used commercially by Siemens' firm to equip lines in Hannover and Dresden in 1893). Nonoverhead systems were used quite frequently for inner-city routes, and (in "mixed" systems) for portions of routes in squares and streets of high symbolic importance. These "aesthetically pure" lines were so plagued with operating difficulties that, by 1900, the search for alternatives had lost its impetus and the overhead system was being adopted on almost all new tramway projects. The main aesthetic issue now was mitigating the visual impact of the overhead system, and on this point the tramway entrepreneurs went to considerable lengths to satisfy the municipalities. Heavy feeder cables were laid underground; elegant cast-iron poles and wall brackets, carefully set out, supported the wires; and in many cities the poles incorporated streetlighting fixtures.

European municipalities were willing to accept the overhead system because they recognized the fact that the electric tramway offered positive social benefits, resulting primarily from greatly increased travel speed and reduced fares. Cheap transportation would enable laborers and factory workers to travel considerable distances between their places of residence and places of employment; thus suburban housing would also become available to the lower economic classes, and the crime, disease, and "moral degeneracy" characteristic of the overcrowded inner-city slums could be alleviated. Fares and tramway lines therefore became important issues in negotiations between municipalities and tramway entrepreneurs. Fare rates—and, in many cities, special "workmen's fares" for early-morning and late-afternoon travel on weekdays—were specified in franchise agreements; and tramway companies were often compelled to build initially unprofitable suburban lines, sometimes extending beyond existing built-up areas, in return for lucrative concessions on more heavily traveled routes. There is evidence indicating that the low fares made transit available to all but the very poorest sections of urban society, and although the construction of new lines in suburban and semirural areas tended to push up rents and property values in those areas, it did facilitate a gradual diffusion of residential population outward from the crowded central city areas.

In 1900, tramway electrification was at its height in Belgium, France, and Germany. In Great Britain, the tramways legislation of the 1870s, which limited tramway companies' tenure of their lines to periods of 21 years, was such a strong deterrent to private investment that large-scale electrification did not commence until the late 1890s, and then generally under municipal ownership and operation. Glasgow was the pioneer in tramway "municipalization." The Glasgow (Municipal) Corporation took over the city's horse tramways in 1894, on the expiration of the operating company's lease, and in 1899 commenced conversion to electric traction. By 1911, four-fifths of the tramway passengers in Britain were being carried on networks owned and operated by local authorities. At least in its early, constructive stages, the British institutional innovation was eminently successful, and municipal enterprise became an important factor in tramway development on the Continent, especially in Germany, after 1900. In the United States, municipalization "was studied with interest and even awe" (McKay 1976), but was followed only several decades later.

The magnitude of what is sometimes referred to as the "tramway revolution" in Europe is illustrated by the threefold increase in tramway track length that occurred from 1890 to 1910. A typical European tramway with trailer from that period is illustrated in Photo 1.6. During the same period, the number of annual rides per capita ("riding habit") in the four largest U.S. cities increased from 195 to 293; in the four largest British cities, from 56 to 226; and in the four largest German cities, from 56 to 203. Although portions of these increases were due to the new rapid transit systems opened at that time, the rate of increase was very similar in cities with streetcars only. These statistics also reflect the fact that in the beginning of this "revolution," horsecar networks were more extensively developed in America than in Europe; thus the impact of electric traction was relatively greater in some European countries than it was in the United States.

1.4 STREET TRANSIT DEVELOPMENT SINCE 1900

At the beginning of the twentieth century, the basic breakthrough in transit—invention of an operational mechanized technology—had been achieved, and streetcar systems were in use in most large and medium-sized cities. Yet, that was only the beginning of the progress that was to follow in subsequent decades. Streetcar vehicles and infrastructure were further improved and new modes—notably the motorbus and trolleybus—were invented and made operational; the motorbus eventually became the dominant street transit mode.

1.4.1 Streetcars/Tramways[9]

The typical electric streetcar, from its introduction in the late 1880s up to World War I, was a short, two-

[9] The text in this section is based on APTA (2004), Cudahy (1982), FERC (1920), Klapper (1961), Miller (1941) and Smerk (1968).

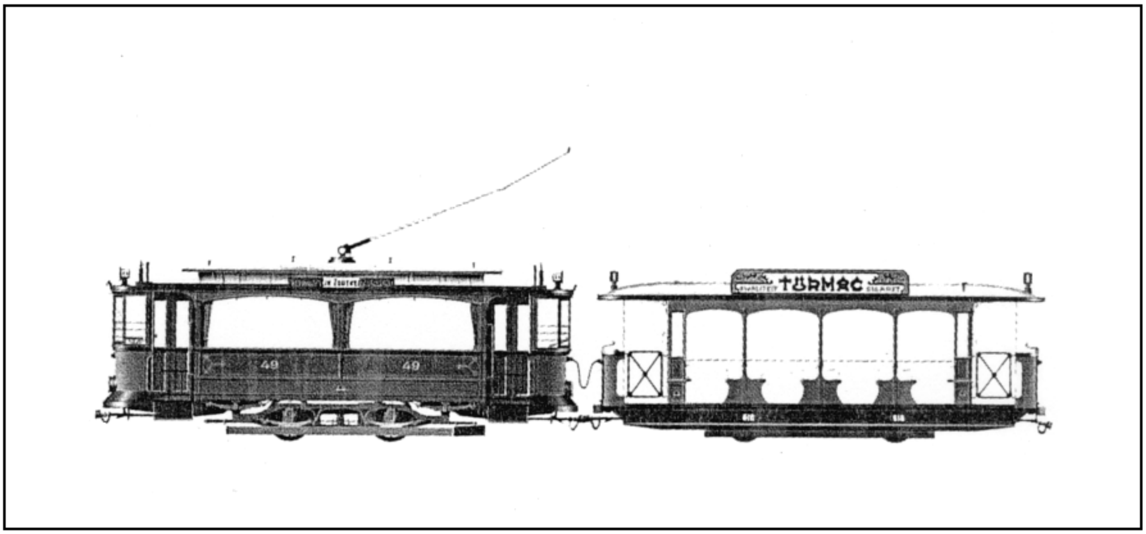

Photo 1.6 *Amsterdam's two-axle tramway with an open trailer in 1900* (*Courtesy of Gemeentevervoerbedrijf, Amsterdam*)

axle, wooden-body vehicle operated by a driver and conductor. In many respects it resembled its immediate predecessors, the horse tram and cable car. Somewhat enlarged (up to about 10 m in length) and often towing one or two trailers (Photo 1.7), this type of vehicle was still widely used in many European cities as late as the 1960s.

Four-axle vehicles, 12 to 16 m long, made their first appearance during the 1890s, mainly on American interurban lines; however, their introduction into urban transit systems was slower. Most U.S. cities operated two-axle cars around 1900; only during the following three decades were most of them replaced by four-axle ones. The change was gradual; still, in 1916, a new two-axle lightweight car designed for one-person operation, the Birney ‘‘Safety Car,’’ was introduced and extensively used on lightly traveled routes. By the 1920s, four-axle cars already dominated most transit systems in large cities. Some transit systems used motor cars with trailers on heavily traveled routes, but this practice was far less common in American than in European cities.

Early streetcar fleets in many cities included special summer cars with open sides and peripheral footboards instead of central aisles. Designed for pleasure, these cars were very popular and in some cities were retained through World War II (Photo 1.8). A few cities also had convertible cars. Both types were, however, gradually replaced by enclosed cars (Photos 1.9 and 1.10 show some typical models). Most of the cars up to about 1930s were still operated with two-person crews but had fare payments at entry or exit, providing directional passenger flow inside the vehicles.

In spite of their vital role in cities and increasing ridership, transit companies in U.S. cities were far from continuous financial success or even operation with reasonable fiscal stability. Competition among different streetcar companies on parallel lines prevented the achievement of economies of scale in operations. In some cities, jitneys and later buses ‘‘skimmed the profitable cream’’ of transit ridership. Moreover, the costs of labor and other operating costs were rising, but regulatory bodies did not allow corresponding increases of fares. For example, the traditional 5-cent fare was retained in some cities even through World War II, although long before that time such a fare could not cover operating and maintenance costs. Since transit companies had no other financial assistance, these conditions resulted in many bankruptcies.

An early widespread financial crisis in the transit industry occurred at the time of World War I. In 1919, President Woodrow Wilson appointed the Federal Electric Railway Commission to study the problem. The Commission’s report, submitted in 1920, con-

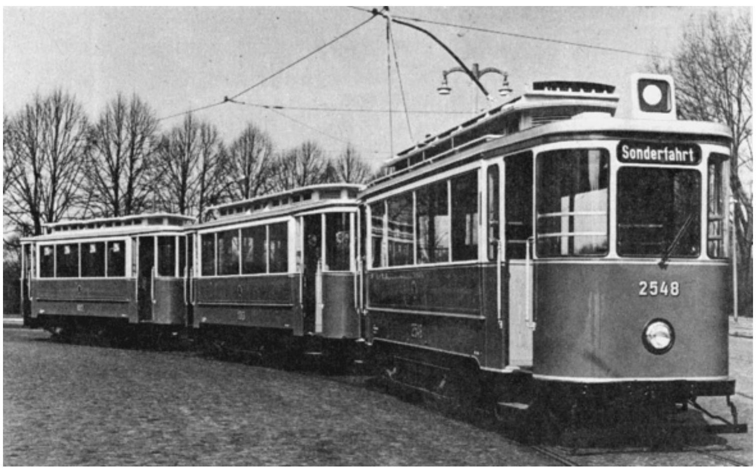

Photo 1.7 *A typical European two-axle car with two trailers in Hamburg, operating between the 1920s and 1960s*

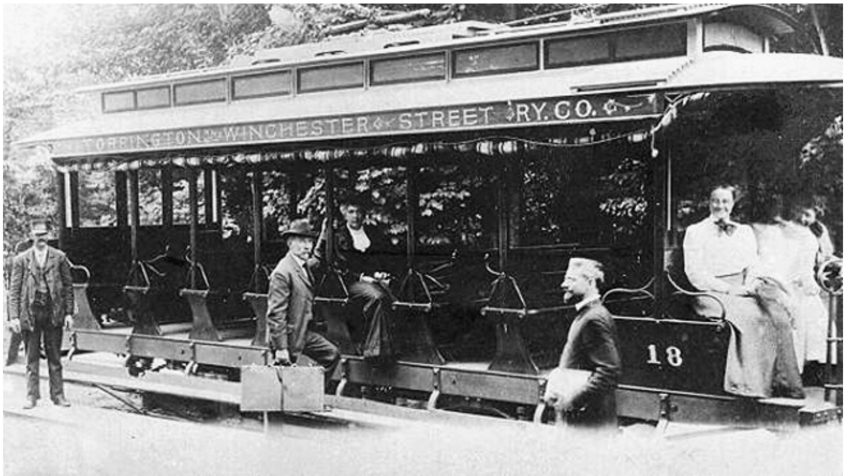

Photo 1.8 *Open four-axle streetcar in New Haven, operated until the late 1940s* (*Courtesy of William D. Volkmer collection*)

Photo 1.9 *Large four-axle motorcar in Newark, New Jersey in 1935* (*From the collection of Jeffrey Marinoff*)

Photo 1.10 *Articulated streetcar (over 30 m in length) in the Public Square, the main transit junction in Cleveland, ca. 1946 (From the collection of J. W. Vigrass)*

tained some extremely progressive statements about the role and nature of public transportation (see Section 1.6) and a set of recommendations for improvements of its condition. Only a few of these recommendations, however, were implemented. Fare increases allowed financial recovery of some transit companies, but the continuing precarious financial condition of others was reflected in inadequate maintenance of tracks and other infrastructure and in the operation of obsolete rolling stock. This condition was a major obstacle to the provision of efficient transit services and later contributed to conversion from streetcars to buses.

During the 1920s and early 1930s, competition from the private automobile began to have a significant impact on streetcar ridership in the United States. In addition to diverting passengers, the automobiles created congestion, which impeded streetcar operations. The old cars, which had low acceleration, were poorly suited to running in mixed traffic. To improve operation in congested streets and avoid the investment required for track maintenance, transit operators began to convert streetcar lines to bus operation.

The problems of streetcar decline in the U.S. cities in the late 1920s were seriously discussed by the transit industry. The American Electric Railway Association (AERA) at its 1929 conference concluded that if the streetcar was to retain its important role, it would have to match the performance, comfort and modern image of its competitors: the bus, trolleybus, and private automobile. The conference gave Thomas Conway of the University of Pennsylvania the task to organize a project that would develop an entirely new streetcar design that would use state-of-the-art technology to achieve these goals.

At its 1930 conference, AERA followed Conway's recommendation that a special committee be founded to perform this research and development task as a joint venture of transit companies and vehicle manufacturers, designated the Presidents' Conference Committee (PCC). This project, led by Clarence F. Hirschfield of the Detroit Edison Company, was one of the most thorough and efficiently organized development ventures in the history of transit technology. Its product, the PCC car (Photo 1.11) was in many respects far more advanced than any of its predecessors. An extremely quiet vehicle with soft suspension, it was able to accelerate and brake rapidly thanks to sophisticated indirect motor control (Cudahy 2003).

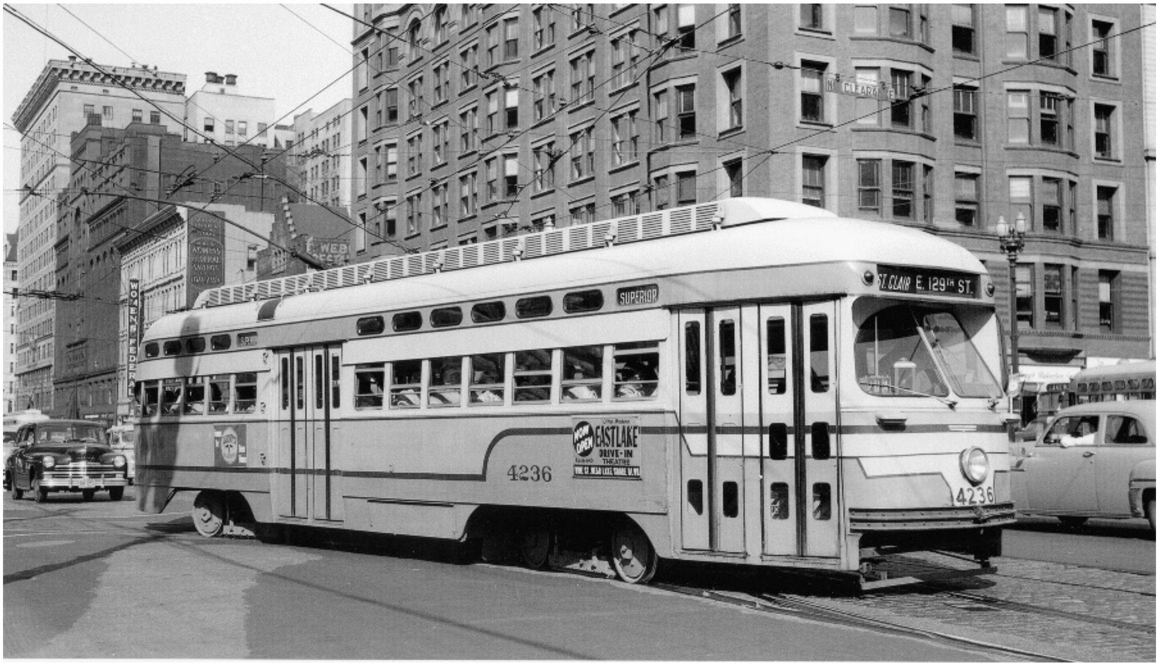

Photo 1.11 *PCC car, circa 1950* (*From the collection of J. W. Vigrass*)

The first commercial application of the PCC car was in Brooklyn in 1936. Acceptance of this model was slow at first: by 1940 only about 1100 vehicles had been purchased. Later the orders accelerated, so that by 1952 about 6000 PCC cars had been produced in the United States by St. Louis Car Company, and Pullman-Standard Car Manufacturing Company and in Canada by Canadian Car and Foundry. At that time production of surface rail transit vehicles in the United States ceased, and it was resumed only about 20 years later. Modified versions of PCC cars continued to be produced in Europe (Belgium and Czechoslovakia), however.

The PCC car did help to improve the competitive position of transit systems vis-à-vis the private automobile and to slow down the conversion of streetcars to buses; but in the absence of other improvements—particularly provision of separate rights-of-way for which support from city authorities was not available—the PCC car was not able to secure long-term stability for the streetcar mode or for transit's role in cities in general. About 1950, many U.S. cities still had extensive streetcar networks, but they would not last long.

In many cities it was considered desirable to "mix" transit with auto traffic rather than provide it with priority treatment and maximum possible separation. The conversion of streetcars to bus and trolleybus operations, which began on a large scale during the 1930s, was discontinued by the increased demand for transit services during World War II; it resumed in the late 1940s. By 1960, streetcar systems remained in only about a dozen U.S. cities.

The change from rail to road transit modes in small cities and on lightly traveled lines in large cities was a logical consequence of the improved technology and economics of buses and trolleybuses. But for numerous major transit systems with heavy passenger volumes, many of which even had fast lines on separate rights-of-way, the change from rail to road modes represented a degradation of service and contributed greatly to a further decrease of transit ridership. The change was a result of the absence of any significant public assistance to transit, either financial or in securing reliable transit operations on city streets. Transit operators were thus forced to adopt the lowest-cost mode in the short run, regardless of long-term costs and impacts on ridership.

Another major force in this elimination of streetcars even where they offered superior services on exclusive rights-of-way (Los Angeles, Detroit, Cleveland, and many other cities) was the National City Lines consortium. As researched and reported in a congressional testimony by Snell (1974), The National City Lines was organized by General Motors Corporation (GMC), Firestone, and Esso Oil Company, which had the common goal of replacing electrified rail systems by the highway vehicles (buses and automobiles) that purchased their products—buses, cars, rubber tires, and oil. National City Lines purchased transit companies in many cities. To eliminate the often very popular streetcars, their maintenance and modernization were decreased, and then it was proclaimed that "streetcars are an obsolete transit mode." Buses were presented as "modern" and "flexible" vehicles with many advantages. Their disadvantages—such as the facts that they were smaller, less comfortable vehicles with inferior dynamic and environmental characteristics—were ignored. The virtual elimination of streetcars resulted in a massive loss of ridership and weakening of the image and role of transit in U.S. cities. Black (2006) gives extensive documentation of this destructive development.

In Great Britain and France, transit operators faced many of the problems that appeared in U.S. cities: labor and equipment costs were rising, transit companies were required to perform construction and maintenance of tracks, while bus operators usually had no responsibility for maintaining roads and streets. Cities often took over track rights-of-way for roadway widening. While many French cities had never acquired modern rail vehicles, a number of British operators attempted to modernize their systems and increase labor productivity through the introduction of high-capacity double-decker cars. As late as after World War II, there were several serious attempts to modernize tramway systems. For example, Fitzpayne proposed in 1948 an innovative plan for an upgraded "light railways" system for Glasgow (Skelsey 1976), which contained many ideas used in developing light rail transit systems initiated in the 1960s and 1970s. But public policies and governmental attitudes toward transportation in these countries did not provide adequate support for tramway modernization or for public transportation improvements in general. Similar to the events in the U.S., conversion of tramway rights-of-way into street lanes downgraded transit to operation in mixed traffic. Thus, tramways gradually disappeared from most British and French cities.

In several other European countries, on the other hand, attitudes toward tramways were much more positive. The organizational and financial situation of transit agencies were more stable, since transit systems were usually consolidated into single, municipally owned agencies. Separate tramway rights-of-way in many German, Dutch, Swiss, Austrian, and other central European cities were preserved, upgraded, and in many cases extended.

European tramway technology was initially less developed than that in the United States. Although four-axle cars were produced between the two world wars in Germany, Italy, Czechoslovakia, Great Britain, and elsewhere, most fleets were largely composed of simpler and slower two-axle cars. Some Italian (Breda) cars of the late 1930s, however, were quite advanced, matching or exceeding PCC cars in their body design and riding comfort. The decisive progress of tramway/streetcar technology and applications came during the 1950s when German manufacturer DÜWAG produced a new model of articulated cars (Photo 1.12) far superior to all earlier articulated cars, including European and U.S. models. The wide application of these cars and subsequent upgrading of tramway networks—through the provision of separate rights-of-way, priority treatments, and other technological and organizational advances—resulted in the creation during the period of the 1960s and '70s of light rail transit (LRT), a rail system that is, by its performance, more similar to rapid transit than to streetcars operating in mixed street traffic.

Following the lead by most German cities, the development of LRT since the 1970s resulted in contin-

Photo 1.12 *The first model of DÜWAG's articulated cars, produced for many cities between 1956 and 1970, shown in Jan Wellem Platz, Düsseldorf, in 1972*

uous innovations: the introduction of two- to four-car trains on lines that use separate rights-of-way in streets, tunnels, and aerial structures; construction of low-floor vehicles to better serve pedestrian zones and enhance their livability; operation on intercity railway lines, etc. With this diversity, LRT has acquired the central role of a high-quality, attractive transit mode in cities of different sizes in many countries world over.

In retrospect, the twentieth century saw the development of streetcars from small, noisy, low-speed vehicles in 1900 to the spacious, high-speed, quiet, comfortable units of today. The mode lost its dominant position to other technologies (mostly buses) in many cities, but it then evolved into the LRT that has become the dominant medium-capacity high-quality transit mode in many of the cities that had abandoned streetcars as well as in many new, growing cities in industrialized as well as developing countries.

1.4.2 Motorbuses[10]

In the course of the nineteenth century, numerous attempts were made to equip omnibuses with mechanical propulsion; but for technical and economic reasons or because of legal restrictions, these ventures were un-

[10]The primary sources for this section are Klapper (1961), Miller (1941), and Singer (1960).

successful. At about the turn of the century, the first successful applications of the internal combustion engine (ICE) to highway vehicles were achieved, providing the technological basis for a new vehicle, the motorbus, which would soon replace the horse omnibus.

An ICE developed by Etienne Lenoir in 1859 was modeled upon stationary steam engines of the time: it was a double-acting two-stroke engine running on a gas-air mixture. Far more important, however, was the invention of the German engineer Nicholaus Otto in 1876. He built the first operational four-stroke ICE running on gas-air or oil-air mixtures. The new "Otto cycle" engines were soon finding extensive industrial uses. Realizing that many applications, particularly for vehicle propulsion, require a rather light power unit, Gottlieb Daimler (1834–1900) designed a lightweight high-speed motor in 1883. Three years later came the most important event in the development of modern highway transportation: Carl Benz (1844–1929), of Mannheim in Germany, constructed the first automobile. By the late 1890s, gasoline-powered vehicles were being manufactured in substantial numbers in Germany, France, and Great Britain; but the first ICE-powered transit vehicles, buses, were developed only about 1900; the first operation in Great Britain was in 1899, and in Germany in 1903.

Another invention that later had a great significance for buses took place during the 1890s: Rudolf Diesel (1858–1913), also a German engineer, developed a high-speed compression-ignition engine. This engine, named after its inventor, was initially very heavy and had no immediate influence on motorbus development. But after numerous design changes over some four decades, its efficiency was greatly improved, and the diesel motor gradually became nearly the exclusive propulsion unit for buses.

The introduction of motorbuses in Great Britain was facilitated by the Locomotives on Highways Act of 1896, which relaxed repressive provisions against motor vehicles. After 1899, the first gasoline-powered buses were introduced in England, and by 1911, all of the London's omnibus proprietors had replaced their horse buses with motorbuses.

In 1910, under pressure of police regulations issued in the previous year, several British manufacturers commenced production of new-model buses whose light weight, reliability, and low cost represented a significant improvement upon their predecessors. Reliability was further improved later by the introduction of preventive maintenance procedures evolved during World War I. Vehicle safety was increased by the adoption of four-wheel braking systems. A bus from that period is shown in Photo 1.13. Pneumatic tires, first used for bicycles in 1888 and for automobiles in 1900, were first used for heavy vehicles, including buses, around 1920. Soon afterward, British engineers consolidated these improvements by giving their attention to the overall design of the bus chassis, which at that time still retained many features of the freight truck chassis. The new type of bus chassis had a low center of gravity and suspension designed for improved passenger comfort.

In the United States, the first city to begin conversion from horse bus to motorbus operation was New York. Between 1905 and 1908, the Fifth Avenue Coach Company (by then the only remaining omnibus proprietor in the city) replaced its entire fleet of horse-drawn vehicles with 35 double-decker motorbuses. These vehicles, like most of the early buses, were hybrids: each had a chassis built by the French DeDion-Bouton company and a body built by Brill of Philadelphia, the famous streetcar building firm.

The appearance of jitneys in many cities around 1914 gave a further impetus to motorbus development in the United States. The jitneys were private automobiles plying the main traffic routes for hire; at first they were not subject to any official regulation, and they represented a serious threat to the profitability of established streetcar systems. The first jitney bus—a makeshift, box-like body mounted on a light truck chassis—appeared in Los Angeles in 1914, and for 5 years jitneys and jitney buses flourished in many American cities, competing chaotically not only with streetcars but also among themselves. As some of the jitney operators realized that the use of buses instead of small vehicles offered economic and operational advantages for their major lines of service, they converted jitney operations to regular bus lines.

Regulation of jitney and bus transportation was gradually introduced during the 1910s and 1920s, reducing or eliminating their uncontrolled operations on

Photo 1.13 *Double-decker bus in Paris, ca. 1920* (*Courtesy of RATP, Paris*)

major routes already served by streetcars. In the meantime, the streetcar companies began to perceive the potential of motorbuses for some services, particularly on lightly traveled routes. Thus buses were introduced for services coordinated with streetcar lines rather than competing with them. In 1920, only 10 streetcar companies in the United States were operating buses, but soon afterward their number began to increase quickly.

Many of the improvements in bus design introduced by European engineers were paralleled by the Fageol brothers, Frank and William, who produced their first gasoline bus in 1920 at Oakland, California. The advantages of the Fageol Safety Coach (Photo 1.14) over previous bus types—with respect to acceleration and braking, suspension, larger body, and others—were soon recognized, and its principal features became almost standard in buses produced in the United States.

Further mechanical innovations in bus design appeared during the 1920s. Gas-electric propulsion, introduced in 1924 in Philadelphia and Buffalo, consisted of a drive system comprising a gasoline motor/electric generator/electric motor. Elimination of the gearbox from the drive train made possible a significant reduction in wear and tear and an increase in riding comfort. After a study showed that the useful life of buses was on average no more than 5 years (compared with 20 to 30 years for rail vehicles), many other U.S. cities introduced this propulsion system. Photo 1.15 depicts a typical bus from the 1920s.

Another innovation, of more permanent value, was the introduction of the diesel motor for bus propulsion. Use of lower-cost fuel and high operating efficiency were the chief attractions of the diesel motor. Its initial commercial development was in Germany and other European countries where fuel prices were especially high. The first British use of diesel buses was in Nottinghamshire in the late 1920s. In 1929, a New Jersey transit company began to import Mercedes-Benz diesel buses, providing them with electric transmissions. The use of diesel propulsion for buses spread rapidly during

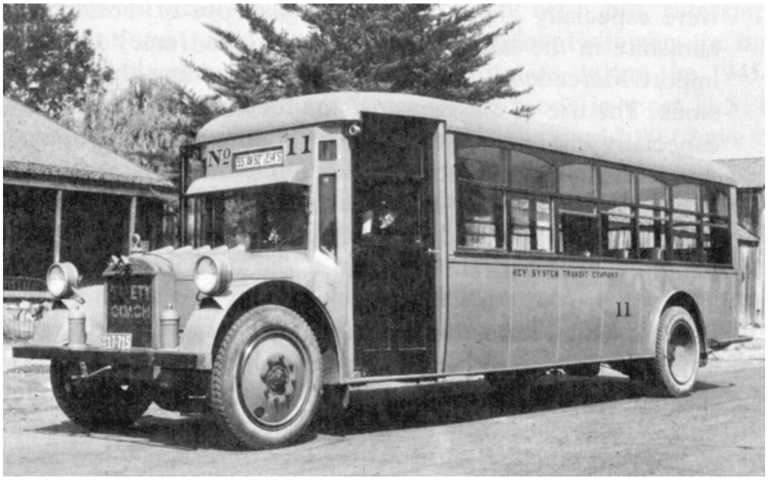

Photo 1.14 *Fageol's "Safety Coach" in Oakland, mid-1920s (Courtesy of APTA, Washington)*

the 1930s, especially in Great Britain, where attention was focused on hydraulic transmission rather than electric drive; but it was in America, at the Yellow Coach Factory, that the last major technical problem with this system, achieving interlock at high speed, was effectively overcome. The first American buses equipped with hydraulic transmission were introduced in New York City in 1939.

Meanwhile, buses had become much larger. Seating capacities common in 1912 had been 16 for single-deckers and 34 for double-deckers; by 1939, capacities had approximately doubled. In 1938, the Fageols introduced an articulated single-decker bus with a seating capacity of 58 passengers, but this model did not find wide use.

Following the stagnation of developments due to World War II (see Photo 1.16), the European bus manufacturers took a definite lead in vehicle design innovations, and they have retained the lead ever since. The articulated buses developed in Europe since the 1950s have found extensive use in many countries around the world. The European manufacturers have also made substantial improvements in vehicle suspension, body design (large windows, wide doors, etc.), and low-noise motors. In the United States, on the other hand, bus production was for many years dominated by a single manufacturer (GMC), and efforts to utilize or catch up with the European innovations came only under the stimulus of federal research and development programs during the 1970s.

With the conversions from streetcars to buses and trolleybuses described in the preceding section, the role of buses grew rapidly. In the United States, the number of buses in transit service in 1940 was about 35,000, slightly less than the number of streetcars and rapid transit cars; bus ridership was approximately half the ridership of the two rail modes. Following the massive conversions from streetcars and trolleybuses to buses during the 1945–1965 period, buses became the dominant street transit mode in most U.S. cities.

Buses are presently used in nearly all cities in the world that have transit services, alone or in combination with rail modes and paratransit services. The increasing need for higher-quality transit services since 1960 has led to improvements in bus operations through various priority treatments and to their substitution by modern rail transit modes (rapid transit and light rail); in the latter cases, buses continue to play a significant role as suburban feeders.

Many bus improvements have been successful. The variety of vehicle designs has increased by the introduction of double-articulated and low-floor buses. Bus lanes and busways have been successful in some cases, while others have failed when they were converted into

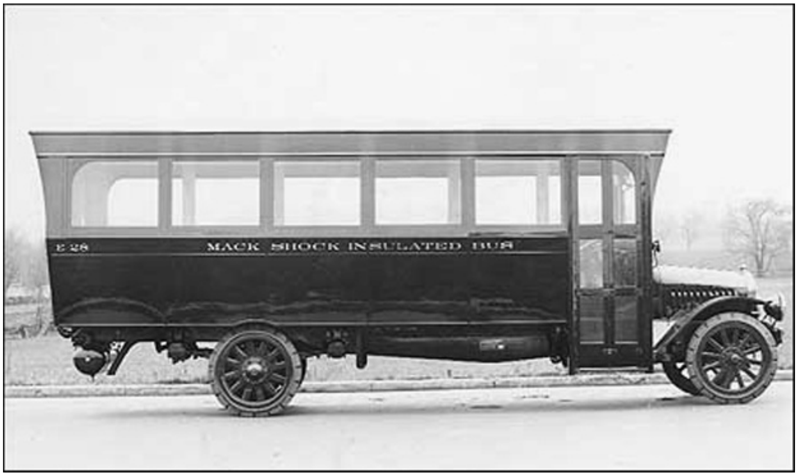

Photo 1.15 *Mack senior tour bus, ca. 1910* (*Courtesy of Mack Trucks, Inc.*)

Photo 1.16 *Transit bus of the Pacific Electric in Los Angeles, produced by Yellow Coach, ca. 1947* (*From the collection of Jim Stubchaer*)

high-occupancy vehicle (HOV) facilities. Guided buses have also had only limited application. However, the most significant change was the organized effort in many cities to coordinate many improvements so as to achieve a high-quality bus transit, named bus rapid transit (BRT). With separate busways, fixed lines with frequent service, and clear information, copying the features of the LRT mode, BRT systems have become a higher-quality mode than regular buses. As a medium-capacity system, BRT generally requires a lower investment, but it also offers lower quality of service, capacity, and positive impacts than the LRT mode.

1.4.3 Trolleybuses[11]

In 1882, Siemens & Halske made experiments at Hallensee, near Berlin, with a small electrically powered road vehicle, the *Elektromote.* Current was collected by means of an eight-wheel troller, which ran on a pair of overhead wires and was towed behind the vehicle by cable. The results were unsatisfactory, however, and the lack of an adequate solution to the problem of power pickup held back trolleybus development for many years. Except for a few isolated experiments, no further progress was made until the beginning of the twentieth century.

Lombard-Gerin built what was probably the world's first working trolleybus line for the Paris Exhibition of 1900. In 1901, he opened a trolleybus line between Fontainebleau and Samois (a distance of 8 km), but this was abandoned soon afterward owing to frequent

[11] The principal sources for this section are Klapper (1961) and Miller (1941).

Photo 1.17 *An early trolleybus: Toronto, 1920s (From the collection of Jeffrey Marinoff)*

derailments of the overrunning troller. German engineer Max Schiemann was responsible for the first really successful trolleybus installation, at Bielatal, in 1902. Here Schiemann used a spring-loaded pole with a forked connection to trolleys underrunning a pair of wires, which were mounted one above the other. Over the next few years trolleybus lines were opened in various parts of Europe: in Denmark, Switzerland, and especially Germany and Italy. By this time electric tramway technology was well developed and tramways were being operated or under construction in most European cities.

In the United States, only limited interest was shown in trolleybuses before the 1920s. In 1903, A. B. Uphan, president of the American Trackless Trolley Company, demonstrated a trolleybus on short lines in New Haven, Connecticut, and Scranton, Pennsylvania; power pickup was by means of pairs of trolley wheels sprung against the overhead wires. In 1910, a converted motorbus provided regular service for a few months in Laurel Canyon, California, and a specially built trolleybus seating 18 passengers operated in Merrill, Wisconsin, in 1913 and 1914. In the early 1920s, several American streetcar and motor-truck manufacturers developed trolleybus designs, and by 1925, trolleybus services were established in Baltimore, Minneapolis, Philadelphia, Rochester, and Staten Island as well as in Toronto (Photo 1.17) and Windsor in Canada.

Trolleybuses were not used for large transit networks anywhere until after 1926. In that year, the first of a series of new models came into service. Guy Motors developed for Wolverhampton (England) new model demonstrating that the trolleybus possessed characteristics which, taken together, would give it a distinct advantage over other modes in many circumstances: fast, quiet, and comfortable running; smooth accelerating and braking; and low operating costs. Consequently, trolleybuses were introduced in many British towns (often as replacements for trams) during the period between 1926 and 1940. In 1931, trolleybuses were introduced in London; by the outbreak of

World War II, London's stock of trams had been reduced from 2600 to 900, while the trolleybus fleet—1764 vehicles—was the largest in the world. Innovations introduced in London during the 1930s included chassisless monocoque construction (body structure supports itself rather than lying on a chassis) and skids lined with carbon inserts in place of trolley wheels. Clearly, Britain, London in particular, was at the forefront of trolleybus development during the 1930s. At the end of the decade, the number of trolleybuses operating in Britain was approximately 2600.

During the 1930s, many American transit proprietors came to see the trolleybus as a viable ''modern'' alternative to the aging streetcar: by 1940, about 2800 trolleybuses were operating in some 60 cities and large towns in the United States. At the time of their greatest use, in 1950, more than 6500 trolleybuses with numerous advanced technological features were operated in U.S. cities (APTA 2004). For example, a trolleybus from that period shown in Photo 1.18 had a dual propulsion: electric and a propane gas ICE, which would propel a generator to provide electric power for the

Photo 1.18 *Dual-mode electric-ICE bus with automated trolley pole raising, Public Service in New Jersey in 1935* (*From the collection of Jeffrey Marinoff*)

motor on nonelectrified sections of lines. Trolley pole control was automated. A few cities also operated articulated trolleybuses (Photo 1.19).

The use of trolleybuses was also increasing in many other countries from the 1930s until the mid-1950s. Extensive trolleybus systems existed in Brazil, Mexico, Spain, France, Italy (55 cities), Yugoslavia, Greece, several countries in eastern Europe, the USSR, and Switzerland. During the 1950s, however, expansion of trolleybus networks ceased and many cities began to replace them with buses. This conversion later accelerated, so that by 1970 in many countries only fractions of former trolleybus networks remained. In Great Britain, one of the greatest users of trolleybuses, this mode actually became extinct. In the United States, only five cities retained it.

Several factors caused the decline of trolleybuses. During the period of maximum efforts to accommodate the automobile, the trolleybus was considered insufficiently ‘‘flexible’’ to operate in mixed traffic. Costs of trolleybuses increased faster than those of buses, and funds for the maintenance of overhead wires were often unavailable, while the advantages of trolleybuses over buses—in passenger comfort and environmental characteristics—did not bring any direct revenue to transit operators.

The changes in attitudes toward urban transportation that occurred in the late 1960s and early 1970s had a direct and positive influence on the position of trolleybuses. Increased attention given to the environmental aspects of transportation systems, greater emphasis on the attraction of passengers to transit, and the increased availability of public funds, particularly for capital improvements, generated a revival of positive attitudes toward trolleybuses. This change resulted in the retention of the remaining lines and even their extension in some cases.

Photo 1.19 *Articulated trolleybus built by Twin Coach in 1940, in Cleveland, ca. 1949* (*From the collection of J. W. Vigrass*)

The position of trolleybuses has always remained strong in several countries, however. Their networks have been retained and modernized in Swiss and many cities in eastern Europe, while the USSR became by far the largest user of this mode: in 1960, a total of 58 Soviet cities utilized trolleybuses; by 1975, the number of such cities grew to 142 (U.S. DOT 1978). The beginning of the twenty-first century finds cities in many countries utilizing and modernizing trolleybus systems. Leading examples in this development are numerous Russian and other former Soviet cities (particularly Moscow and St. Petersburg), Swiss and Chinese cities, Athens, Belgrade, Vancouver, Seattle, San Francisco, and others.

1.5 DEVELOPMENT OF HIGH-SPEED RAIL TRANSIT MODES

Parallel with the beginnings of local transit services, large cities began to utilize rail technology for higher-speed services on lines with partially or fully separated rights-of-way. Three different modes providing such services emerged.

Suburban railways originated as local services on the main intercity railroad lines. *lnterurbans,* large streetcar-type vehicles operating mostly on private rights-of-way between adjacent cities and towns, were developed after the invention of electric traction. *Rapid transit,* intraurban transit on fully separated rights-of-way, eventually became the most important high-speed urban transit mode. Although its first line (1863) was built for steam traction, rapid transit began to be widely utilized only when the invention of electric traction made underground operation efficient and attractive.

Major events in the developments of these three modes are briefly reviewed here.

1.5.1 Suburban Railways/Regional Rail[12]

Although they were initially designed and built for long-distance transportation, the intercity steam railway lines also provided fast and reliable transportation between center-city stations and adjacent suburbs and towns. With growing populations and expansion of cities, passenger volumes on these intraregional sections of railway lines increased, which led to the introduction of special, more frequent local services representing the beginnings of suburban railways.

Because of their similarity with regular railway services, it is difficult to state precisely when suburban railway services commenced. It is known, however, that the first large-scale development of this mode occurred in London. Its first suburban railway line opened in 1838, and most of London's present extensive suburban railway network, covering a circular area with a radius of some 15 km, was built between 1840 and 1875. In addition to serving the middle-class suburbs that were being developed around existing villages and towns in the region, London's railways also gave working people living in the inner parts of the city access to the countryside, to pleasure gardens and racetracks, so that special excursion fares were introduced on suburban lines as early as the 1840s.

As Lehner (1961) points out, the lack of mechanized modes for local travel within cities forced the population to live in the immediate vicinity of factories, commercial centers, and railway stations. Thus the period between the introduction of railways and the invention of the first mechanized transit (electric streetcars) saw the development of very high residential densities and often very poor living conditions in inner-city areas.

London, with its large population and early development of industries, attempted to cope with these problems through the described utilization of railways for intraregional travel and the construction of steam-powered subway lines. The national government also wanted to encourage the relocation of middle- and lower-income people into less crowded suburban areas. Thus, in 1883, the British Parliament passed the "Cheap Trains Act" (Weber 1899), which provided financial aid of $2 million per year to allow suburban railroads to maintain low fares, so that middle- and low-income families could afford commuting expenses. Governments of several other countries also began to provide financial support for suburban rail-

[12] Most of the historical data for this section are taken from Barker (1963), Kellett (1969), Taylor (1951), and Yeates (1976).

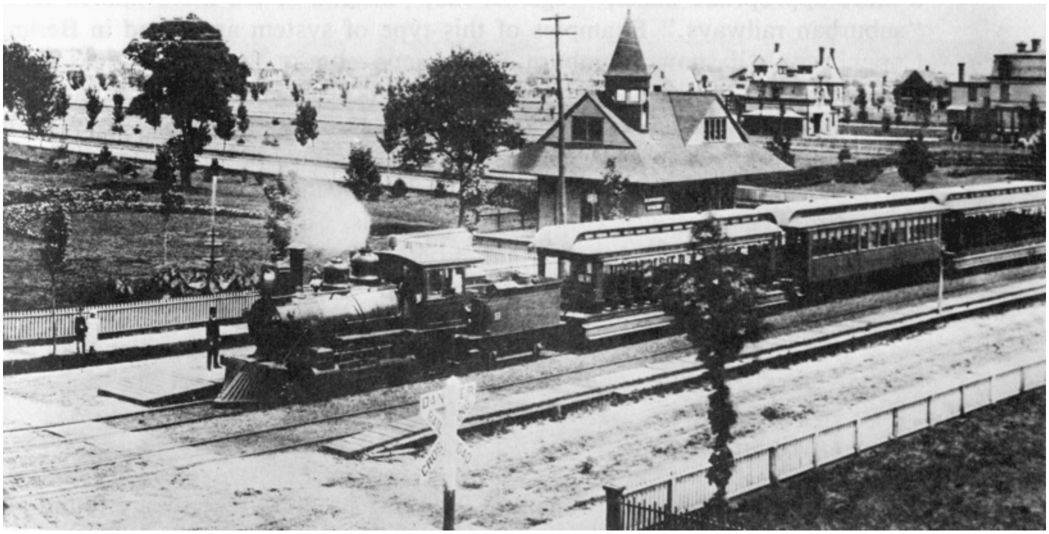

Photo 1.20 *A Brooklyn Bath and West End RR at Bensonhurst Station on Long Island, 1880s* (*Courtesy of APTA, Washington*)

ways during the same period. Other European cities started operating suburban railways somewhat later: Hamburg in 1866, Berlin in 1882, Liverpool in 1886, and Glasgow in 1887.

In the United States, suburban services on the main intercity railroad lines began with the practice of providing special ''commuted'' fares for morning and afternoon travel between city terminals and outlying residential areas. Probably the first American ''commuter railroad'' was the Boston and West Worcester Railroad, which introduced annual commuter tickets in 1838 and in 1843 instituted regular commuter trains on its line between Boston and West Worcester. By the mid-1850s, this railroad reported carrying nearly half a million passengers annually between Boston and stations no farther than Auburndale (16 km). The first commuter service in Chicago started in 1856.

The early patrons of commuter railroads were relatively wealthy people who could afford the luxury of suburban living. The ''exurban'' communities they inhabited were clustered fairly closely around commuter railroad stations. As a consequence, many commuter rail lines in Chicago, New York, Philadelphia, and other cities today connect a ''string'' of towns around their stations. As the older ''exurbs'' became swamped by ''streetcar suburbs,'' there was a continuing demand for housing beyond the edges of existing built-up areas. For this reason, commuter lines—offering service with high speed, comfort, and reliability—continued to extend well beyond the expanding streetcar suburbs, serving satellite communities increasingly distant from city centers. An early suburban train is pictured in Photo 1.20.

Electrification of suburban railways began about 1900; during the subsequent three decades, many cities opened their first suburban rail lines designed specifically for electric traction. Electrification intensified after World War II particularly in Europe and Japan, so that most suburban and regional rail systems are now electrically powered. There are, however, some important exceptions, mostly in the countries that have little or no electrification on their railroad systems. For example, only a small part of Chicago's extensive suburban rail system is electrified, and entire systems in Boston, Toronto, San Francisco, Los Angeles, and several Latin American cities are still diesel-powered.

The period from 1930 to 1960 was one of stagnation for many suburban railways, and a number of lines, particularly in U.S. cities, were forced to close down. The main problems operating agencies faced were obsolete labor and operating practices, increasing wages, and lack of governmental support in terms of policies and financial assistance. Since 1960, however, suburban growth and highway congestion have resulted in a revival of interest in this mode. Lines and rolling stock have been modernized, services improved, and networks expanded. These developments began in Europe (e.g., Paris, Munich, Hamburg, Copenhagen); more recently, U.S. cities have begun to follow the same trend. Los Angeles, Miami, San Diego, Seattle, Dallas, Albuquerque, and several other cities have reintroduced passenger services on lines on which, for many years, only freight trains had operated; Boston, Chicago, New York, and Philadelphia have modernized their extensive networks of lines.

The initial layouts of railroad networks have influenced the character and role of suburban and regional railways in different cities. Two main types of networks can be defined, each with a characteristic set of functions.

The first type is the radial network, consisting of lines running from stub-end-type city terminals outward into the suburbs. Its main customers are usually commuters traveling into and out of city center. Rapid transit often provides the downtown connections between the suburban terminals and serves as the distributor for these lines. Examples of this type of system include London (where ten terminals at the periphery of the central city are connected by the Underground Circle Line, New York (Grand Central Terminal), and Boston.

The second type of urban railway service has been developed in cities that have lines passing through central areas, usually connecting suburbs on different sides of the center city. When this type of network has several stations in the central area, it offers a much more extensive area coverage than the radial network with its stub-end terminals. By its character and function, the latter type is rather similar to rapid transit: it serves many different types of trips throughout the region rather than mostly radial commuting trips. Its major distinctions from rapid transit are somewhat greater station spacings, higher speed, and operation by railroad instead of transit agency.

Based on their character and function, systems of this type have been given a more appropriate name, "regional rail," instead of the more limited term "suburban railways." Examples of regional rail system are found in Berlin, Hamburg, Vienna, Copenhagen, Osaka, and—by far the largest—in Tokyo.

A number of cities have made great efforts to change the suburban-type networks into regional rail. By connecting stub-end terminals, they have provided important coverage and created truly regional lines between different suburbs. Examples of this type of system modification—and, usually, concomitant upgrading of service—are found in Brussels, Munich (S-Bahn), Oslo, Paris (R.E.R.), and Philadelphia. Thus the trend is clearly away from the traditional commuter-oriented suburban railways and toward multifunctional regional rail systems, which are better suited to the present more decentralized, multifocal cities than are their nineteenth-century predecessors.

1.5.2 Electric Interurban Railways[13]

At the end of the nineteenth century, electric streetcar technology found an important new field of application in *electric interurban railways.* This mode consists of large, high-speed single cars or short trains operating on electrified lines, mostly on separate rights-of-way. A typical interurban network connects a group of cities and towns at distances of 15 to 80 km (10 to 50 mi). In some cases freight is carried on the same tracks, but passenger service generally has precedence.

A line fitting this definition was built in Northern Ireland in 1883. The commencement of large-scale development of this mode, known in the United States as "interurbans," was marked by two lines built in the United States in 1893: one in Oregon (Portland to Oregon City), and one in Ohio (the Sandusky Milan and Norwalk Electric Railway). Between that year and the outbreak of World War I, a considerable number of interurban lines were built in the Netherlands, Belgium, Germany, Italy, and Canada; but the most extensive development of this mode occurred in the United States, where line construction reached explosive pro-

[13] The principal sources for this section are Cudahy (1982), Hilton (1960), and Klapper (1961).

portions during the period from 1901 to 1908 (Photo 1.21).

Flexibility of line layout (from street running to fully separated rights-of-way) and frequent service made possible by the use of single or paired vehicles, which gave the interurbans a competitive advantage over steam railroads on route lengths up to about 80 km. Typically, interurbans were developed in a radial pattern of lines linking a major city with surrounding country towns. In New England, the radial interurban networks were, in fact, extensions of urban streetcar systems. They were so extensive that at one time it was possible to travel from New York to Boston by transferring among streetcars and interurbans and never paying more than 5 cents for a fare. Extensive, heavily used interurban systems existed in Los Angeles (Photo 1.22) and Chicago as well as in the states of Ohio, Indiana, and Michigan. The interurban networks in the last three states represented over one-third of the national network length, which, at its peak in 1913, reached nearly 26,000 km (16,100 mi). The interurban terminal in Indianapolis was comparable in size to railroad stations in cities of similar size.

Very soon after their rapid initial development, the American interurbans began to decline. The profitability of many lines was very low even at the height of investment in the industry. In many cities, the interurbans were prevented legally or physically from penetrating downtown areas or from making efficient connections with other transit services. Some streetcar systems, for example, were deliberately built with nonstandard-gauge tracks, to prevent joint interurban-streetcar operation. But by far the most important reason for the demise of interurbans was the automobile: the primary type of interurban service, 15 to 80 km, was also the most convenient one for auto travel. With increasing auto ownership and rapid construction of highways (which sometimes even took over the interurbans' separate rights-of-way), they lost ridership steadily. Reduced travel during the Great Depression speeded up closings. World War II caused a temporary return of riders, but by the mid-1950s this mode of transportation had practically disappeared in the United States. Only two lines have been retained permanently. One is the Norristown Line in Philadelphia, with fully separated rights-of-way, speed up to 110 km/h, and high-level platforms. The other is the South Shore Line in Chicago. Both have become electric regional transit lines in their respective metropolitan areas.

Photo 1.22 *A typical high-speed interurban car of the Pacific Electric in Los Angeles* (*Courtesy of William D. Volkmer collection*)

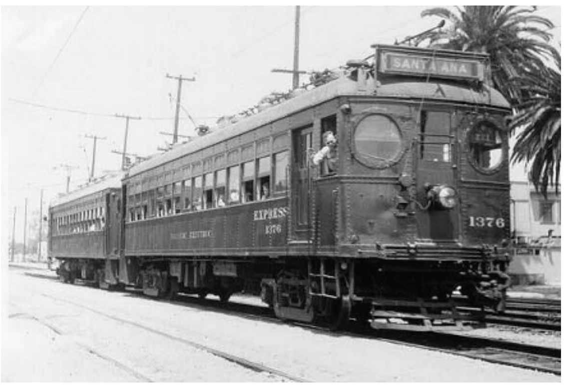

Photo 1.21 *An interurban train of the Pacific Electric at Fullerton, on the Santa Ana line, ca. 1920s*

Several other countries have retained interurban lines. The best-known ones are in the Rhein-Ruhr region in Germany. The existing interurban lines (Düsseldorf-Duisburg, Essen-Müllheim, and others) have been upgraded and supplemented by additional lines into a regional light rail rapid transit system that is planned to serve all major cities in this densely populated region. A rail line along the coast of Belgium is also an interurban, as are some lines in Switzerland, Italy, and France.

The private railways in Japan are by far the most extensive systems now providing interurban-type services. They have interurban functions, although they are closer to regional rail or even rapid transit in several respects. They have, for instance, rights-of-way with controlled crossings or full separation, stations with high-level platforms, and up to 10-car trains. These railways carry millions of passengers per day in the suburban areas of Tokyo, Osaka, Kobe, Kyoto, Nara, and other Japanese cities. Generally, they are closely integrated with other transit systems (some lines share tracks with rapid transit lines).

1.5.3 Rapid Transit/Metro[14]

Suffering from chronic street congestion, London was the first city in the world to build a fully separated, high-speed rail transit line. This was the Metropolitan Line, opened in 1863, which connected two railway terminals. Its 6-km (3.75-mi)-long tunnel was built by the cut-and-cover method, along existing street alignments wherever possible. The steam locomotives employed on the line incorporated special devices designed to minimize smoke emission, but these devices were never very effective and there were many complaints about the poor quality of the air in the carriages and in the stations. Nevertheless, the fast service provided on the line attracted large numbers of passengers.

The Metropolitan was the first in a long series of similar subway lines built in London over the ensuing 30 years, and it was in London that the next major innovations in subway technology were first introduced, on the City and South London Line, opened in 1890: this line ran in a 10-ft (3.05 m)-diameter steel-lined ‘‘deep tube’’ tunnel cut through the London clay and utilized electric traction (small electrically driven locomotives) with third-rail power pickup.

[14] Historical information about rapid transit was obtained from Barker (1963), Cudahy (1982), Howson (1964), Miller (1941), and Burr (1906).

The Liverpool to Birkenhead line, connecting railway terminals in the two cities via a tunnel under the River Mersey, commenced operation in 1886. In the same year a similar line opened in Glasgow. Local as well as through services were provided on these lines. The extension of London’s subway network was continuing, and in the 1890s subways designed for purely urban transit service were built in several other European cities. The first rapid transit (subway) line on the Continent was opened in Budapest in 1896, and the Glasgow District Subway, a tube-type 10.5-km (6.5-mi)-long circle line with 15 stations, was opened in 1897. The Glasgow line utilized cable traction until 1926, when it was electrified. The first line of the Paris Metro was opened in 1900; the Berlin U-Bahn followed in 1902, Hamburg’s Hochbahn in 1912, and the Buenos Aires Subte in 1914.

Berlin’s regional rail (S-Bahn) line, opened in 1882, had elevated sections on embankments and structures. So did Hamburg’s rapid transit Ring Line, opened 30 years later, and lines in several other European cities. Yet, elevated lines were used much more widely in the United States than in Europe.

The first elevated line in New York City was built along Greenwich Street in the late 1860s. The railway tracks were carried approximately 15 ft above the level of the roadway on a structure supported by wrought-iron columns placed along the edges of the sidewalks. Cable traction was employed on the first section of the line, opened in 1868, but serious operating difficulties were encountered. In 1871, the line was successfully converted to steam traction and later extended north along Ninth Avenue. Three additional elevated lines were built in New York during the 1870s and 1880s, but in each case the service was unreliable and noise from the steam trains was a serious nuisance. Also, because the supporting structures kept light from the sidewalks, owners of adjacent buildings often objected to the construction of these lines.

In 1891, a publicly constituted Rapid Transit Commission decided that additional rapid transit facilities were needed in New York and that they should be built underground. It was known that construction expenses would be considerably greater for subways than for elevated rail lines, and there was some concern that tunneling along city streets might seriously weaken the foundations of adjacent tall office and apartment buildings; but elevated lines were considered inadequate to deal with the great and rapidly growing volume of traffic in the city, and developments in electric traction in the preceding decade gave the commission a salubrious alternative to steam traction. In 1900, following a long period of negotiation and planning, construction was begun on a total of 29 km (18 mi) of line, most of it as a subway, and including 8 km of four-track subway (express and local). This first part of New York's vast subway network opened for service as a great civic event in 1904.

Rapid transit subway lines were built in several other American cities around the turn of the century. Actually, the first transit tunnel in the Western Hemisphere was opened in 1897 in Boston for operation of streetcars converging on the city center from many lines. The first rapid transit tunnel in that city was opened in 1908. Philadelphia's Market Street Line, opened one year earlier, comprised a central section of subway with elevated sections at each end. Part of the subway contained two streetcar tracks paralleling the rapid transit tracks.

The first elevated line in Chicago opened in 1892 with steam traction. In 1897, the line was converted to electrical operation, with a multiple-unit (MU) control system designed by Frank Sprague. Previous electrically operated rapid transit lines (such as the City and South London line and the Chicago line, opened in 1895) had employed electric locomotives and trailer cars; MU control provided greater flexibility and efficiency in the deployment of rapid transit vehicles.

Construction of rapid transit lines in several large cities on three continents during the 1890–1910 period shows that there was already a distinct need for a high-speed, high-capacity, reliable transit service. The high costs of construction, however, represented a major constraint on the development of this mode. The outbreak of World War I, which put a stop to most municipal building activities, found 11 cities around the world with rapid transit systems.

Difficult and unstable economic conditions between the two world wars in most countries limited further construction. Only six cities opened new systems between 1919 and 1935, when the Moscow Metropolitan opened as the last new prewar subway. There was, however, construction of additional lines in cities that had opened their first lines prior to World War I. For example, rapid transit networks in Hamburg, New York, Paris, and Philadelphia were expanded considerably during the period between the two world wars. Photos 1.23 and 1.24 show, respectively, a U.S. and a German rapid transit train from that period.

World War II caused a major interruption in rapid transit development: few cities had any construction between late 1930s and mid-1950s. Following the war, European and Japanese cities had little capital available, while U.S. cities concentrated on the construction

Photo 1.23 *New York City rapid transit train of the Brooklyn-Manhattan Transit Corporation, built ca. 1936 (Courtesy of William D. Volkmer collection)*

Photo 1.24 *Berlin rapid transit train*

of freeways and other facilities for private transportation. Eventually, however, public officials and civic leaders began to realize that the private automobile does not diminish but rather increases the need for rapid transit because the separate right-of-way is the major element making a transit system competitive with the automobile. This recognition of the importance of rapid transit and gradually increasing financial resources led to a continuous acceleration of rapid transit construction. The scale of this activity is evident from the fact that the number of cities in the world that have rapid transit quintupled (increased from 20 to over 100) during the period from 1955 to 2006 (see Section 6.7).

1.6 OVERVIEW AND CONCLUSIONS: TRANSIT DEVELOPMENT AND CITIES

The preceding review of the history of transit development and the chronology of major milestone events presented in Table 1.5 show the tremendous progress in urban transportation technology that has been achieved since the early 1800s but particularly during the last 125 years. The great impact that these developments have had on modern civilization is also evident: the intensive urbanization that has taken place in all countries would not have been possible without modern transportation systems.

At the beginning of this period of technological progress, the main problems in providing efficient urban transportation services were technological: motors for vehicles were impractical; vehicle, road, and track designs were rudimentary and offered limited speed, comfort, safety, and performance in general. The long series of inventions that subsequently took place created a number of different technological systems. As Chapter 2 will show, there exists today a ‘‘family of urban transportation modes’’ that offers a nearly continuous spectrum of modes and performance characteristics. These modes are capable of satisfying the needs of any urban area, from a small town to a large metropolis.

In light of this abundance of technologies, it appears paradoxical that today many cities suffer from serious transportation problems, albeit different ones from those faced a century ago. The problems often include chronic street/highway congestion, unsatisfactory quality of transit services, lack of adequate transportation for some population groups, financial problems, and—often the most serious one—negative impacts of transportation conditions on cities and their environments

A particularly complex problem facing cities has been how to allocate proper roles to different transportation modes. The basic policy decision with respect to transportation is what roles the two basic modes—private automobile and public transit—should play in the city; that decision depends on the city size, its character and topography, living standard and habits, etc. This decision is in many cases neither well understood nor given adequate attention. Regulation of automobile traffic is in many cities so inadequate that the great potential mobility of this mode is defeated by congestion, while pedestrians have little pleasure, or even safety, while walking in many urban areas. The balance between auto and transit modes is usually determined more by the degree of street congestion than by rational regulatory and economic measures.

Neglect of public transit is a major problem in many cities and countries despite many policy recommendations at the national level. For example, the Federal Electric Railway Commission appointed by President Wilson to resolve the serious crisis in the ‘‘electric railway’’ (transit) industry stated that ‘‘urban transit is an essential public utility and should have the sympathetic understanding and cooperation of the public if it is to continue to perform a useful public service’’ (FERC 1920). The report also stressed the need for integration of services into coordinated systems and for regulatory control by public bodies. It further stated that ‘‘The employees [in the transit industry] . . .should have a living wage and humane hours of labor and working conditions.’’ and ‘‘All labor disputes should be settled voluntarily or by arbitration. . .’’ because ‘‘It is intolerable that the transportation service of a city should be subject to occasional paralysis, whether by strikes or by lockouts.’’

Most of these statements apply to the requirements for transit services today as they did in 1920. Actually, a number of similar statements pointing out the im-

Table 1.5 Chronology of inventions in urban public transportation

Year	*Location*	*Event*
ca. 1600	London	"Hackney coaches"—taxicab services
1612	Paris	"*Fiacre*"—taxicab service
1662	Paris	First urban public coaches—common carriers, horse-drawn carriage
ca. 1765	England	Invention of steam engine (Watt)
1825	Stockton-Darlington, England	First railway opened (Stephenson)
1826	Nantes, France	First horse-drawn omnibuses
1832	New York	First horse-drawn streetcar line
1838	Boston	First commuter fares on a railway line
1838	London	First suburban railway service
1863	London	First underground rapid transit line
1868	New York	First elevated rapid transit
1873	San Francisco	Invention of cable car (Hallidie)
1876	Germany	Invention of internal combustion engine (Otto)
1879	Berlin	First application of electric motor for traction (Siemens)
1881	Berlin	First electric streetcar (Siemens)
1882	Hallensee, Germany	Demonstration of the first trolleybus (Siemens)
1883	Germany	First lightweight ICE (Daimler)
1886	Mannheim, Germany	First ICE-powered automobile built (Benz)
1886	Montgomery, Alabama	Invention of underrunning spring-loaded trolley pole for streetcars (Van Depoele)
1888	Richmond, Virginia	First successful major electric streetcar line (Sprague)
1890	London	First rapid transit with electric traction
1892	Germany	Invention of compression-ignition engine (Diesel)
1893	Ohio and Oregon	First interurban lines
1897	United States	Invention of multiple-unit train control (Sprague)
1897	Boston	First streetcar tunnel
1899	Great Britain	First motorbuses
1901	Wuppertal, Germany	First successful monorail
1901	Fontainebleau, France	First trolleybus line in operation (Lombard-Gerin)
1902	Bielatal, Germany	Practical overhead power pickup for trolleybus (Schiemann)
1904	New York	First four-track rapid transit subway line for local and express services
1914	United States	Introduction of jitneys
ca. 1920	United States	Use of pneumatic tires for buses
ca. 1927	Nottinghamshire, England	Introduction of diesel motors for bus propulsion
1936	Brooklyn, New York City	First PCC car in service
1955	Düsseldorf	First modern articulated streetcar, contributing to the development of LRT mode (DÜWAG)
1955	Cleveland	First extensive park-and-ride system (with rapid transit)
1956	Paris	First rubber-tired metro
1957	Hamburg	First rapid transit with one-person train crews
Late 1950s	West Germany	First modern articulated buses and trolleybuses
1962	New York	First fully automated rapid transit line (42nd Street shuttle)
1960s	Europe	Widespread use of self-service fare collection
1966	Hamburg	First Transit Federation (*Verkehrsverbund*) with integrated fares and services
1968	Victoria Line, London	First automated fare collection with graduated fare

Table 1.5 (*continued*)

Year	*Location*	*Event*
Late 1960s	Western Europe, U.S.	Introduction of transit (LRT, bus) malls
1965	Pittsburgh	First Automated People Mover (APM) demonstration by Westinghouse at South Park
1969	Shirley Highway, Washington	First exclusive busway for commuter transit (later converted into HOV roadway)
Early 1970s	Western Europe, U.S., Japan	First major use of thyristor chopper control of electric motors
1972	BART, San Francisco	First computer-controlled rapid transit system
1970s	United States	Widespread development of innovative types of paratransit services
1974	Dallas-Fort Worth Airport	First fully automated guided transit network with driverless vehicles (AGT) in airport
1975	Morgantown, West Virginia	First AGT system in public service
Late 1970s	Western Europe, United States	Testing of AC electric motors on transit vehicles
1977	San Diego	First wheelchair-lift-equipped bus on transit line
ca. 1978	West Germany	Dual-mode trolleybus with remote trolley pole control
1979	Hamburg	Low-floor bus tested; wide use from late 1980s
From 1980s	Sao Paulo, Curitiba, Ottawa, Pittsburgh	Bus lines on separated lanes and high-frequency service; first BRT systems
1983–88	Lille, Vancouver, London, Miami	First fully automated regular transit lines
1985	Geneva	First 60% low-floor LRT vehicles
1990	Bremen	First 100% low-floor LRT vehicles
1993–2002	Lyon, Paris, Singapore	Fully automated full-size metro lines
Since 1990	Western Europe, U.S.A., Japan, Singapore	Extensive applications of Intelligent Transportation Systems (ITS) technology in transit systems

portance of transit for cities' economic viability and living conditions can be found in the three last federal transportation acts: ISTEA of 1991, NEXTEA of 1996, and SAFETEA-LU of 2005. Implementation of these policy goals, however, is often a major problem.

With respect to the integration and regulation of transit services, considerable progress has been achieved. In most large cities, formerly independent transit services have been integrated into regional transit authorities, districts, and other forms of public agencies. Since the 1990s, the trend toward intermodal coordination has resulted in the founding of agencies that coordinate transit with parking control, traffic regulation, and, particularly, incorporation of transit in pedestrian-oriented areas, resulting in the increased livability of cities. Today by far the best transit services are found in cities that have achieved full integration of all transit operators and improved coordination of transit, street traffic, and pedestrians in attractive, liveable environments, such as Munich, Paris, Portland (Oregon), Stockholm and Toronto.

Although the nature of contemporary urban transportation problems varies among different cities and countries, their general causes have many common elements. For example, most large cities in developing countries suffer very seriously from poor mobility, pollution, noise, accidents, and economic waste caused by chronic traffic congestion. This condition is often a consequence of the failure to ensure an acceptable level of transit service through separation of this mode from other traffic and the introduction of high-capacity rail systems.

Consequently, technological and operational innovations of transportation systems dominated the first decades of the development of modern urban transportation systems. They have by no means been exhausted: technological progress is still very important, and it is continuing. But in recent decades the main problems in urban transportation have occurred due to deficiencies in the treatment of transportation—its planning, organization, and policies—rather than by a lack of technological solutions. Inadequate understanding of urban transportation has often caused technological problems, such as incorrect selection of modes and the decline of technical expertise in the field of transit. Thus, to achieve efficient urban transportation and healthy cities in general, it is necessary to improve understanding of both areas—planning, organization, and policies on the one hand and transit systems and technology on the other.

EXERCISES

1.1. Select two cities and analyze the probable reasons for their locations: which local factors and which external forces influenced the initial development of each of these cities? Can transportation be traced as one of the major forces?

1.2. Define urbanization and describe its major causes.

1.3. Find data, show them graphically, and discuss the urbanization process in two different countries for approximately the last 100 years.

1.4. a) Describe the basic principles of cable car technology. b) Explain why its invention led to intensive construction of cable car lines in various cities. c) Which invention of a new transit mode caused the end of cable car expansion and the replacement of this mode?

1.5. Explain why the invention of electric streetcars is considered to have been a major "revolution" in urban transportation. Compare the service characteristics that electric streetcars could offer with those available by previously available modes.

1.6. Describe the following developments:

a) The introduction of long-distance railways and their effects on the sizes and densities of cities.

b) The introduction of mechanized transit and its effect on residential densities, physical sizes, and forms of cities.

1.7. Select a city you know well and research the beginnings of its public transportation. Present a short review of major developments and discuss the impacts of these developments on the city's growth and character, including its population, physical size (area), and form.

1.8. List and briefly describe the major technological/operational improvements in the development of streetcar/LRT vehicles from 1880 to the 1950s.

1.9. What were the major factors that led to the replacement of streetcars/tramways by buses in many countries? Under what conditions was that change of modes logical, and in which cases was it a mistake?

1.10. What were the main technological inventions that led to the development of operational trolleybuses?

1.11. Describe the technological advances in bus design between 1915 and 1935 that made buses efficient transit vehicles.

1.12. List and briefly describe the technical and operational innovations led to the creation of BRT.

1.13. Why did jitney services practically disappear from U.S. cities?

1.14. List and briefly describe the changes in streetcar/tramway systems that led to the creation of LRT.

1.15. What impact did suburban railways have on cities prior to the introduction of mechanized transit?

1.16. Describe recent trends in suburban/regional rail systems in U.S. cities: usage, extensions, and modifications of networks. Which developments contributed to the reversal, since the 1980s, of their decline, which occurred from 1930 to 1960?

1.17. Discuss the reasons for the relatively rapid disappearance of interurbans in the United States.

1.18. What were the main reasons for the construction of the first ‘‘underground’’ (rapid transit) in the world, and why did that happen in London so much earlier than in other cities?

1.19. Explain the major reasons for the accelerated construction of rapid transit systems since the mid-1950s.

1.20. Discuss the influence of two recent trends on the role and performance of transit in cities:

a) The provision of separate transit rights-of-way; and

b) The introduction of transit lines (particularly rail on surface or in tunnel) into the centers of pedestrian-oriented areas such as city centers or suburban major activity centers.

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