TRANSPORTATION TECHNOLOGY AS A DETERMINANT OF URBAN GROWTH

by

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ABSTRACT

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THESIS: that changing transportation technology helped determine the limit of maximum expansion of the city and that the physical characteristics of transportation have determined the pattern of growth to that limit.

Population movements and growth have occurred in two stages: influx into the city and explosion to the suburbs. Transportation technology has advanced in two stages: centripetal, emphasizing a single center, and centrifugal, de-emphasizing one center. There is a correspondence between these stages of population and transportation change.

The growth of cities occurs in cycles. In a cycle, the dominant mode of transportation sets a pattern of land use which determines later need for transportation, and so on, in a continuous cycle of cause and effect.

Along a path of transportation, a stop creates a nodal pattern centered around the stop. If the distance between the stops is long, the nodes retain their identity. If this distance is short, the nodes evolve a linear pattern.

Growth occurs primarily in the linear or nodal patterns. A third pattern, spread, results when the pace of growth is so rapid that growth occurs in units the size of the basic network or larger. The network is the sum of the paths of a mode of transportation.

The growth of Philadelphia, Chicago, and Houston demonstrates that:

a) increasing speed of means of transportation extends the boundaries of the city outward in proportion to speed,
b) the dominant mode of transportation during a cycle of growth establishes its peculiar pattern for future growth,
c) the patterns of urban growth can be categorized as "nodal", "linear", and "spread", and
d) these patterns of urban growth are determined by the physical characteristics of transportation.
CONTENTS

INTRODUCTION

1 ADVANCING TRANSPORTATION TECHNOLOGY 4

2 URBAN GROWTH 11

3 PHYSICAL CHARACTERISTICS OF TRANSPORTATION 22

4 PHYSICAL PATTERNS GENERATED BY TRANSPORTATION 37

5 GROWTH TO 1850 48

6 GROWTH – HORSECAR & RAILROAD ERA 54

7 GROWTH – STREETCAR & INTERURBAN ERA 62

8 GROWTH – AUTOMOBILE ERA 69

9 SUMMARY AND CONCLUSIONS 76

10 BIBLIOGRAPHY 86
INTRODUCTION
In the United States in the last hundred years, population has increased by 160 million, urban population by 125 million. At the beginning of this period, most of the population was living on farms or in rural areas. By the end of the period the situation had completely reversed, with most people living in cities or urban areas.

The process of changing from a rural to an urban population took place in two stages. The first of these was an influx into the cities during the last half of the nineteenth century and the early part of the twentieth. This influx consisted of migrants from the rural areas and foreign immigrants and was occasioned by the industrialization process with its need for large numbers of cheap laborers.

The second stage was an explosion of the city, spreading it farther and farther into the countryside. The first stage saw the growth of dense, single-centered, congested cities. The second stage brought decentralization of the city. This process involved the gradual dispersal of some of the functions previously reserved to the center, the beginning of subcenters, and the decreasing density of the city.
The purpose of this thesis is to explore the relationships between advances in transportation technology and the patterns of urban growth. Two things are required for urban growth: a growing population and increasing available land area. Of these two, the first is the most important. Without large numbers of people there is no city. The city can increase in density rather than expand if additional area is not available.\(^5\)

My thesis is that changing transportation technology helped determine the limit of maximum expansion of the city and that the physical characteristics of transportation have determined the pattern of growth to that limit.

As a continuation of this introduction, parts 1 and 2 trace the development of transportation and the growth of three American cities. Parts 3 and 4 present the basis of the thesis: the characteristics of transportation and the physical patterns generated by them. And parts 5 thru 8 demonstrate the validity of the thesis on the basis of the experience of three American cities which developed during three distinct time periods: Philadelphia - the eighteenth century city, Chicago - the nineteenth century city, and Houston - the twentieth century city.
NOTES

1 ENCYCLOPAEDIA BRITANNICA, 1967, Volume 22, P 690.


4 ibid.

5 In early Philadelphia it was desirable to increase density - destroying Penn's concept of the "green country towne" - because extension meant less safety and longer travel time. See especially Reps, John W., William Penn and The Planning of Philadelphia, TOWN PLANNING REVIEW, April 1956, PP 27-39.
Prior to about 1830 in the United States, transportation consisted of small boats, horses, and carriages. But the prime mode was walking. The diagram at left indicates that there was little paved road in 1800, urban or otherwise. This remained the case until the first quarter of this century, when the automobile made paved roads a necessity.

The growth of railroads is also shown in the above diagram. The rapid growth of rail transportation in the last half of the nineteenth century slowed only when the country was completely connected in a rail network. The network was built between 1830 and 1890.

Also beginning about 1830, means of transportation in cities began to develop, enabling the city to expand by providing ways to travel greater distances in the same amount of time. The first such urban transportation was the horsecar — a horsedrawn car on wooden or metal tracks. It represented major improvements over the carriage in smoothness of ride, greater average speed, and greater capacity per car. It was used, mostly in large cities, extensively until about 1890, when it was being
replaced by the electric streetcar.

The cablecar and subway/elevated were developed at about the same time as the electric streetcar, but were used to a much lesser extent than the streetcar due to their very high cost of track and equipment, and inflexibility of routes. The streetcar was used extensively for almost 50 years. Nearly all cities had streetcars, regardless of their size.

Around 1930 the streetcars began to give way to trolley buses and motorbuses as the city decentralized and more flexible routes were required. Also, at about the same time, the rate of use of public transportation decreased rapidly as a result of the increasing use of the automobile.

In addition to the streetcar, the electric interurban railroads developed extensively between 1890 and 1930. Their intermediate- to long-distance, point-to-point service, combined with the streetcar's block-by-block service provided a complete electric transportation system with its peak of use about 1920.

After this peak of public, urban transportation, the trolley bus and motorbus gradually took over from the streetcar, the "interurbans" folded altogether, and the automobile took more and more people away from all other forms of transportation. The subway/elevated systems continued to grow at a slow rate and only into areas of the city whose density was almost certain to support this expensive system.
The change from public to private transportation was rapid. The almost vertical line representing the rate of private vehicle registration in this country since 1920 illustrates this. But decentralization of the city does not begin with this change.

The growth of public transportation and the beginning of decentralization correlate almost exactly. This indicates that, while public transportation tends to focus on one dominant center, it started the movement away from that center. Still, the major effect of public transportation (streetcar, railroad, interurban, and subway/elevated) was to centralize the city. The effect of the rise of private transportation has been to decentralize it.

Other technological advances have combined with transportation technology to reinforce these tendencies. The elevator, available generally about 1910, permitted more centralization of functions and congregation of more people on less land area in city centers. Its development coincides with that of public transportation, i.e. the streetcar, interurban, and subway/elevated. The elevator, combined with these modes of transportation, provided a centripetal force on the city.

The electrical power grid, telephone, television, and other communications de-
vices, together with the automobile, have provided a centrifugal force on the city. Their effect has been to provide a framework, stretching far out from the center of the city, within which any pattern is possible. Their effects also have been able to adapt to any pre-existing pattern.

There have been two stages of city growth with respect to the advance of transportation technology. The first, from about 1830 to 1930, is characterized by a strong center with all forms of transportation focusing on it. This stage breaks down into five eras — the periods of dominance of each of five modes of transportation. These eras are: 1. until about 1850 — pedestrian, 2. to about 1880 — horsecar, 3. to about 1930 — streetcar, 4. from 1830 to 1890 — railroad, and 5. from 1890 to 1930 — interurban.

The second stage of city growth with respect to the advance of transportation technology, from 1930 to 1960, is characterized by a weakening of the center formed in the first stage and decentralization, with transportation connecting many centers of varying importance. This stage involves only one era — that of the dominance of the automobile supplemented by the motorbus. (The continuing use of the subway/elevated and other centralizing transportation systems points out that the main center is still the dominant focus of activity.)

The first of these stages corresponds to the influx stage of population growth and movement. During this stage large numbers of people were moving into the city from rural areas and foreign countries, providing the cheap labor on which our
rapid industrial growth was based. The increasing average speed of public, urban transportation during this stage permitted the city to grow horizontally, but it retained the dominant city center and remained relatively densely settled.\textsuperscript{11}

The second stage corresponds to the explosion stage of population growth. The increasing average speed of public urban transportation during the beginning of this stage permitted further growth horizontally, but the real impact of this stage on the pattern of the city was the result of other factors. Private transportation, increased average speed of movement, and decentralization of formerly central functions caused the city to grow horizontally at a rapid pace with the traditional center becoming less dominant and the density of settlement steadily decreasing.\textsuperscript{13}

Taken together, the growth and movement of population and the advance of transportation technology acted to form dense, congested, centralized cities until about 1930 and after that acted to form less dense, decentralized cities.\textsuperscript{14}
NOTES


2 "It has been said that 'when the nineteenth century takes its place with the other centuries in the chronological charts of the future, it will, if it need a symbol, almost inevitably have as that symbol, a steamengine running upon a railway'." Willson, Beckles, THE STORY OF RAPID TRANSIT, McClure, Phillips & Co., New York, 1903, P 5, quoting H. G. Wells.


5 The electric streetcar was likewise inflexible, but the cost of discarding a route was not prohibitive during the period of the extensive use of it. The streetcar also had the advantage of being able, in most cases to operate on the old trackage of the horsecars and on the railroads.


8 Certainly the expense of contemporary freeways is great. But these are built with public money. The early subway/elevated systems were built as a private enterprise. On that basis, their initial capital costs were extremely high.

9 ENCYCLOPAEDIA BRITANNICA, 1967, Volume 15, P 937, and Volume 19, P 369 - In comparing this diagram with the growth of ROADS & RAILROADS, it is interesting to note the following; in 1960, there was one automobile per three persons, four-tenths of a mile of paved road per automobile, and one-tenth of a mile of urban road per automobile. This is some indication of the extent of congestion.


12 See part 3.


PHILADELPHIA was founded in 1682 by William Penn. Its early growth was based on commerce. For its exports, Philadelphia had the Delaware, Schuylkill, and Susquehanna river valleys to draw on. It did the largest volume of commerce in the country for its first 120 years.

Philadelphia's manufactures grew as a result of its commercial activities. In 1690, flour and paper mills were operating. In 1718, leather goods, rum, steel, carriages and wagons, fire engines, and glass were all being produced. 1725 marked the beginning of Philadelphia's shipbuilding industry.

By virtue of being the largest city in the colonies and its commercial, industrial, learning, and cultural leader, Philadelphia was also its capitol from 1775 to 1800. During this period it also became the country's financial leader.

From a handful in 1683, Philadelphia's population grew to about 10,000 in 1725 and to about 40,000 in 1775. By the time Chicago was being founded in 1833, Philadelphia already had a population of about 86,000.

The beginning of the nineteenth century brought the end of Philadelphia's reign as the number one city in this country. The capitol moved to Washington and
commercial leadership to New York.

During the nineteenth century Philadelphia remained second in population to New York until 1890, when the population of Chicago exceeded that of Philadelphia.

Philadelphia's growth in textiles, iron, steel, glass, locomotives, ships, hats, and shoes, and its rise as the distributing center of the Pennsylvania coal fields made it a leading center of the industrial revolution. Throughout the nineteenth century Philadelphia was a rail and shipping center of the first importance.

The twentieth century has seen a continuation of industrial and commercial emphasis in the growth of Philadelphia. The increasing population has come from migration and immigration and the expanding rate of births over deaths.

Philadelphia had two periods of intensive growth relative to Chicago and Houston. The first was the commercial-political era of the eighteenth century. The second was the commercial-industrial era of the nineteenth century. Its growth in the twentieth century has proceeded at a slower pace as compared with that of younger cities.

CHICAGO was surveyed and platted in 1830 by James Thompson, C.E., on the site of a long-used trading crossroads. In 1834 it was incorporated and a town government was set up.
Like Philadelphia, the early growth of Chicago was due to commerce. By 1851, Chicago was this country's largest corn market. By 1854 it was the largest wheat market and by 1856 it was the largest lumber market. In the decade 1870 to 1880 Chicago claimed the distinction as the largest distributing center in the world.

Chicago's industrial growth began with grain storage and farm machinery production. In 1848, McCormick began what is now International Harvester. In 1865 the first steel rail for railroads was produced in Chicago, and in 1867 Pullman began producing his railroad cars there.

In the 1880's Chicago became a leader in the production of primary metals and by 1953 had overtaken Pittsburgh as the nation's number one producer of steel. By 1890, Chicago was second only to New York in manufacturing. Other important manufacturing enterprises in Chicago are meat packing, electrical machinery, and metal fabrications.

Chicago's population grew at a very rapid rate from its beginning. From 350 in 1833, it grew to about 4000 in four years. By 1847 the population was near 30,000, less than half of whom were born in this country. Chicago's population growth has been due to migration and immigration; the migration being primarily negroes.

Chicago's history shows two periods of intensive growth, separated by the great fire of 1871, which destroyed $196,000,000 in property. The first era was that of extensive expansion of transportation facilities making Chicago a great commercial
center. The second era was that immediately following the fire and continuing until the "crash" of the '30s and was a period of intensive industrial growth along with continuing commercial importance.

HOUSTON was founded in 1837 by Augustus C. Allen and John K. Allen at the most interior point of navigation in Texas. From 1837 to 1840 it experienced some growth due to being the capital of the Republic of Texas, but its early growth, like that of Philadelphia and Chicago, was due to commerce. Until after the Civil War, growth was very slow.

Between the Civil War and World War I, Houston emerged as a railroad center of regional importance. The decade of the '20s was a great boom period for Houston, with 111.4% growth of population due to the impetus of World War I.

The most important period of Houston's growth is only now well begun. The period immediately following World War II has seen the great expansion of the port of Houston and its petrochemical industries. Houston's primary industries are petrochemicals, oil field tools and equipment, grain storage, and shipping.

Houston's population, in spite of the boom of the '20s, didn't really rise until the '40s. From 1940 to 1960, Houston's population grew from 348,514 to 938,219. Houston's population growth has been due to migration and immigration, but the latter has played a much less important role than it did in Philadelphia and Chicago.
Houston, like both Philadelphia and Chicago, has experienced two boom periods of intensive growth. Unlike either of the others, Houston's have both been wholly in this century, and the second is still very much in progress. The first was the period between World Wars I and II, during which Houston came of age as a commercial center. The second is the period since World War II during which Houston has established itself as an industrial and managerial center of the first order.

The following series of diagrams illustrates graphically the comparison between the population and land area growth of the three cities, the extent of land area occupied, and the comparative rates of growth of Philadelphia, Chicago, and Houston.
PHILADELPHIA\textsuperscript{5} (top), CHICAGO\textsuperscript{6} and HOUSTON\textsuperscript{7} POPULATION & LAND AREA
The growth of all three of these cities has been a response to transportation. All were originally located because of their favorable location for both land- and water-borne commerce. Their first periods of intensive population and extensive area growth were a response to favorable commercial locations.

The second boom periods of Philadelphia, Chicago, and Houston were a response to the growth of industry. Industry was located in them because of their favorable locations with respect to transportation. So, it can be said that the growth of these three cities was a result of advancing transportation technology in that they are first commercial centers and second industrial centers by virtue of their capacity for commerce.

The first stage of population growth and movement and advancing transportation technology produced dense, congested, centralized cities. The second stage created less dense, decentralized cities. These two stages are shown on the diagram at left, along with the eras of transportation dominance and the boom periods of the three cities.

This diagram indicates that the patterns of growth of Philadelphia should show the effects of the pedestrian, horsecar, and railroad primarily, and that it should be relatively dense, centralized, and congested, since both of its boom periods occurred
during the first stage of transportation technology and during the period of population influx.

Chicago, on the other hand, should show the effects of the pedestrian, horsecar, streetcar, railroad, and interurban primarily, and it should be relatively dense, centralized, and congested, since both of its boom periods occurred during the first stage of transportation technology and during the period of population influx.

And, in the case of Houston, the patterns of growth should show the effects of the streetcar, motorbus, and automobile primarily, and it should be less dense and less centralized, since both of its boom periods occurred during the second stage of transportation technology and during the period of population explosion.

The stages of the growth of American cities are made up of two things: first the influx and explosion of population with respect to the center city, second the centralizing and decentralizing tendencies of advancing transportation technology. The eras of transportation technology are the time periods during which one form or another was dominant. The booms of the city are periods of both intensive population growth and extensive area growth.

Both population and area growth are necessary for transportation to show an effect. Transportation provides the necessary area into which the city can expand and it patterns that growth by its physical characteristics. The patterns will be strongest during boom periods and these patterns will shape future growth.
NOTES


2. See Bibliography, Philadelphia

3. See Bibliography, Chicago

4. See Bibliography, Houston


10. First diagram in this series compares the original plat area (black rectangle)
with the 1955 city limits (outlined). Sources: Houston City Planning Department, POPULATION, LAND USE, GROWTH, December 1959, and Houston City Planning Department, URBAN FORM, August 1966.

General Note: For comparative purposes all maps are drawn at the same scale. North is up on all maps. The scale for the map showing the location of the three cities at the beginning of this section is one graphic unit per 50 miles. The scale for the maps in section 5 is one graphic unit per 500 feet. All other maps that show a scale are drawn to one graphic unit per mile.
All means of transportation have a number of things in common. All require a vehicle and a path and expend energy in producing movement. All occupy space, require some form of storage, and have an average effective speed and capacity. And all have a maximum frequency of stops above which they cannot operate efficiently. This is the economic distance between stops of a means of transportation.

The following tabulations relate pedestrian, horsecar, streetcar, steam and diesel railroads, interurbans, subway/elevated, motorbus, and automobile transportation on the basis of ten primary characteristics: the vehicle itself with its characteristics of energy source, efficiency of changing that energy into mechanical energy, average speed, physical size, momentum, capacity, and economic distance between stops, the path over which the vehicle can operate most efficiently, and the storage area required.

There are many other physical characteristics of means of transportation which have had some effect on the resulting patterns and which could be compared here. Some of these are: comfort (the motorbus represents a vast improvement over the horsecar), physical appearance of the vehicle or path (a modern parkway presents a more desirable image than the highway with interurban in the same right-of-way did), noise (the motorbus is considerably noisier than the streetcar was), pollution (though the difference in smell is obvious, the horsecar and automobile both pollute the city's air), and so forth. But it is believed that the ten characteristics compared here are those most consistently affecting the physical pattern of the city.
<table>
<thead>
<tr>
<th>PEDESTRIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
</tr>
<tr>
<td>Energy Source</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td>Momentum</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
<tr>
<td>EDBS</td>
</tr>
<tr>
<td>Path</td>
</tr>
<tr>
<td>Storage</td>
</tr>
<tr>
<td>HORSECAR</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Vehicle</td>
</tr>
<tr>
<td>Energy Source</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td>Momentum</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
<tr>
<td>EDBS</td>
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<td>Path</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>STREETCAR</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Vehicle</strong></td>
</tr>
<tr>
<td><strong>Energy Source</strong></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
</tr>
<tr>
<td><strong>Size</strong></td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
</tr>
<tr>
<td><strong>EDBS</strong></td>
</tr>
<tr>
<td><strong>Path</strong></td>
</tr>
<tr>
<td><strong>Storage</strong></td>
</tr>
</tbody>
</table>
### STEAM AND DIESEL RAILROAD

<table>
<thead>
<tr>
<th><strong>Vehicle</strong></th>
<th>steam or diesel-powered train on tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Source</strong></td>
<td>organic fuels: wood, coal, coal oil</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>low, 4% for steam and 23% for diesel powered trains</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>fast, 40 mph, average</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>large, 11500 cubic feet per car</td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
<td>great, dangerous</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>forty to sixty per car</td>
</tr>
<tr>
<td><strong>EDBS</strong></td>
<td>since a large amount of energy must be expended to get a train underway the economic distance between stops is great. A minimum of one to two miles is tolerable, but greater distances are better.</td>
</tr>
<tr>
<td><strong>Path</strong></td>
<td>most flat, straight, fixed, mechanical</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>720 square feet per car, average. Since this is a public conveyance, storage occurs in terminal facilities, hence storage is necessary neither at the origin nor the destination of movement.</td>
</tr>
</tbody>
</table>
**INTERURBAN**

<table>
<thead>
<tr>
<th><strong>Vehicle</strong></th>
<th>electric-powered train on tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Source</strong></td>
<td>steam generated or hydro-electric power</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>greater than steam railroad, but energy must be transformed into mechanical energy then to electrical energy, transmitted, and transformed back into mechanical energy</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>medium, 20 mph, average (a few were high-speed, averaging in the 45 to 55 mph range)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>large, 4800 cubic feet per car</td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
<td>great, dangerous</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>thirty to fifty per car</td>
</tr>
<tr>
<td><strong>EDBS</strong></td>
<td>since the interurbans were marginal operations using cheap rolling stock, borrowed right-of-way, and light roadbeds, and since they were providing services not available from other railroads, their best possibilities lay in point-to-point service. The farther apart the points were, the better.</td>
</tr>
<tr>
<td><strong>Path</strong></td>
<td>most flat, straight, fixed, mechanical</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>400 square feet per car, average. Since this is a public conveyance, storage occurs in terminal facilities, hence storage is necessary neither at the origin nor destination of movement.</td>
</tr>
<tr>
<td><strong>SUBWAY/ELEVATED</strong></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Vehicle</strong></td>
<td>electric-powered train on tracks below or above grade</td>
</tr>
<tr>
<td><strong>Energy Source</strong></td>
<td>steam generated or hydro-electric power</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>same as streetcar and interurban</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>fast, 30 mph, average</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>large, 4800 cubic feet per car</td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
<td>great, dangerous</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>thirty to fifty per car</td>
</tr>
<tr>
<td><strong>EDBS</strong></td>
<td>high cost of underground or overhead stations encourages limitation of number of stops. Also, this form of transportation's main selling point is speed: more stops, lower average speed.</td>
</tr>
<tr>
<td><strong>Path</strong></td>
<td>most flat, straight, fixed, mechanical</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>400 square feet per car, average. Since this is a public conveyance, storage occurs in terminal facilities, hence storage is necessary neither at the origin nor destination of movement.</td>
</tr>
<tr>
<td><strong>Vehicle</strong></td>
<td>gasoline-powered bus</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>Energy Source</strong></td>
<td>gasoline</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>most efficient of all - fuel is more powerful and engine more efficient</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>medium, 15 mph, average (express up to 30 mph average)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>large, 4400 cubic feet</td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
<td>great, dangerous</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>thirty to fifty</td>
</tr>
<tr>
<td><strong>EDBS</strong></td>
<td>none, i.e. distance between stops is not the primary consideration in operation. Minimum of 400 to 600 feet: one stop per block.</td>
</tr>
<tr>
<td><strong>Path</strong></td>
<td>most flat, variable, organic</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>400 square feet, minimum. Since this is a public conveyance, storage occurs in terminal facilities, hence storage is necessary neither at the origin nor destination of movement.</td>
</tr>
<tr>
<td>AUTOMOBILE</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Vehicle</strong></td>
<td>gasoline-powered car</td>
</tr>
<tr>
<td><strong>Energy Source</strong></td>
<td>gasoline</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>most efficient of all - fuel is more powerful and engine more efficient</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>fast, 25 mph, average (limited access roads up to 35 mph average)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>large, 750 cubic feet</td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
<td>great, dangerous</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>four to six</td>
</tr>
<tr>
<td><strong>EDBS</strong></td>
<td>none, i.e. distance between stops is not the primary consideration in operation</td>
</tr>
<tr>
<td><strong>Path</strong></td>
<td>mostly flat, variable, organic</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>180 square feet, minimum.</td>
</tr>
</tbody>
</table>
The comparisons between these eight modes of transportation are fairly obvious. All except the pedestrian and the automobile operate along more or less fixed routes. For all, except the pedestrian and the automobile, storage is not a problem. Momentum of all save the pedestrian is great and dangerous to human life and limb, and all occupy separate rights-of-way from the pedestrian to a greater or lesser degree. For all, except railroads, interurbans, and subway/elevateds, the distance between stops is of little concern. And each new mode of transportation increased the average speed of movement in the city.

Increased average speed meant that more land area could be settled within the same travel time. The average speed set the limit of growth within a given time from the center of the city. Assuming that time to be thirty minutes, the first series of diagrams on the next page shows the maximum size of the city. The second series of diagrams results from the fact that the city cannot always spread out in all directions from the center. These two series of diagrams show the extent of the city for each of the modes of transportation whose economic distance between stops is of little concern in operation.

The third series of diagrams shows the maximum size of the city within 30 minutes of the center for the modes of transportation whose economic distance between stops is of concern in operation. Two miles has been used as the minimum economic distance between stops. This is consistent with the minimum for the railroad, and the subway and interurban can be more or less, but this is accepted as average for them.
CITY SIZE DETERMINED BY 30 MINUTES' TRAVEL TIME TO THE CENTER
On the basis of average speed, these diagrams show that the city can now be over 75 times as big as it was in 1860, with no one more than 30 minutes from the city center. That is, it could be 75 times as large if everyone didn't try to get to the center all at the same time, which is virtually what happens now between 7 and 9 in the morning, five days a week.

Since this is the case, average speed drops to between 15 and 20 mph, and the city can be on the order of 15 times as big as it was in 1860, with no one more than 30 minutes away from the center. This is to say that the maximum size of the city has not changed since about 1930, which was the heyday of the streetcar and interurban, given the assumption that people maximize travel time at 30 minutes.

People do not maximize travel time at 30 minutes. There are substantial numbers of people living more than this 30 minutes' commuting time from the center of Philadelphia and Chicago, and even some in Houston. So, the effect of advancing transportation technology making more land area available for the growth of the city is supplemented by people's willingness to spend more time traveling in order to satisfy other of their desires.

But, whatever the limit for travel time, the horsecar made the city 2.5 times as large (potentially) as the pedestrian; the streetcar, 6 times as large as the horsecar; the motorbus, twice as large as the streetcar; and the automobile, 3 times as large (potentially) as the motorbus. So, the effect of advancing transportation
technology has been to increase the area available into which the city could grow.

There are two exceptions to this conclusion: the interurban and the subway/elevated. Both of these have physical characteristics similar to those of the steam railroad, but both operate at a lower average speed, so their effect could only be to reinforce existing patterns rather than increase the area available to the city, since they both came after the steam railroads.

It will be recalled that the first stage of the advance of transportation technology was over by 1930, as was the increase in area available for expansion within the same travel time. Along with these goes the influx of population into the city. Together these factors result in a dense, congested, centralized city.

The second stage, which had begun by 1930, resulted in no increase in the area available for expansion within the same travel time for two reasons. First, transportation had changed from public to private. This meant that the daily trip to work now required greatly increased numbers and size of paths of movement and storage spaces if the potential increase in average speed was to be realized. Neither the paths nor the storage was available, so congestion kept the potential increase in area from being realized.

The second reason is that people did not maximize the tolerable travel time at 30 minutes or lower. Instead, they were willing to spend more and more time
travelling in order to realize higher priority objectives in their everyday lives. Along with this stage goes the population explosion away from the center of the city. These factors, congestion, willingness to spend more time travelling, and the explosion to the suburbs, together result in a less centralized and less dense city.

From 1830 to 1930 advances in transportation technology were responsible for providing the city with a large area into which to grow. Since 1930 that area has not substantially changed and people are spending more and more time travelling once in the city. The maximum size is now determined by the upper limit of their tolerance regarding time spent travelling.

The necessity to spend more time travelling in the city has been accompanied by two factors making that waste of time tolerable. The first of these is the fact that the time is available to waste. The working day is considerably shorter than in the days of the horsecar. The second is that the comfort of the traveller in the city has increased to the point that the time spent in his car in a traffic jam is not intolerable.

The assumption in all of this is that there is only one center. Since 1930, this is increasingly unlikely to be true. With subcenters, the potential area of the city increases, the travel time to the subcenter having the same role in determining size as travel time in the city with one center.
NOTES


2. ibid.

3. Concensus of all sources listed in Bibliography under headings of the particular means of transportation

4. Estimated by scaling photographs and drawings contained in sources listed in Bibliography under headings of the particular means of transportation

5. Concensus of all sources listed in Bibliography under headings of the particular means of transportation


7. Estimated by scaling photographs and drawings contained in sources listed in Bibliography under headings of the particular means of transportation

In addition to average speed, the economic distance between stops has had important effects on the growth of the city. Its effect has been to pattern the city's growth. The economic distance between stops refers to the minimum feasible distance between stops – any more frequent stops diminishes the usefulness of the means of transportation.

At the point where one mode of transportation stops, another takes over. The change is almost always the change between a mechanical conveyance and pedestrian movement, but it can be the change between two mechanical conveyances with the linkage provided by the pedestrian, or the change between paths of movement for the same vehicle. In any case, a stop is a point of interchange between means of transportation.

These stops can be far apart or close together, depending on the characteristics of the mode of transportation. The railroad, interurban, and subway/elevated must have a substantial distance between stops in order to operate efficiently. The pattern consistent with this long minimum economic distance between stops is the nodal pattern, as shown below.

A node is a point of intensive activity generated by the process of interchange between modes of transportation. There are more people here than at other points along the path of movement. This point
highly accessible and visible to many people.

The size of the node is determined by its distance from the center city. The time required to travel to the center is the sum of the time required to get to the point of interchange and the time required to get from that point to the center. So the average speed of travel limits the size of the node as it does the maximum size of the city.

The pedestrian, horsecar, streetcar, motorbus, and automobile all have a much shorter minimum economic distance between stops than the railroad, interurban, and subway/elevated. The nodes of interchange connected with their stops are so close together that they grow together forming the finger pattern as shown in the above diagram.

The intensity of hatching in these last two diagrams indicates several things. The first is the time away from the point of interchange. The first band is two, the second four, and the third six minutes away. The second thing indicated is the likely density of population. The more intense the hatching, the closer to the node of interchange, the higher the density. Finally, the hatching indicates the combination of accessibility, visibility, and land value and because of these, likely intensity of land use. The more intense the hatching, the closer to the node of interchange, the more accessible, visible, and valuable the land, the
The use of land generating the need for transportation and the presence of transportation generating land use is a never-ending cycle as shown at left. Land use is the result of the availability of transportation. This land use, in turn, generates amounts of traffic which may or may not justify new means of transportation. Finally, transportation comes first or concurrent with land use. It is certainly possible to have means of transportation which do not directly serve land uses, but it is not possible to have land use of any kind with no means of access to it.

The two patterns generated by the economic distance between stops are the basis for the pattern of the city. The patterns of density, land use, land value, and the intensity of movement all respond to the level of transportation technology, particularly its speed and minimum economic distance between stops.

The diagrams on the next page illustrate the patterns of growth of the city. The first series illustrates the growth of the nodal pattern. In the first stage it is little more than a building on a path of movement. The second stage shows the beginning of the growth of other facilities supporting the transportation possibly, and some residence. At the third stage the node may have some commercial facilities and it has definitely begun to grow out the major access path to the main path of move-
PATTERNS OF URBAN GROWTH - NODAL, LINEAR, AND SPREAD

In the fourth and fifth stages it has commercial, large areas of residential, and perhaps some of its own industry. And in the final stage, the node has grown to the point that means of transportation other than pedestrian is needed to reach the main path of movement.
The second series of diagrams on the preceding page illustrates the growth of a linear pattern. In the initial stage, it is little more than a couple of buildings on a path of movement. Each successive stage is comparable to the stage of the growth of the nodal pattern.

The city consists of more than just straight paths of movement radiating from its center or centers. In addition to these, cross-paths linking the center-oriented paths are also apparent. The sum of these radial and linking paths is a network.

The city has basically three scales of networks. The first is the small scale, which is the size of the city block. It is consistent with slow movement systems, the pedestrian and horsecar. In the small scale network population density is high, the increment of growth is the building, and all paths are of virtually the same importance.

When the pace of growth in a city dominated by this scale of network has speeded up to the point that the smallest increment of growth is the block, the resulting pattern of growth is as shown in the third series of diagrams on the preceding page.

The second scale of network is the intermediate scale which is eight to ten city blocks in size. It is consistent with medium speed movement systems, the streetcar, motorbus, and automobile. The population density is lower than the small scale network, the minimum increment of growth is the block, and all of these
paths are of virtually the same importance, with the small scale network as a
distribution system for them.

Growth at this scale typically takes place in the linear pattern. The fourth
series of diagrams of patterns of urban growth shows this form. When the pace
of growth is so rapid that the smallest increment is the size of this network,
the resulting pattern is structured by the linear patterns along the intermediate
scale paths of movement.

The third scale of network is the large scale, which is at least twenty to thirty
city blocks in size. The railroad, interurban, subway/elevated, and automobile
operate at this scale. Population density is lower than either the small or inter¬
mediate scale, the minimum increment of growth is the neighborhood, and all
of the paths are of virtually the same importance with the intermediate scale
network as a distribution system for them.

Growth at this scale typically takes the nodal pattern, as indicated in the final
series of diagrams of patterns of urban growth. When the pace of growth is so
rapid that the smallest increment of growth is the size of this network, the result¬
ing pattern is structured by the nodal pattern at the large scale and the linear
patterns at the intermediate scale.

Spread occurs at all scales of network in the city. It is the pattern which re¬
sults when the pace of growth is so rapid that the nodal and linear patterns of
growth do not show up in growth. These two patterns are still the structure of
the growth, no matter how fast it is occurring.

Before 1900 the basic unit of spread was the building. From 1900 to 1930 this
unit grew to the scale of a city block, and from 1930 to 1955 it grew to the
group of blocks or the neighborhood. The basic, day-to-day unit of spread is
still the individual building on its individual piece of land, but the units of
spread for longer time periods have grown from the building to the neighborhood.
That is, in a ten year period before 1900, one block of growth would have taken
place compared to a whole neighborhood in a similar length of time since 1930.

Each scale of network contributes its own characteristics to the overall makeup
of spread. The small scale, which is all but lost in the shuffle now, contributed
the pedestrian scale and buildings with detail—an environment consistent in
scale with slow movement systems. The intermediate scale has contributed to a
simplification and abstraction of building detail, and an intermediate building
scale influenced by both pedestrian and mechanical movement systems. And the
large scale network discourages building detail and is dominated by mechanical
movement systems.

The size of the networks is a function of two factors. The first is travel time.
The key measure determining size is the time elapsed between intersections, not
the distance. As the average speed of travel in the city has risen, the size of
the network has proportionately increased.
The second factor determining size of network is population density. As the population of the city exploded to the suburban areas, the density of the city decreased at the center as well as overall. In order to provide the same accessibility to the same number of people, the network had to enlarge. Similar numbers of people lived within one unit of the small scale network in the nineteenth century as live within one unit of the intermediate scale network of the early twentieth century.

The average speed of movement sets a limit on the maximum size of the city, the maximum size of the node, and the maximum width of the linear pattern. The minimum economic distance between stops sets the pattern of either nodal or linear form because of the activity generated by the interchange process between different means of transportation at stops. Combinations of these two patterns, happening as they do in the networks of the city, along with growth at a small scale, give us the spread pattern of city growth.

These networks set the pattern for the city. The development of a linear pattern of intensive activity along major flows in the network and the development of a nodal pattern of intensive activity at highly accessible points provide a hierarchical structure for the city based on volume of movement and degree of accessibility. 4

In the demonstration to follow, four periods of growth are used to analyze Philadelphia, Chicago, and Houston. These three cities were chosen because
they represent three phases of the effects of transportation technology on the patterns of the city and the extent of its growth. Philadelphia grew during the first part and Chicago during the second half of the first stage of the advance of transportation technology. Houston has grown almost entirely during the second stage.

From the preceeding analysis, and recalling the implications of the diagram at the end of part 2 showing comparative eras, the following demonstration should find:

PHILADELPHIA exhibiting the effects of the pedestrian, horsecar, and railroad
It should be
dense, centralized, and congested
and have
a large area of small scale network, linear patterns at the center,
and nodal patterns surrounding the center

CHICAGO should exhibit the effects of the pedestrian, horsecar, streetcar, railroad, and interurban
It should be
dense, centralized, and congested
and have
a large area of medium scale network, linear patterns at the center,
and nodal patterns surrounding the center

HOUSTON should exhibit the effects of the
streetcar, motorbus, and automobile

It should be

less dense and less centralized

and have

a large area of large scale network, linear patterns at the center,
and nodal patterns surrounding the center.
NOTES

1 Adapted from: Methods and Machines to Shape the Future, ARCHITECTURAL FORUM, October 1963, P 89.


3 "It's unimportant to do details... Our aesthetic and emotional concerns are at a different scale, at a much larger scale - maybe because we move much faster and we see much more in one week of our lives and a thousand times more during our lifetimes and each building is just a small part of a total set of aesthetic memories. So each building is a detail." Cesar Pelli, PROGRESSIVE ARCHITECTURE, January 1969, P 99.

PHILADELPHIA's first boom period was in the last half of the eighteenth century. The major form of movement during this period was pedestrian. The city was laid out originally in large blocks - too large for the natural density consistent with slow means of transportation. So the blocks were subdivided so that growth could occur within the city as well as spreading out around it.

The diagrams above indicate that the natural pattern for growth with only pedestrian transportation available is the finger pattern extending out the major paths of movement, in this case, Market Street and the Delaware River.

The average speed of movement seems to have had some limiting effect on the
maximum distance of development from the center. The limits up and down¬
stream and inland are 1.25 mile, or thirty minutes' travel time on foot from
the center.

The density of Philadelphia in 1800 was about 27,000 persons per square mile, which is very dense. It was centralized on the Delaware - its source of sup¬
port through commerce. Its unit of growth was the building or small groups of
buildings and it had a strong small scale network of streets for pedestrian
movement. In short, all of the characteristics previously mentioned in associa¬
tion with slow movement systems are evident in the early growth of Philadelphia.

CHICAGO's early growth shows the same characteristics as Philadelphia's.
The city was laid out in smaller blocks, and growth proceeded at a block-by-
block pace rather than building by building as in Philadelphia. But the pattern
of growth is the same - linear along the main transportation routes.

The average speed of movement apparently set a limit here also, since the extent
of development away from the confluence of the two forks of the Chicago River
does not exceed 1.25 mile, or thirty minutes' radius from the center.

The density of Chicago in 1840 was about 3,000 persons per square mile, which is
much less dense than Philadelphia, reflecting the influence of beginning use of
the horsecar and railroad. By this time, the density of Philadelphia had dropped
to 13,000 per square mile, lower than in 1800 but still showing the influence of
the long period of growth under pedestrian movement.
Chicago was centralized on the source of its support - the river for commerce. Its unit of growth was larger than Philadelphia's because it was growing faster. The scale of its construction and transportation network were small, in keeping with the slow movement systems. Only a small part of this stage of Chicago's development survived the fire of 1871 since it was primarily constructed of wood. It was replaced by the patterns of the next stage of transportation development. But the characteristics of pedestrian movement once were visible in the pattern, scale, and density of Chicago, as they were in Philadelphia.

HOUSTON's early growth is similar to that of both Philadelphia and Chicago. The pattern is that of linear growth along the major paths of movement. The block size is similar to that of Chicago and growth proceeds on a block-by-block basis. The extent of growth was not great enough for average speed of movement to have any effect on the size of the city.

The density of Houston in 1850 was about 10,000 persons per square mile, reflecting both the need for density for protection as well as the limitations of pedestrian movement.

Houston was centralized on the source of its support - Buffalo Bayou. Its unit of growth was small. Its network scale was small and the effects from this era on the pattern of the city are slight.
The preceding patterns of growth for the three cities indicate that the pattern of growth generated by pedestrian movement is the linear pattern. Travel time is maximized at 30 minutes in both Philadelphia and Chicago, but Houston's growth is not extensive enough to draw any conclusions about it.

Growth in the linear pattern occurs outward along major transportation routes. In all three cases these are water routes, since the basis for settlement at these locations was water-borne commerce. Philadelphia and Houston also developed along one main overland route.

In the pedestrian era, all three of these cities are dense. Their density, except for Chicago, decreased from this point on. The maximum unit of development was the city block and the small scale was the only appropriate network. All of the cities were centralized.

The differences between these three cities are the result of the pace of growth. Philadelphia was well established and was the largest in terms of population. In spite of the slow pace of growth, the dominant characteristics of the pedestrian city were completely developed by 1850.

Chicago grew very rapidly, but with impermanent structures. These structures were destroyed in the fire and very little of the pedestrian scale survives.

None of pedestrian era Houston survives. There are two reasons for this. First,
the developed area was scarcely half a square mile, so its effects would be limited at best. Second, the whole of pedestrian Houston was destroyed and rebuilt as the city grew.
NOTES


3 Houston City Planning Department, POPULATION, LAND USE, GROWTH, December 1959, P 10.


5 41,000 population on approximately 1.5 square miles of urbanized area

6 4,500 population on approximately 1.5 square miles of urbanized area

7 94,000 population on approximately 5 square miles of urbanized area

8 5,000 population on approximately 0.5 square mile of urbanized area
GROWTH - HORSECAR & RAILROAD ERA

PHILADELPHIA\(^1\), CHICAGO\(^2\) and HOUSTON\(^3\)
PHILADELPHIA's second boom period was during the middle of the nineteenth century. The major forms of movement during this period were the horsecar and the steam railroad.

The diagrams on the preceding page indicate that the effect of these two modes of transportation was to form linear patterns of growth in the central area of the city and nodes surrounding it. The linear pattern up and down the Delaware River which was set by the pedestrian era is reinforced and new linear growth patterns down the Schuylkill and westward along the main land route developed.

During this period the small outlying towns on the railroad lines grew and some new railroad suburbs were begun. Some of the towns which had developed along with Philadelphia were connected (and encouraged to grow) by the horsecar lines.

People were obviously willing to travel more than a half hour to and from the center of the city during this era since the limits of growth exceed the area which could be travelled in that time by horsecar. Judging by the extent of the city, the maximum tolerable time was 45 minutes.

The density of Philadelphia decreased further during this era. In 1880 it was about 17,000 persons per square mile, compared with 27,000 in 1800. The city was still centralized on the area of the original plat – particularly on the Delaware end. The unit of growth was still the building and the scale of the
network remained small, since horsecars ran on almost every street in the center of town.

The railroads provided the beginnings of a large scale network, with their routes radiating out from the center of the city. This mode of transportation was not a network, however, since the radial routes were not connected by other lines of similar transportation.

This boom period, combined with one during the pedestrian era, set the pattern for Philadelphia. By this time it covered almost half the area it would in 1955 and the scale, density, and pattern had been determined by slow movement systems. The pattern for the surrounding area began to be set by the earliest settlements. These were linked by the railroads to become railroad suburbs of Philadelphia and Camden. The growth of such suburbs stems from this era. Each subsequent improvement in the transportation system has reinforced these patterns.

CHICAGO's first boom period occurred in the middle of the nineteenth century. The effect of the horsecar and steam railroad was identical to their effects on Philadelphia.

As in Philadelphia, people were willing to travel about 45 minutes to get to the center by horsecar. The density of Chicago during this period increased to about 13,750 persons per square mile in 1890, from about 3,000 in 1840. This still did
not make it as dense as Philadelphia during the same era.

The city was still centralized on the original plat, and the unit of growth was still the city block, at most. The scale of the network remained small at the center where horsecars ran on almost every street, but approached intermediate scale in the distinct fingers formed on the edges of development.

The railroads provided the beginnings of a large scale network, but the connecting lines for the radials were lacking. The growth patterns of this era provide the beginnings of the nodal and linear patterns of Chicago's later growth.

HOUSTON is still in its early growth stages during this era. The pattern of growth is that of fingers responsive to the routes of the horsecars, but since growth was so slight, Houston did not develop the pattern of railroad suburbs that Chicago and Philadelphia had.

The density of Houston in 1890 was about 2,500 persons per square mile, or one fourth what it was in 1850. Just as in Philadelphia and Chicago, people were apparently willing to travel 45 minutes to the center by horsecar.

Houston's growth is so slow in this period by comparison to that of Philadelphia and Chicago that the effects of the period are hardly apparent in the resulting pattern of the city. The only effect this period had was to begin the pattern of the streetcars, i.e. the main horsecar lines became streetcar lines with the
electrification of the system just after the turn of the century. The unit of growth was still at the scale of the block during this period, but some whole neighborhoods were already beginning to be developed which is really remarkable considering Houston's slow pace of growth during this era.

The preceding indicates that the linear pattern of growth is consistent with the horsecar and the pattern of nodal growth is consistent with the steam railroad. In all three cities, travel time is maximized at nearer 45 than 30 minutes, and the effect of the horsecar and railroad in all was to lower density.

Both Philadelphia and Chicago were served by a dense network of horsecars, so the scale of the network remained small and Philadelphia decreased in density less than Houston did. Houston's network of horsecars was less dense, i.e. the interval between areas served was greater, therefore the linear pattern is more pronounced than in Philadelphia and Chicago.

All three cities remained centralized and relatively dense during this era. Chicago increased in density because its population growth was more rapid than the advance of transportation technology which could have provided more area for growth.

At this stage the pattern of Philadelphia has already been set. Subsequent modes of transportation will serve to support this pattern. Philadelphia is the most dense, most centralized, smallest in scale, and has the most complex pattern.
of the three cities due to the early solidification of its fabric. Transportation has located major land uses and later forms of transportation will be bent and shaped by them.

Chicago's pattern has begun to take shape, but its area growth is not a quarter of what it will be. Houston is still only a market town and is on the verge of growing into a city in the next period.
NOTES


4 Germantown, Manayunk, Darby

5 850,000 population on approximately 50 square miles of urbanized area


7 1,100,000 population on approximately 80 square miles of urbanized area
50,000 population on approximately 20 square miles of urbanized area


Because it has been effected by all of the modes of transportation. Houston and Chicago are both simpler because the patterns are clearly the result of only one dominant mode. (the automobile in Houston and the streetcar in Chicago)
GROWTH - STREETCAR & INTERURBAN ERA

PHILADELPHIA\textsuperscript{1}, CHICAGO\textsuperscript{2} and HOUSTON\textsuperscript{3}
PHILADELPHIA between 1900 and 1920 experienced growth in the patterns set by transportation in use in preceding eras. The continued growth of the nodal pattern shows the continuing influence of the steam railroad which is supported by the interurbans of this era. The linear patterns are the result of the extension and electrification of the main horsecar routes.

The density of Philadelphia in 1920 was about 15,000 persons per square mile, continuing the steady decrease—it was 17,000 in 1880. The city remained centralized on the original plat area, but, along the major public transportation lines, strips of high intensity land use were detaching themselves from the center. Market Street west and Broad Street north were becoming more and more high density residential and commercial due to the continued heavy flows of traffic on them.

The streetcar lines ran at less frequent intervals than the horsecars, making each path a more powerful influence on the pattern of the city and changing the scale of the basic network to intermediate. Instead of major flows occurring on every street, they now occurred at several block intervals.

The linear and nodal patterns were already determined by earlier forms of transportation, and with the increased speed of the streetcar it was once again possible to get to the center in 30 minutes from the farthest point of development.

CHICAGO's second boom period was during the last quarter of the nineteenth and
first quarter of the twentieth centuries. The major forms of movement during this period were the streetcar and interurban.

The effect of the interurbans was to reinforce the nodal pattern set up by the steam railroads. The growth of the streetcar system was an extension, electrification, and elaboration of the horsecar routes. The result was continued linear growth patterns.

The maximum travel time to the center during this era was close to an hour. The pace of growth had completely outstripped the advance of transportation technology.

The density of Chicago in 1920 was about 18,000 persons per square mile, which is more than that of Philadelphia in this period. The density of Chicago was still increasing.

The combination of the effects of the railroad and interurban has provided Chicago with a well-developed, large-scale public transportation network consisting of both radials and connections between them. Since the streetcars ran on less frequent path intervals than the horsecars, a strong intermediate scale network developed within the city during this period.

The linear patterns of the streetcar lines soon evolved, high intensity land uses, high density residential and commercial, contributing to the decentralization of the city. Milwaukee Avenue northwest and Archer Avenue southwest are examples of this
in the pattern of Chicago. All modes of transportation still focus on the center, so the city remained centralized in spite of this trend to decentralize.

The scale of growth during this era was the neighborhood with either a streetcar line or a railroad station as its hub. The density and centralization combined with this make Chicago the prototypical city of the population influx stage. After this era the density of Chicago will decrease as the explosion stage progresses, but the pattern of the major portion of the city is the result of the extensive use of the streetcar.

HOUSTON's first boom period was during the first quarter of the twentieth century. Since Houston's interurban network consisted of a freight line to Goose Creek and one line to Galveston, the major form of movement can be effectively limited to the streetcar, which was an extension and electrification of the horsecar system.

Growth during this period proceeded in the linear pattern along the streetcar routes. The maximum travel time to the center was slightly more than 30 minutes, which was an improvement over the horsecar.

The density of Houston increased briefly during this era to 4,600 persons per square mile in 1930, largely due to the influx of people following World War I.

The city remained centralized, dense by Houston standards, and had a strong
intermediate scale resulting from the streetcars combined with the previous patterns of the horsecar. The increment of growth was the neighborhood, but Houston was still less than one quarter the size it would become in the 30 years to come.

The preceding indicates that the pattern of linear growth is consistent with the use of the streetcar and that the pattern of nodes is reinforced by the interurban. In Philadelphia and Houston travel time was a maximum of 30 minutes, but the growth of Chicago was so great that a maximum of an hour was required to get to the center by streetcar.

The effect of these two modes of transportation was to continue to lower it, but both Chicago and Houston were growing faster in population than in land area so they became more dense during the era of the streetcar and interurban.

This era added the intermediate scale network to the city. All three cities exhibit the effects of the streetcar at this scale. Chicago is dominated by it.

By the end of this period the pattern of Chicago has been established and subsequent means of transportation will serve to support this pattern. Chicago is the second most dense and centralized, intermediate in scale, and has the second most complex pattern. Transportation has located major land uses and later forms of transportation will be bent and shaped by them.
Houston's pattern has finally begun to be determined. The major growth has not taken place yet, but the beginnings of the linear pattern which predominates has been set by the pattern of streetcars in use during this period. These patterns will be extended by newer means of transportation in the next era.
NOTES

1  See notes in part 2 for sources of first two drawings in this sequence.
Source for interurban routes: Hilton, George W., and Due, John F., THE
ELECTRIC INTERURBAN RAILWAYS IN AMERICA, Stanford University Press,
Stanford, 1960, PP 292 & 308. Sources for streetcar routes: ELECTRIC RAILWAYS,
Speirs, Frederic W., THE STREET RAILWAY SYSTEM OF PHILADELPHIA, ITS

2  See notes in part 2 for sources of first two drawings in this sequence.
Source for interurban routes: Hilton, George W., and Due, John F., THE
ELECTRIC INTERURBAN RAILWAYS IN AMERICA, Stanford University Press,
Stanford, 1960, P 340. Source for streetcar routes: CHICAGO AREA TRANSPORTATION STUDY, FINAL REPORT IN THREE PARTS, Harrison Lithographing,

3  See notes in part 2 for sources of first two drawings in this sequence.
Source for interurban routes: Hilton, George W., and Due, John F., THE
ELECTRIC INTERURBAN RAILWAYS IN AMERICA, Stanford University Press,
Stanford, 1960, P 379. Source for streetcar routes: Houston City Planning
Department, REPORT OF THE CITY PLANNING COMMISSION, 1929.

4  1,800,000 population on approximately 120 square miles of urbanized area

5  2,700,000 population on approximately 150 square miles of urbanized area

6  300,000 population on approximately 65 square miles of urbanized area

7  Due to the effects of so many different forces - second to Philadelphia, the only differences being no pedestrian scale in Chicago, and a truly dominant intermediate scale.
GROWTH - AUTOMOBILE ERA

PHILADELPHIA\(^1\), CHICAGO\(^2\) and HOUSTON\(^3\)
PHILADELPHIA in this period exhibits the effects of the automobile on the small and intermediate scale city. The extent of the subway/elevated system indicates that it plays little or no part in the growth of the city. It is influential in changing the areas it runs through only. It encourages intensive land uses near its stops.

The motorbus routes are not shown because they do not effect the pattern of the city. They are employed on the old routes of the electric streetcars and only serve to support the continuation of the patterns generated by the streetcar. The buses are not a factor in the pattern of the city for another reason also, they are not restricted by fixed routes. This does not encourage development along their present routes.

The automobile is the only means of transportation which can operate at all scales of networks. It therefore causes growth at all scales, simultaneously. Growth at the intermediate scale produces commercial strips which are visible in the city, but not on these diagrams. The extension of Market Street westward in Philadelphia is an example of such a strip. Growth at the large scale tends to produce nodes which are also visible in the city, but not on these diagrams. These nodes are the result of accessibility.

The pattern of growth that the automobile promotes is spread in every direction. The existing pattern of land uses and topography are the only real restraints to the growth pattern of the automobile. As is apparent from the diagrams, what
happened to the pattern of Philadelphia as a result of the automobile was that all the voids in it were filled in and the linear and nodal patterns of the past no longer show.

The large scale automobile network skirts developed areas. It avoids major obstacles, but it connects existing major land uses. The intermediate scale takes over the routes of the streetcars, along with the little-used motorbus. And the small scale network becomes the parking spaces, being no longer capable of moving this new kind of traffic.

The density of Philadelphia in 1960 was about 14,900 persons per square mile, only a slight decrease from the 15,000 in 1920. The scale of the city itself was not much changed from that which had been determined by 1920. The major change was the encircling of the railroad suburbs by automobile suburbs.

The city is still centralized, though more and more functions are located out of the center. It is still dense, and retains its small and intermediate scale networks as altered by the automobile. Maximum travel time is on the order of an hour.

CHICAGO's growth during this period exactly parallels that of Philadelphia. The pattern set by previous eras prevails. The density of Chicago in 1960 was about about 15,000 persons per square mile, or almost the same as Philadelphia's.
Chicago's density is decreasing at a more rapid rate than Philadelphia's, having come down from 18,000 in 1920 while Philadelphia's remained almost unchanged at 15,000.

HOUSTON's second boom period is still going on. Since there is no subway/elevated, and since the bus service is completely inadequate, it is safe to say that the primary influence on the growth and pattern of Houston during this era has been the automobile.

Population more than tripled during this era and the density changed from 4,600 persons per square mile in 1930 to about 2,850 persons per square mile in 1960. Maximum travel time during this period has risen to an hour.

For all practical purposes, there is no public transportation. Houston has the tendency to destroy tradition almost as Philadelphia tends to preserve it. These two facts indicate why Houston is an ideal place to observe the effects of the automobile uncomplicated by conflicting transportation or tradition.

The scale of development is the neighborhood. The network scale is effectively restricted to the intermediate and large, with the intermediate predominating and providing the structure of the city. The small scale network has at this stage become merely a supporting system for the intermediate scale network.

The linear pattern at the intermediate scale predominates and the nodal pattern
in connection with major large-scale network intersections is developing. The linear pattern is typified by the Westheimer strip and the nodal pattern by the intersection of the Southwest Freeway and West Loop.

The density is low and the city is decentralized more than either Philadelphia or Chicago, but it still has a major center which is recognized as "downtown." The only small, pedestrian scale in Houston is that which is part of buildings or large groups of buildings. The smallest scale in Houston is that which can be served by the automobile.

The preceding indicates that the pattern of linear growth, as well as nodal development is consistent with the automobile, since it can operate at any speed and in any of the three scales of networks of the city. Rapid growth rates, produce spread patterns, and the automobile has facilitated spread by being operable at all network scales during a period of intensive growth.

In all three cities, travel time is at a maximum at about an hour. The density of all three has decreased due to the influence of the automobile and the large scale network has been added to the small and intermediate scale networks of earlier eras during the period from 1930 to 1955.

The patterns of Philadelphia and Chicago remained much the same during this era. The automobile's effect on these two cities is seen primarily in the effects they had on rapid development of large areas of suburban land. With the exception of
the large scale, the automobile adapted itself to the network scales of the pre-automobile city by employing devices such as traffic signals, one-way streets and the other methods of sorting out traffic. The effect of the automobile in these networks has been to extend and intensify the existing pattern, modifying it with the automobile's storage requirements. Transportation of other eras has located major land uses and the automobile has been adapted to suit these locations.

Houston's pattern has finally been determined during this era. With flat land, little other transportation, and rapid areal growth, the patterns of the automobile dominate. The pattern is hierarchical and clear, and it consists of a small scale which serves buildings, an intermediate scale fed by the small scale which carries major flows in the central part of the city, and a large scale network fed by the intermediate scale which allows movement at higher speeds from the center to the suburbs with little conflicting traffic compared to the intermediate scale.
NOTES


3 See notes in part 2 for sources of first two drawings in this sequence. Source for expressways: Contemporary road map, Humble Oil Company, General Drafting Co., Inc., Convent Station, N.J., 1968. No subway/elevated in Houston.

4 2,003,000 population on approximately 134 square miles of urbanized area

5 3,550,000 population on approximately 250 square miles of urbanized area

6 940,000 population on approximately 330 square miles of urbanized area
SUMMARY

The average speed of movement does not by itself determine the limit of expansion of the city. The desires for lower density suburban living, private transportation, and the other advantages of living out of the central city affect this limit. The maximum time spent travelling can be set between 30 and 60 minutes from the center, as the study of Philadelphia, Chicago, and Houston has established. With this rather loose limit, the size of the city is determined by the average speed of movement to the center.

The existence of more than one center raises the point that all persons do not commute to the center any more. Many travel to subcenters within the city and some commute out from the center. These movements may have the effect of increasing the size of the city within the same travel time without any discernable changes in transportation technology.

The advance of transportation technology, making greater average speed possible, had an effect in determining the maximum outward expansion of the city. It did not determine the limit, but it was a consideration. Without it, the great expansion of the city surely could not have taken place.

Philadelphia, Chicago, and Houston all display the linear and nodal patterns in conjunction with paths of movement that are the result of the economic distance between stops of the transportation systems.
Each of these three cities went through two boom periods, one commercial and one industrial based. The first boom took place along with an influx into the city and the second saw the explosion of population to the suburbs. The first boom caused the formation of dense, centralized cities, and the second resulted in less dense, decentralizing cities. The first boom took place while public transportation was dominant, and with the exception of Houston, it was still dominant during the second boom.

All three of these cities have a major central node of activity with linear strips of activity radiating out from the center in corridors of high accessibility. Yet, Philadelphia's rate of growth peaked about 1870, Chicago's about 1930, and Houston's hasn't yet in 1969.

All three of these cities began as the dominant center in the area - as a focus for land and water movement which was the basis for commerce. They grew because of their commercial location and attracted industry because of it, which, in turn, spurred more growth. And they retained the focus on a single dominant center.

The earliest locations for commerce and industry were at the center. All early forms of transportation are thus completely center-oriented. Being center-oriented, they, as a response to the pattern of land use which puts group destination at the center surrounded by individual origins, set up a linear pattern of land use and intensive activity radiating out from the center. The basis for this
pattern was the horsecar.

The streetcar strengthened, extended, and changed the scale of the strip pattern. The motorbus routes are determined by it. And the intermediate network of the automobile is an extension of it. The linear pattern of growth determined by the short economic distance between stops was set early in the development of the three cities and extended by the advance of transportation technology.

The reason Philadelphia, Chicago, and Houston are so much the same is that they all experienced their first boom during periods dominated by centralizing transportation. The pedestrian Philadelphia, horsecar Chicago, and streetcar Houston all set the pattern which later means of transportation adapted to.

The density of Philadelphia is higher than that of Chicago. And that of Chicago is higher than that of Houston. Philadelphia has a large area of small scale city, Chicago is dominantly intermediate scale, and Houston is primarily large scale. Philadelphia is the most centralized of the three. Chicago is second and Houston is the least centralized.

The advance of transportation technology has the effect of decreasing the density of the city as average speed of movement rises. Philadelphia's and Houston's density began decreasing after their first boom periods, widely separated though they were in time. Chicago's density began to decrease only after its second
The prevailing level of transportation technology during periods of extensive growth helps determine the scale of major units of growth. It also influences the size of the major networks of movement and the scale of construction. It is involved in the pace of change. All of these are the result of increasing average speed of movement in the city.

The tendency of the advance of transportation technology has been to make a larger area available to the city, increase average speed of movement, and increase the scale and size of the physical environment. In spite of the centralized nature of Philadelphia, Chicago, and Houston, the overall effect of the change has been to decentralize some land uses formerly found in the central city.

In this category, Philadelphia is the least decentralized and Houston the most. Decentralization is a matter of convenience. It is no longer necessary to have everything in a single, central location. The automobile has made subcenters available. Only those things which require the support of the whole city need be at the center. Civic and government spaces are such activities. Other centers suffice for activities with a limited service area.

So, these three cities are somewhat the same, yet very different because of when and how they grew and the influence of transportation technology on the patterns
of their growth. The clearest patterns have been those which emerged from a great deal of growth dominated by one major transportation system. So, Philadelphia can be categorized as the eighteenth century pedestrian city, Chicago as the nineteenth century streetcar city, and Houston as the twentieth century automobile city.
CONCLUSION

Land use determines which paths will carry major movements of people. Transportation determines where major concentrations of people will be. Land use and transportation are determined by one another.

The first land use and mode of transportation begin the pattern of the city. New land uses must take advantage of the existing transportation system. By the same token, transportation must be provided to serve the pattern of land uses. This cycle of cause and effect is unending.

The role of the traffic and transportation planners in the cycle is that of insuring that the transportation system serves the pattern of land uses. For the land use planner, accessibility to the transportation system is a major criterion. Inevitably, a close relationship between land use and transportation develops. The planners are the public part of the cycle.

Land owners constitute the private part of the cycle. The land owner has an economic interest in transportation because it affects the value of his property. The value and use of his land will be directly related to its accessibility.

Thus the cycle depends on the private use of land and on public provision for transportation.

The relationship between the planner and the land owner suggests that existing
patterns of transportation and land use may be expected to continue in much the same way as we now know them. The activities of the planner and land owner have been determined by an existing physical pattern, maintenance of which is in their best interests. The planner must maintain the level of service to existing land uses and the land most profitable to own is in the most accessible areas of the city.

The result of the cycle has been to overlay new transportation systems on the routes of old ones. The diagram titled MOVEMENT on the next page are composites of all main transportation routes in Philadelphia, Chicago, and Houston. The corridors of high accessibility shown on these diagrams serve a pattern of intensive land uses consisting of high density residential, commercial, and industrial, as indicated on the LAND USE diagrams. Until the land uses change, the transportation system cannot change.
MOVEMENT & LAND USE: PHILADELPHIA, CHICAGO, and HOUSTON
As our society is presently structured, private property is sacrosanct and change may be instigated by private land owners. The planner, because the activity of planning is a public one, is restricted to responding to the decisions of the land owners in serving their property with water, light, power, and transportation. The patterns of the city are, therefore, substantially the result of the financial interests of private land owners.

Patterns of change will evolve slowly because the patterns of the city reinforce themselves. Change will be restricted to areas adjacent to existing corridors of high accessibility. Here will be found new high intensity land uses and new transportation systems.

Transportation and land use determine one another in a continuing cycle of cause and effect. There are two possible ways out of the cycle: public ownership of land or control of access. Either of them could control the cycle, but neither would change it. The cycle of cause and effect between transportation and land use is the basis of the pattern of the city.
NOTES

1 Composite of all maps previously used to illustrate the discussion of the growth of Philadelphia, Chicago, and Houston related to their transportation systems.

<table>
<thead>
<tr>
<th></th>
<th>URBAN GROWTH, FORM, STRUCTURE, AND PATTERN</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>TRANSPORTATION PLANNING</td>
<td>87</td>
</tr>
<tr>
<td>B</td>
<td>TRAFFIC PLANNING</td>
<td>91</td>
</tr>
<tr>
<td>C</td>
<td>LAND USE PLANNING</td>
<td>98</td>
</tr>
<tr>
<td>D</td>
<td>PEDESTRIAN</td>
<td>100</td>
</tr>
<tr>
<td>E</td>
<td>HORSECAR</td>
<td>101</td>
</tr>
<tr>
<td>F</td>
<td>RAILROAD</td>
<td>102</td>
</tr>
<tr>
<td>G</td>
<td>INTERURBAN</td>
<td>103</td>
</tr>
<tr>
<td>H</td>
<td>STREETCAR</td>
<td>104</td>
</tr>
<tr>
<td>I</td>
<td>SUBWAY/ELEVATED</td>
<td>105</td>
</tr>
<tr>
<td>J</td>
<td>MOTORBUS</td>
<td>106</td>
</tr>
<tr>
<td>K</td>
<td>AUTOMOBILE</td>
<td>107</td>
</tr>
<tr>
<td>L</td>
<td>PHILADELPHIA</td>
<td>108</td>
</tr>
<tr>
<td>M</td>
<td>CHICAGO</td>
<td>109</td>
</tr>
<tr>
<td>N</td>
<td>HOUSTON</td>
<td>110</td>
</tr>
</tbody>
</table>
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