

THE REGIONAL IMPACT OF HIGHWAYS

by

PHILIP B. HERR

B.Arch., Rensselaer Polytechnic Institute  
(1953)

SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF  
MASTER IN CITY PLANNING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June, 1959

Signature of Author . . . . .  
Department of City and Regional Planning, May 25, 1959

Certified by . . . . .  
Thesis Supervisor

Accepted by . . . . .  
Chairman, Department Committee on Graduate Students

ABSTRACT

Title of thesis: THE REGIONAL IMPACT OF HIGHWAYS

Author: PHILIP B. HERR

Submitted to the Department of City and Regional Planning on May 25, 1959, in partial fulfillment of the requirements for the degree of Master in City Planning.

This study is an investigation of the importance of intercity and interregional highway location to the growth and economic health of cities, and an attempt to evaluate highway location as a regional planning tool. A comparison is made between the construction of railroads in 1840 and their effect on accessibility patterns and growth rates, and the contemporary highway building program, its impact on accessibility patterns, and its probable effect on city growth rates. The comparisons are made by means of gravity models designed to measure locational advantage with respect to transportation under varying transport system assumptions.

This comparison suggests that except under unusual circumstances intercity expressways will have less pronounced effect on city growth or health than did the railroads of the nineteenth century. New highways do not produce as great or as localized changes in accessibility patterns as did the railroads, and the range of accessibility values is narrower today than a century ago. This indicates a diminution of the effectiveness of transport channel location as a planning tool.

Change in accessibility relative to other areas of the same region is found to be the critical correlative to population growth at this scale, with level of accessibility at most a minor factor in influencing the level of urban growth.

Thesis Supervisor:

Title: Associate Professor of Land Economics

## TABLE OF CONTENTS

I	INTRODUCTION	1
II	MODEL ANALYSIS	6
	Method	
	Models	
	Findings	
	Comparability of the Models	
III	POPULATION GROWTH AND ACCESSIBILITY	32
	Empiric Evidence	
	Further Considerations	
IV	CONCLUSIONS	40
	General Applicability	
	Land Use Implications	
	Planning Implications	
	Further Studies	
V	APPENDIX	47
	Notes	
	Bibliography	

## ILLUSTRATIONS

Figure		Page
1	Transportation Network 1840-1845	4
2	Highway Network 1950-1959	5
3	1840 Potential	8
4	1840 Accessibility	9
5	1845 Accessibility	10
6	1950 Potential	11
7	1950 Accessibility	12
8	1959 Accessibility	13
9	Cost - Distance	15
10	Isopotential Accessibility	18
11	Rte. 3 only Road Change	20
12	Hypothetical Highway	23
13	Cost of Freight Transportation 1800-1959	26
14	Passenger Travel Speed 1800-1960	27
15	National Production and Freight Volume	29
16	National Production and Freight Revenue	29
17	Population Density	34
18	NE-U.S. Comparisons	41
19	Population Growth	54

#### ACKNOWLEDGEMENTS

I wish to acknowledge the assistance of Professor John T. Howard, informal advisor since the conception of this investigation, and of Professor Lloyd Rodwin, my thesis advisor. I also wish to acknowledge S. Gunnar Myrbeck for his contribution of reproduction services, and Dulcie Jones for her editorial and typing assistance.

Finally, I wish to acknowledge the financial sponsorship of this study by the J.C. Nichols Foundation of the Urban Land Institute and the impetus which that Foundation provided to investigate the impact of expressways on land use.

## I INTRODUCTION

The construction of the Interstate Highway System is probably the most ambitious transportation improvement program in the history of the country; possibly in the history of the world. It has been heralded with such statements as:

When it is completed, it will have produced not merely more and better roads, but a new transportation system, surpassing in its impact the great canal and railroad building booms that so radically altered the face of the country in the last century.<sup>1</sup>

This legislation prescribes environmental changes for America on a scale so mammoth as to dwarf all previous public works projects and indeed all man-made physical enterprises except war.<sup>2</sup>

The land use impact of this system has to some extent been made a consideration in its design. We now have enough experience with highway improvements within metropolitan areas to understand the ability of highways to eradicate slums, channel growth into new areas, revive declining areas, and to curtail growth in sections poorly served.<sup>3</sup>

Our understanding of highway effects at a larger scale is less complete. Does making Scranton a major junction of interstate routes give it an advantage over Wilkes-Barre, which is not? Is Evansville, not connected with the interstate system, significantly hurt in comparison with better served cities in the area?

Can the general alignment of intermetropolitan highways be used as an effective tool for implementing our national policy of aid to depressed

---

<sup>1</sup>"The Highway Billions," Fortune, Vol. LVII, No. 3, September, 1958, p. 106.

<sup>2</sup>"The Hundred Billion Dollar Question," Edward T. Chase, Architectural Forum, Vol. 107, No. 1, July, 1957, p. 135.

<sup>3</sup>For a bibliography of material on highway impact, see Arthur E. Warner, The Impact of Highways on Land Uses and Property Values, East Lansing, Michigan State University, 1958.

areas? Could, for instance, a highway system designed to benefit Providence, Fall River, and New Bedford significantly help their economic health?

If it were determined that metropolitan areas of over two million or so are socially and economically "inefficient," could their growth be retarded and development channeled into smaller cities through decisions on highway alignment? Or, conversely, can the growth of such metropolitan giants really be encouraged by highway location, as some contend that they will be by the presently proposed system?

These are all aspects to the question of the importance of highway location to economic and demographic trends at the intermetropolitan or regional scale. This is the subject which this paper explores, with the following ends in mind:

1. A better understanding of broad land-use pressures which may be expected as a result of highway location.
2. An evaluation of highway location as a regional planning tool.

The question of regional highway impact can be resolved into two aspects: Can highway location alter net migration rates, and can highway location significantly alter the relative economic attraction of specific areas?

Whether or not highway location can affect migration rates depends largely upon its ability to influence regional economics. A positive relationship between economic health and migration has been well substantiated statistically. Net migration shows a strong correlation with differences in median income; people move out of low income (or depressed) areas and into high income (or healthy) areas, not only interregionally,

but also within each region.<sup>1</sup> If highway location can significantly affect economic health, it can through that affect migration rates.

The effects of highway location upon the economic health or advantage of one area compared with others depends upon the magnitude and pattern of transportation service changes and differentials between points which can be produced by highway location, the importance of these changes and differentials as a part of living and production costs, and the extent to which these differences in transport costs (measured in both money and time) affect locational decisions of persons and firms.

The method of this study is to analyze, describe, and insofar as possible measure the pattern of transportation costs, and to study how highway location affects these costs. For comparison with highway cost differentials and resultant land use effects, a study is made of the impact of the new railway network of the 1830's to 1850's, whose ultimate effect upon economic health and migration has been well documented. From such a comparison of transport cost differentials and resultant effects the probable impact of the current intercity highway program and the value of highway location as a regional planning tool can be assessed. The area studied in detail is southeastern New England, chosen because of availability of material and a transportation history well suited to this type of study.

---

<sup>1</sup>See Donald J. Bogue, Components of Population Change, 1940-50, Oxford, Ohio, Scripps Foundation, 1957, p. 27, for one of a number of studies which demonstrate this.



TRANSPORT NETWORK 1840 - 1845

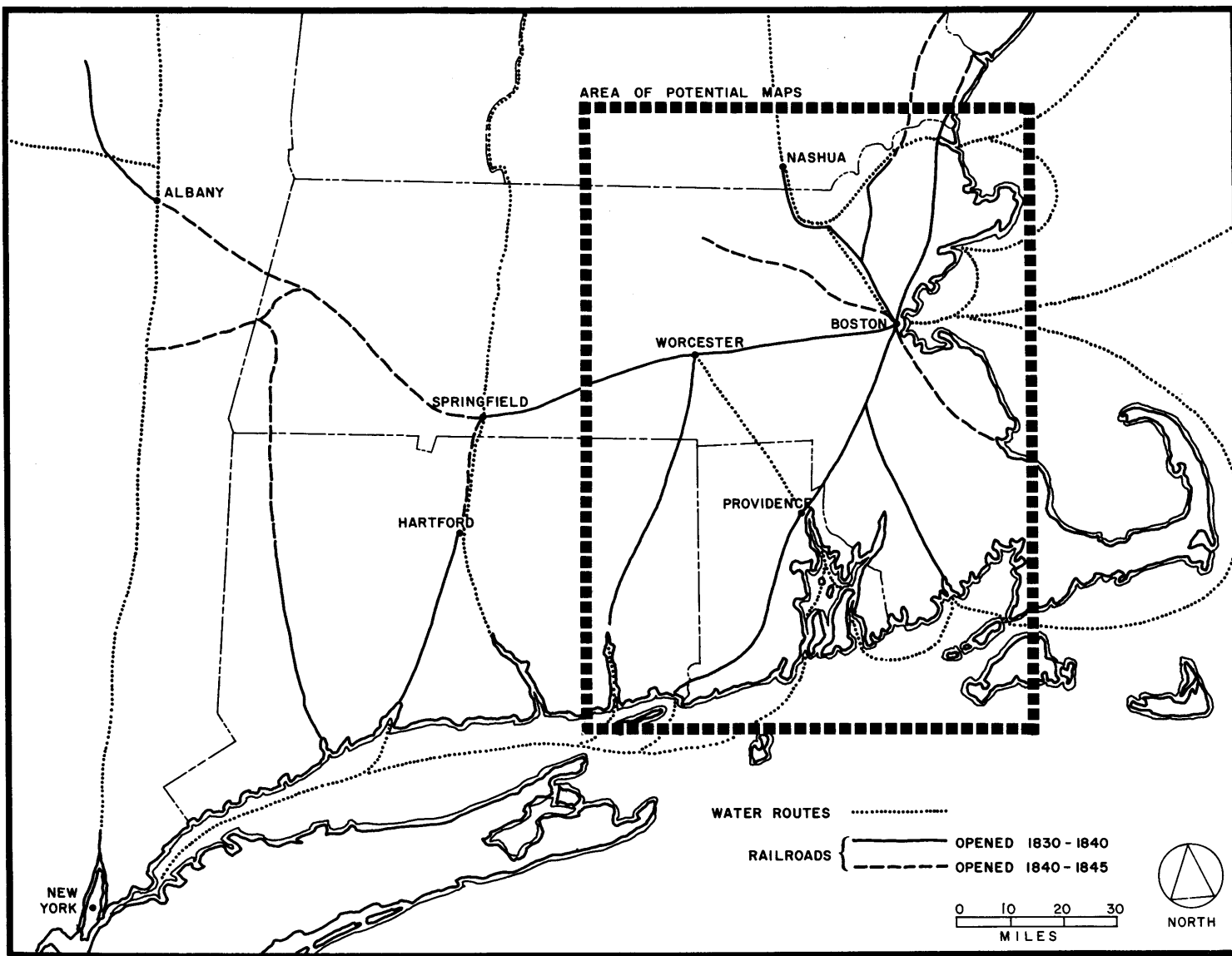
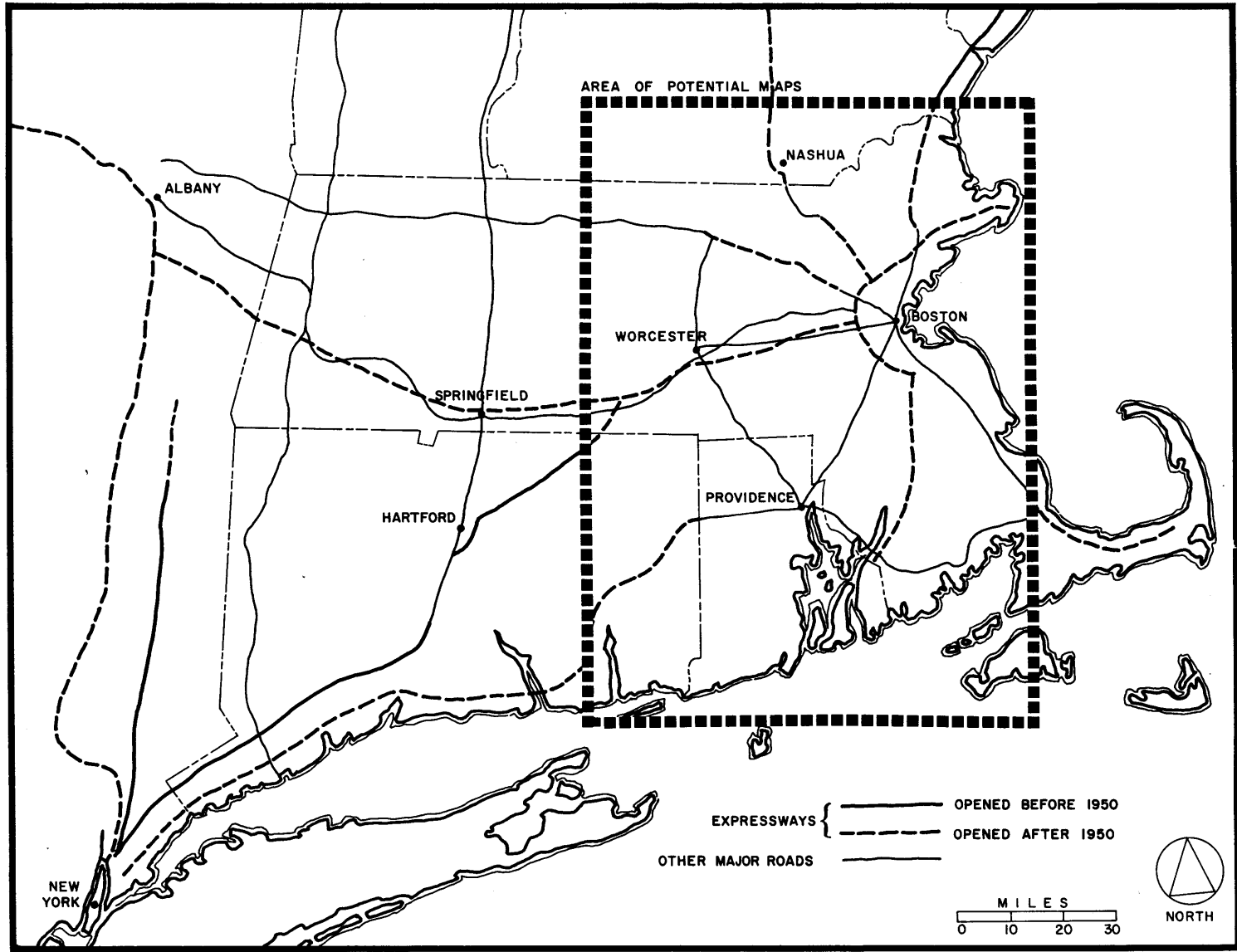


FIG. 1

HIGHWAY NETWORK

1950 - 1959

FIG. 3



## II MODEL ANALYSIS

### Method

The method used for describing the pattern of transportation costs and cost differentials is that of "gravity model" analysis. "Gravity" or "potential" models can be considered as essentially probability models of the desirability (from a transportation cost standpoint) of different locations for the "typical" or "average" firm or individual.

A person or firm will normally want to ship or travel from his location to other cities in direct proportion to their sizes and in inverse proportion to their distances away. While not strictly true in all cases, this general effect has been well established by numerous tests involving freight statistics, airplane trips, and traffic surveys,<sup>1</sup> as well as by simple logic. The probability of any person having a business contact or friend in a neighboring city and so a desire for travel will, all other things being equal, depend upon how large that city is, and how far away it is. For freight shipments, the same sort of logic applies, with the additional distance effect that some goods are nearly ubiquitous (sand need not be imported to Boston from California) and that few are unique; only unique goods need be imported without regard to distance.

The "cost" of carrying out personal and goods interactions is dependent upon how far the locations in question are separated. From the standpoint of transportation costs, then, locational advantage consists of having large amounts of population a short distance away; this can be

---

<sup>1</sup>For a bibliography on gravity models, including many articles confirming the effect of distance on personal and goods interactions, see Gerald Carrothers, "An Historical Review of the Gravity and Potential Concepts of Human Interaction", Journal of the American Institute of Planners, Spring, 1956, p. 100.

quantified and called "potential." The locational advantage or "potential" of a location is the sum of the "potential" contributions of each surrounding point; the contribution of each point is proportional to its size, and inversely proportional to a function of its distance away. This is readily written as a formula and quantified. For this study the general form used is  $V = k_1 \sum \frac{P}{D^2}$  where  $V$  is potential,  $k_1$  is a constant of proportionality,  $P$  is population at any point, and  $D$  is the distance from that point to the location in question. By making this computation for a number of locations, a "contour map" of lines of equal potential, or transport advantage, can be plotted. The higher potential is, the greater locational advantage based on transportation a position has.<sup>1</sup>

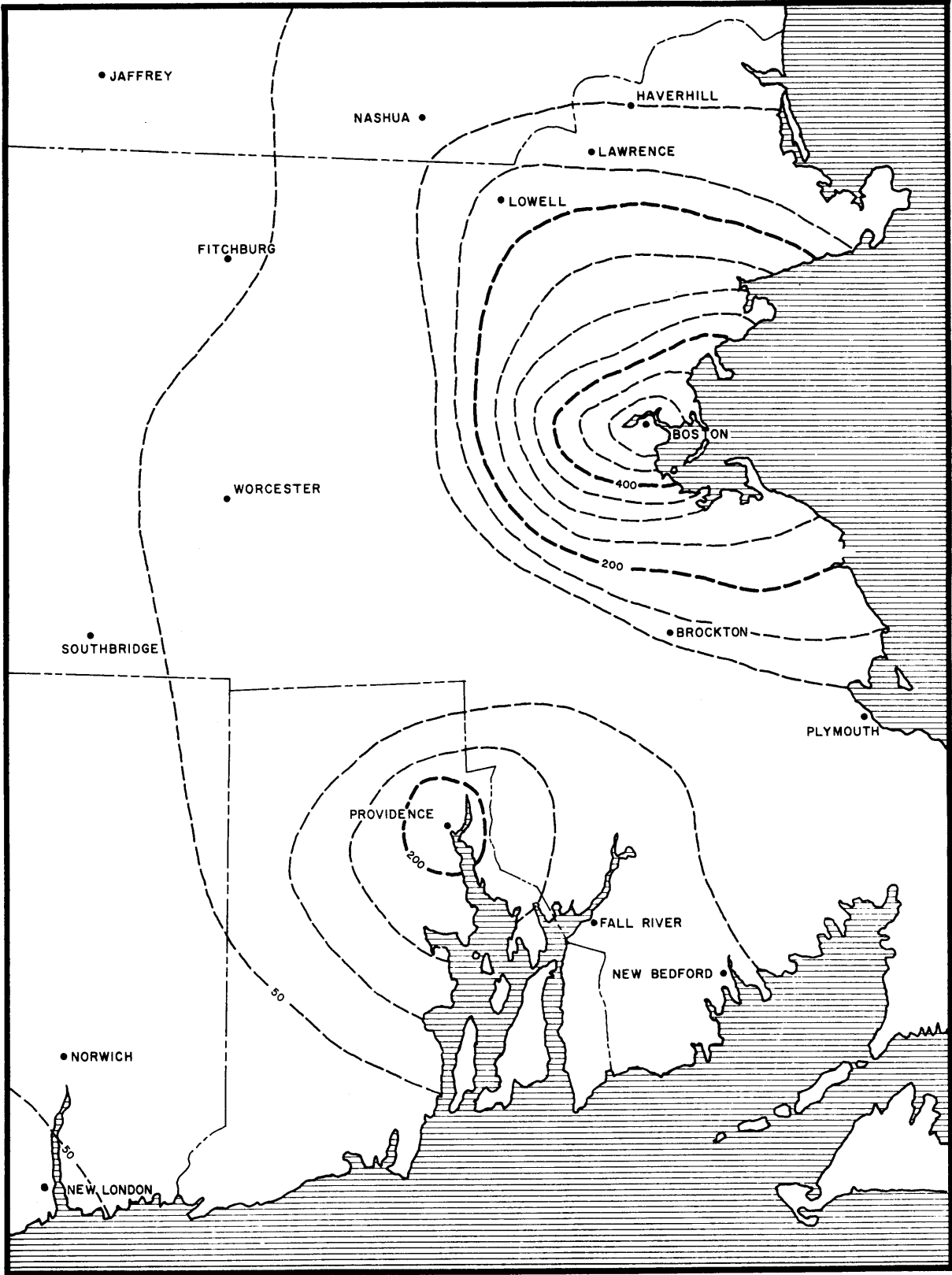
### Models

Figure 3 is a "contour map" of potential for southeastern New England in 1840. Figure 6 is a similar map for 1950. These indicate the pattern of transportation advantage which would obtain if all the northeastern United States were flat and paved, and everyone moved freely in a personal vehicle. Although the magnitudes involved are different, the two maps have strikingly similar patterns, indicating similar population distribution in the two eras.

These models consider only the population of the Northeast, north and east from New York and south from Portland. To consider more or less of the nation's population would make some difference in the values obtained, but the pattern would have most of the same characteristics. A potential

---

<sup>1</sup>Additional technical discussion is found in the Appendix, note 1.



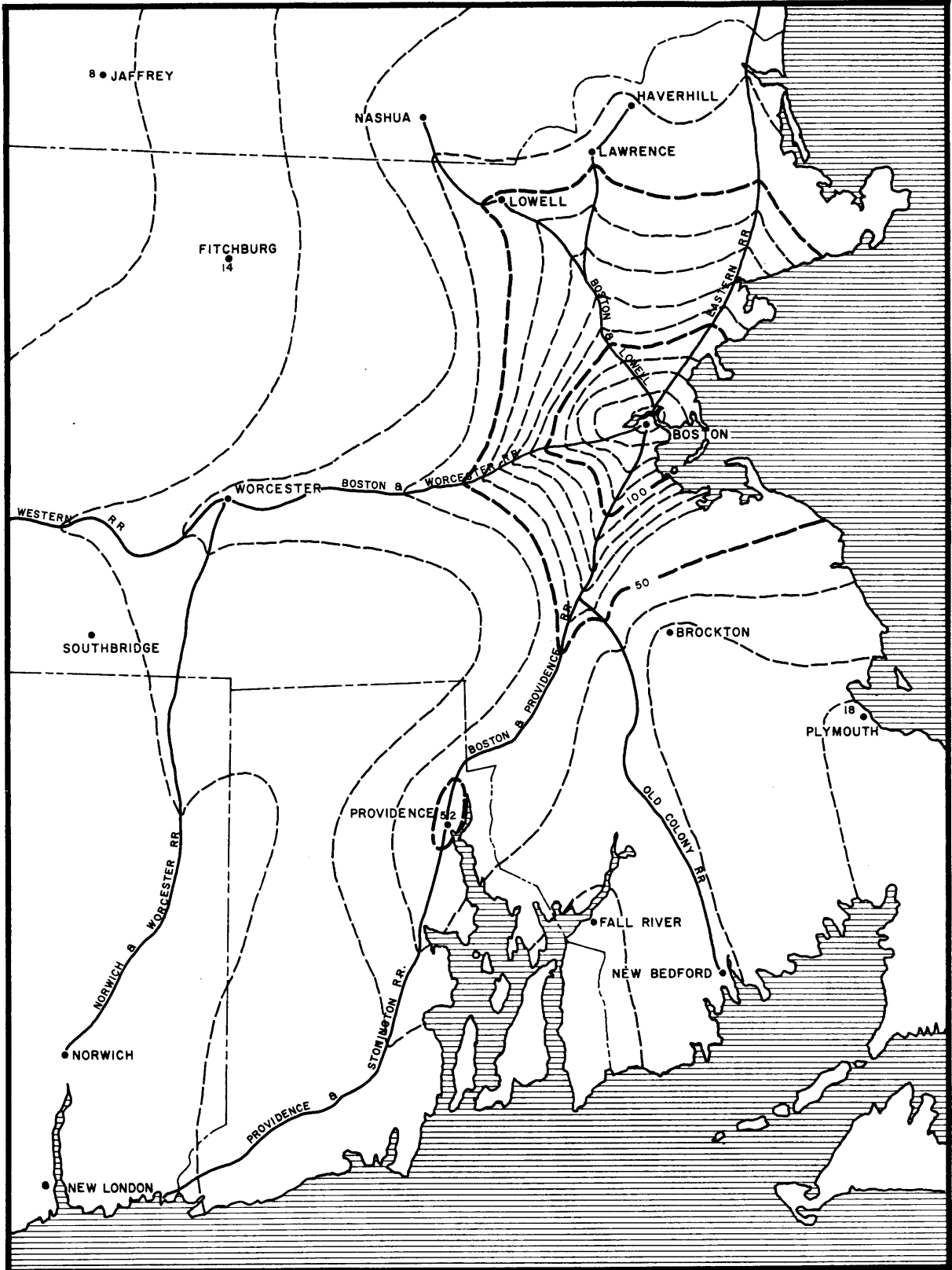
CONTOUR INTERVAL = 50

M I L E S

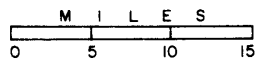
0 5 10 15

FIGURE 3

# 1840 POTENTIAL



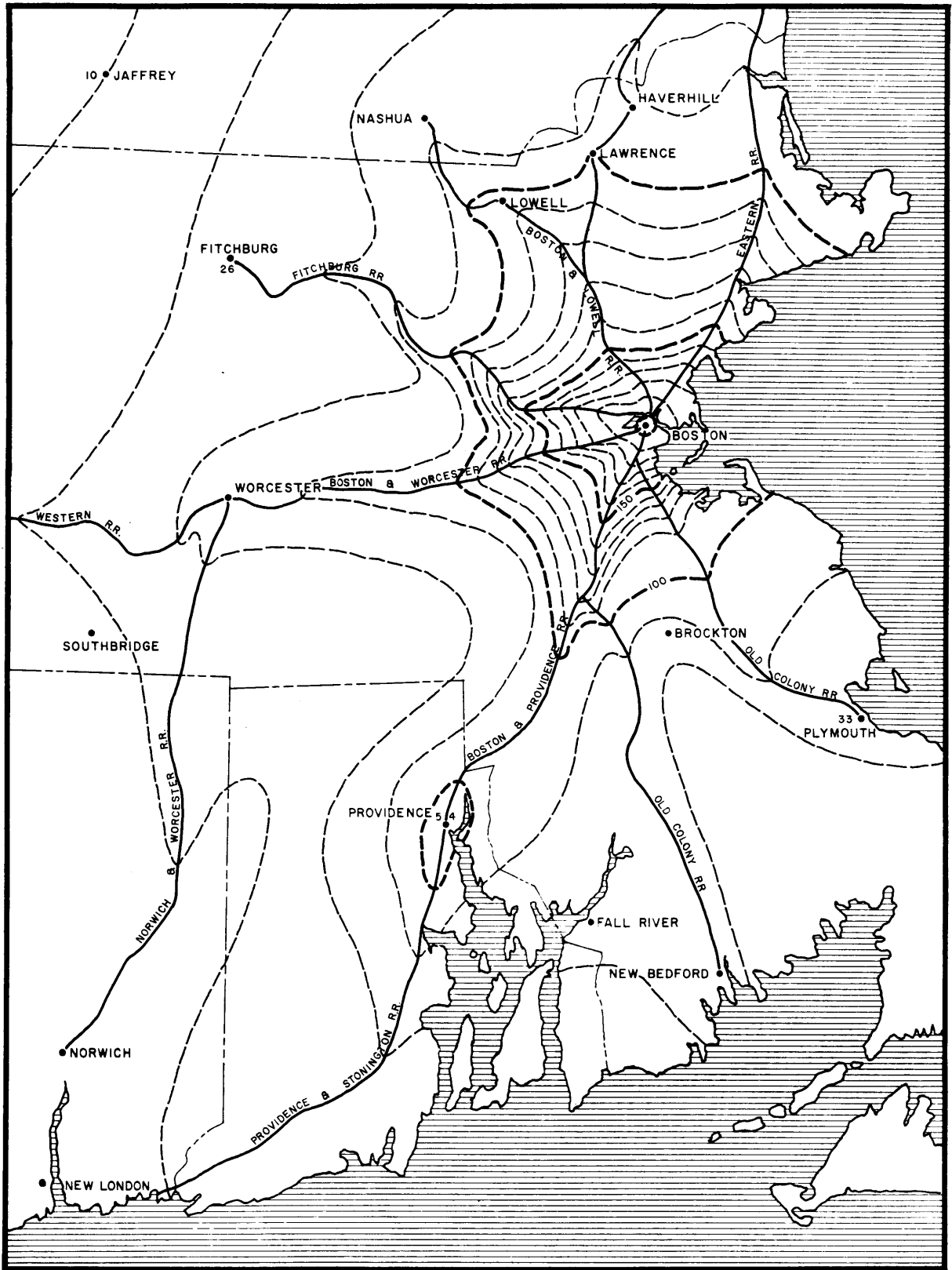
CONTOUR INTERVAL = 10



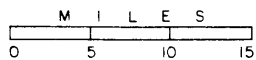
RAILROADS

FIGURE 4

# 1840 ACCESSIBILITY



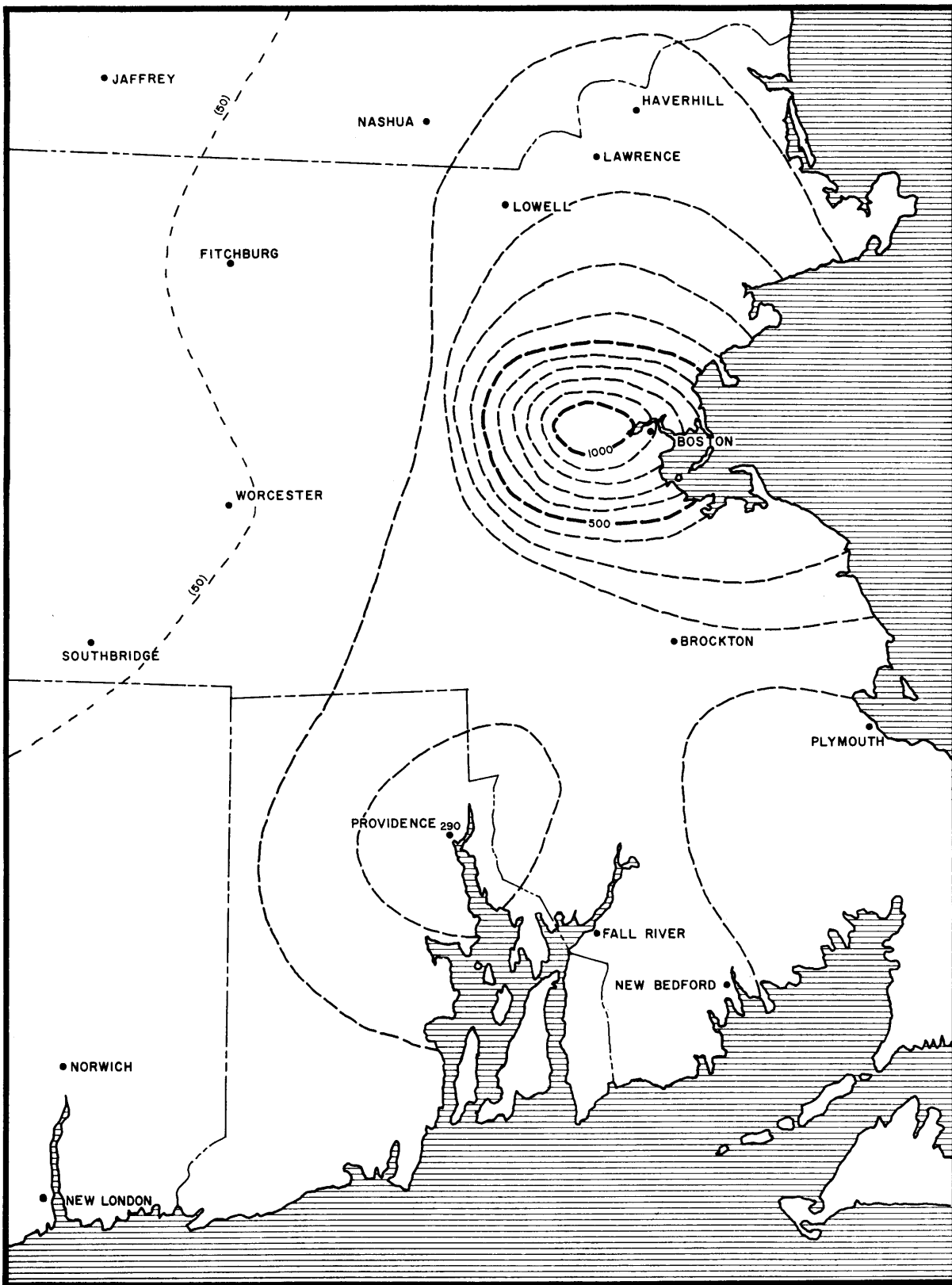
CONTOUR INTERVAL = 10



RAILROADS

FIGURE 5

# 1845 ACCESSIBILITY



CONTOUR INTERVAL = 100

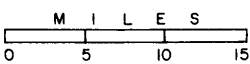
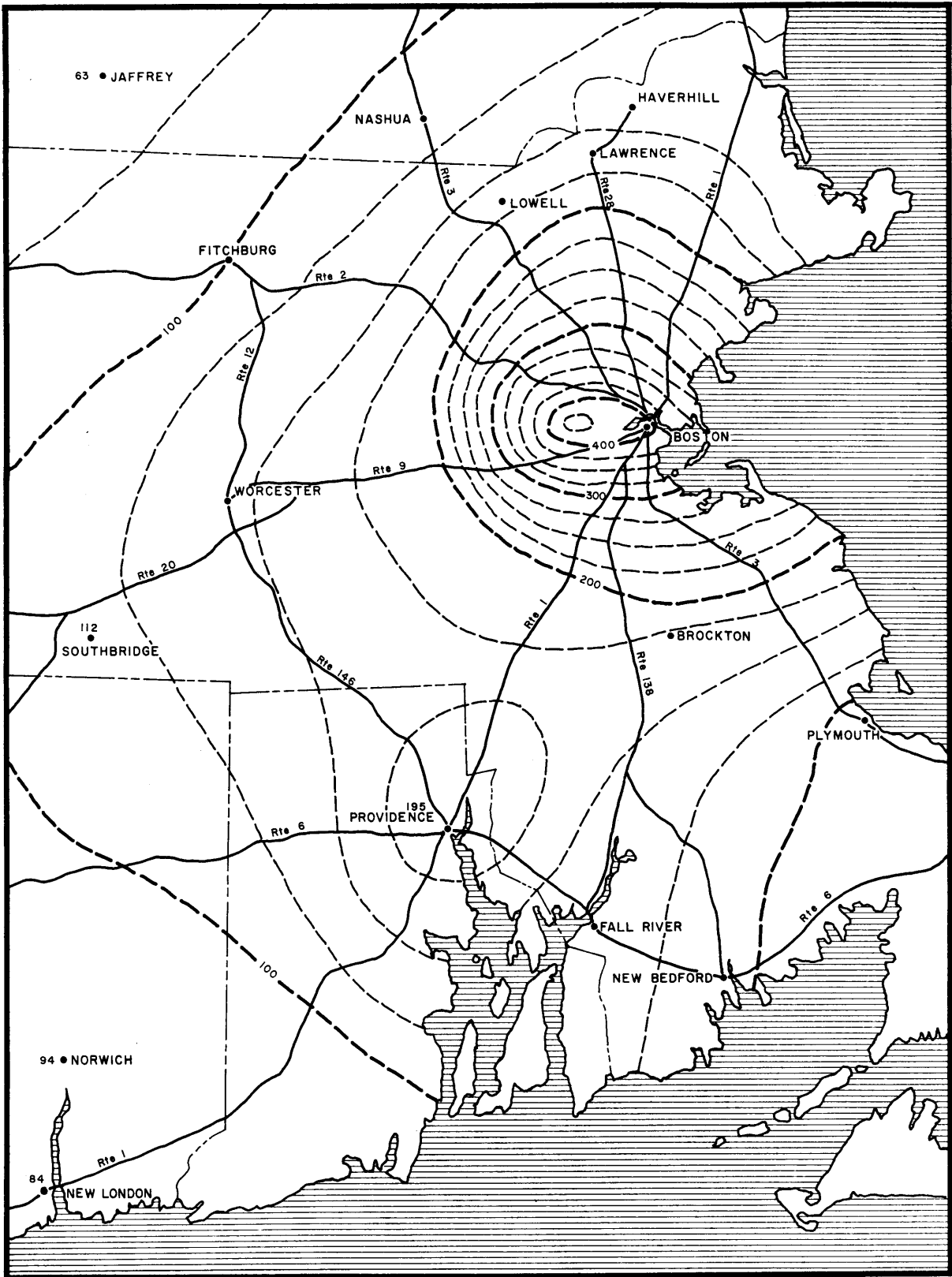


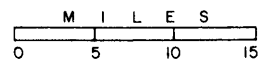
FIGURE 6

# 1950 POTENTIAL





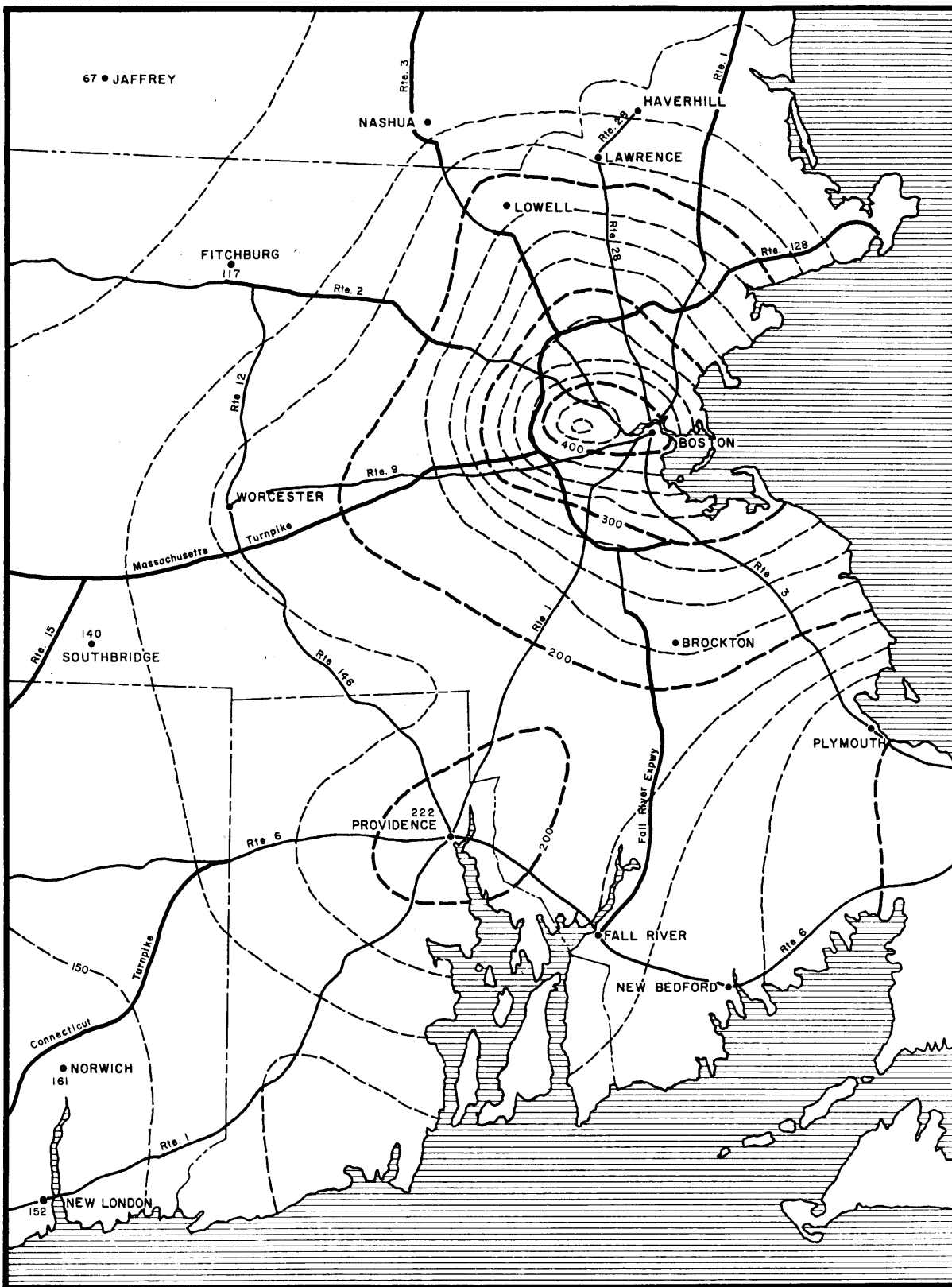
CONTOUR INTERVAL = 25



MAJOR HIGHWAYS

FIGURE 7

# 1950 ACCESSIBILITY

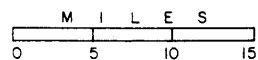


CONTOUR INTERVAL = 25

EXPRESSWAYS

OTHER HIGHWAYS

FIGURE 8



# 1959 ACCESSIBILITY

model considering the population of the entire nation would represent the advantage pattern only for that minority of persons and firms which operate nationally, and would be relatively insensitive to "local" changes in transportation in the Northeast. A model covering less than the area from New York to Portland would fail to include a large part of the intercity trucking and nineteenth-century rail business carried on by persons and firms within the model area.

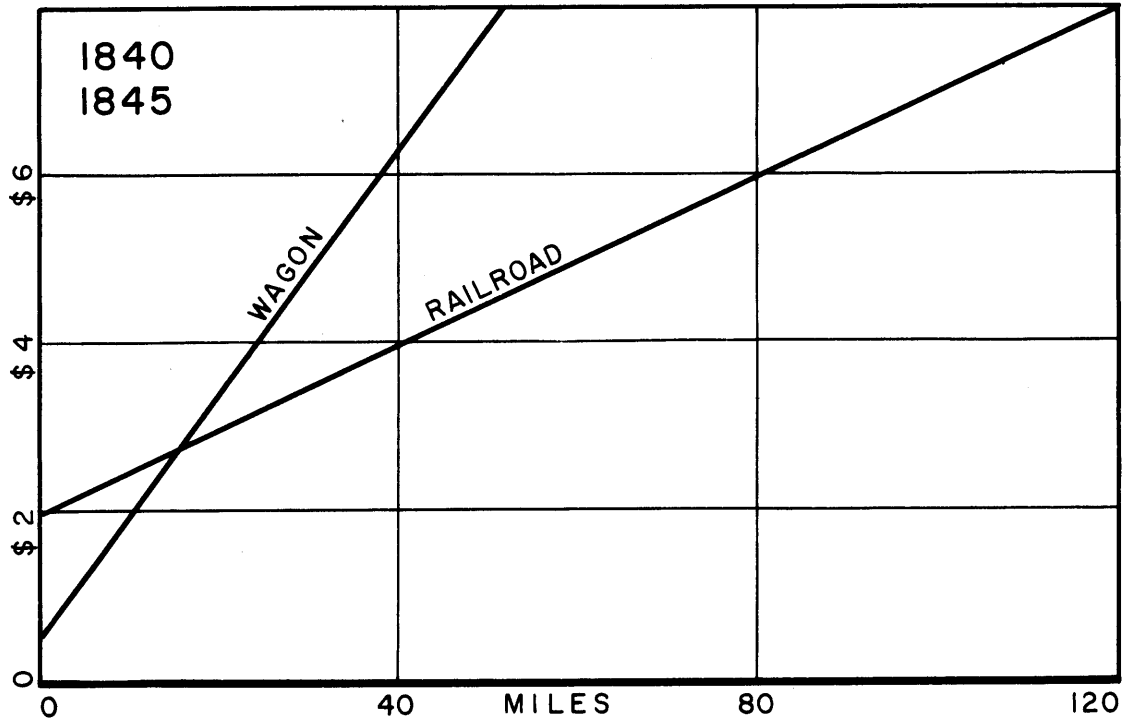
To measure the effects of the transportation system, some of the unrealistic assumptions of these models are dropped. Rather than unchanneled transportation, the actual configuration of transport lines is used. Rather than costs exactly and uniformly proportional to distance, rates varying with mode, distance, and quality of facility (in the case of highways) are used, measuring both dollar cost and elapsed time, which is given an imputed fiscal value (see figure 9).

Instead of two models, one for goods and one for people, one model "weighted" for both has been made. For 1840 and 1845 railroad and highway transportation were considered. For 1950 and 1959 only highway transportation was considered.

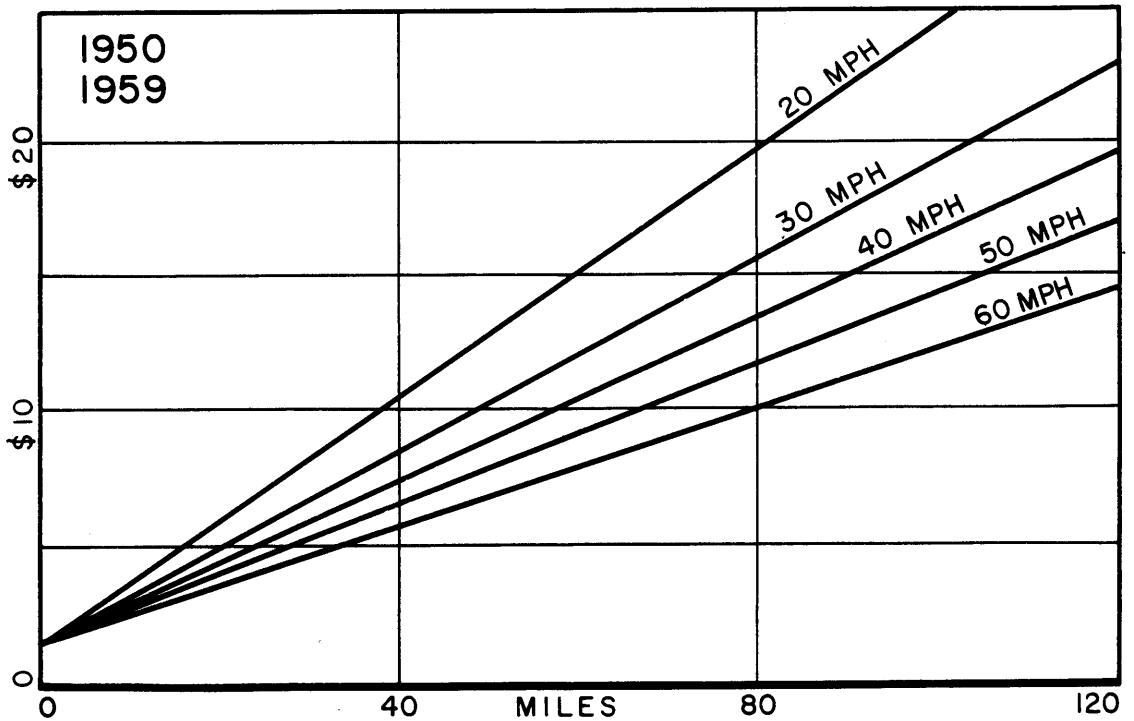
Except for these changes, models are computed exactly as before. Figures 4, 5, 7 and 8 show the results for 1840, 1845, 1950 and 1959. These are called "accessibility" models to distinguish them from the "potential" models which assumed straight-line distances and costs.<sup>1</sup> The mathematical expression for accessibility is:  $A = \frac{P}{C^2}$  where A is accessibility,

---

<sup>1</sup>The terms "potential" and "accessibility" have frequently been used interchangeably. In this study, "potential" refers to the set of values obtained using spatial separation as the "distance" dimension; "accessibility" refers to the set of values obtained using time and cost separation over the actual system configuration.



COST V. DISTANCE  
FIGURE 9



$k_2$  is another constant of proportionality,  $P$  is population, and  $C$  is the time and cost between the points.<sup>1</sup> Potential and accessibility models obviously do not have directly comparable magnitudes, but their patterns can meaningfully be compared. Also, magnitudes of accessibility cannot be directly compared between eras, although their range and patterns can be.

### Findings

Differences between the potential and accessibility patterns are immediately obvious, and are of great significance. The impact of a transportation system on locational advantage could be defined as the differences between the pattern of advantage which would result from an unchanneled system equally efficient in all directions, with straight-line time and cost variations, and the pattern of advantage which actually does result under the realistic conditions. In the terms used here, the impact of a transportation system on locational advantage is indicated by the differences between the patterns of potential and of accessibility.

The first finding made from these diagrams is that the distortions in the pattern of advantage produced by the transportation systems of the 1840's were far greater than the distortions produced today. The "valleys" of relatively low accessibility between rail lines are quite deep in 1840; "valleys" hardly appear in 1950 or 1959 at all. Location on a rail line or a short distance away from it made a great deal of difference in accessibility in 1845. Location on an expressway or a short distance away from it makes relatively little difference today.

---

<sup>1</sup>For additional technical discussion, see Appendix, note 2.

This can be made clearer by following a line of equal potential and observing differences in accessibility along it. That is, we can plot the actual accessibility values along a line where, but for the differentiating effects of the transportation network, accessibility should be equal, taking as a "centerline" an approximate mean value of those along this line, and recording the percentage variations from that mean. Figure 10 does this for each of the accessibility models, using an isopotential line at about the same location each time. The impact of each rail line is clear, but that of individual highways is sometimes indistinguishable and never very pronounced.

This could be expected. Costs of shipment by wagon in 1840 were about 15 cents a ton/mile and moved at about two miles per hour. Shipment by rail cost 5 cents a ton/mile and moved at ten miles per hour. Even a short distance away from the rail line meant the cost of loading a wagon and a very high cost per mile to reach the rail line. Today the "costs" of being away from an expressway are only relatively small ones of slower roads and some circuitry until the expressway is reached. No unloading and re-loading costs are involved.

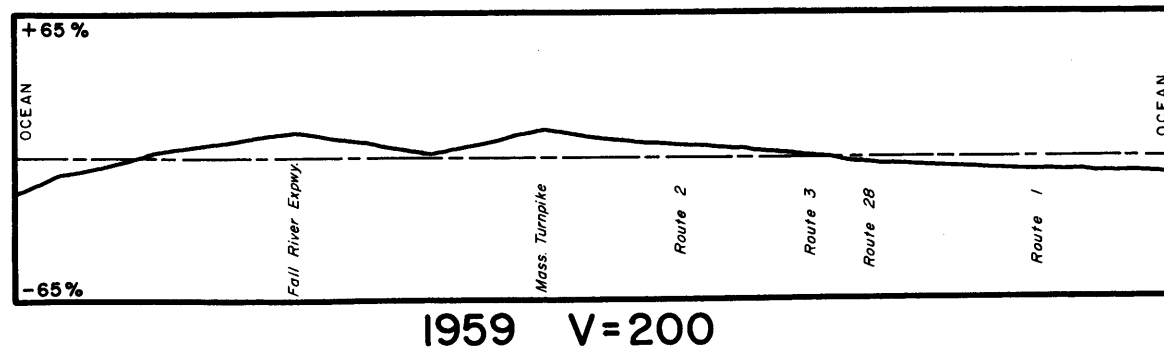
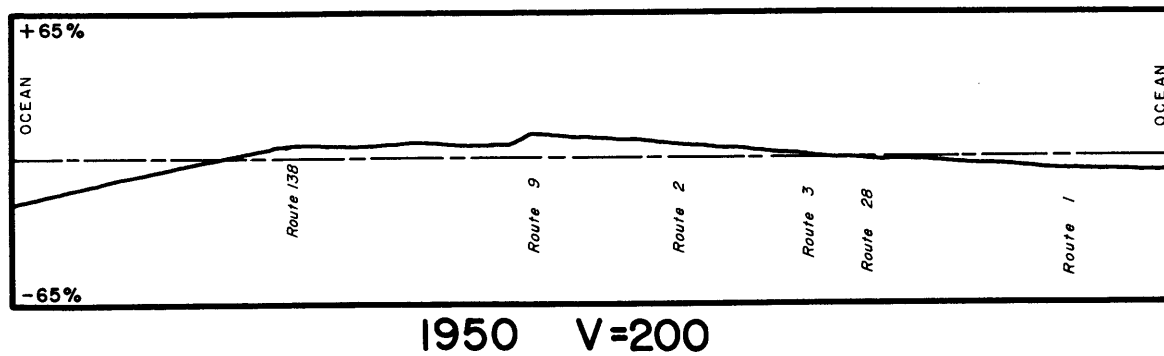
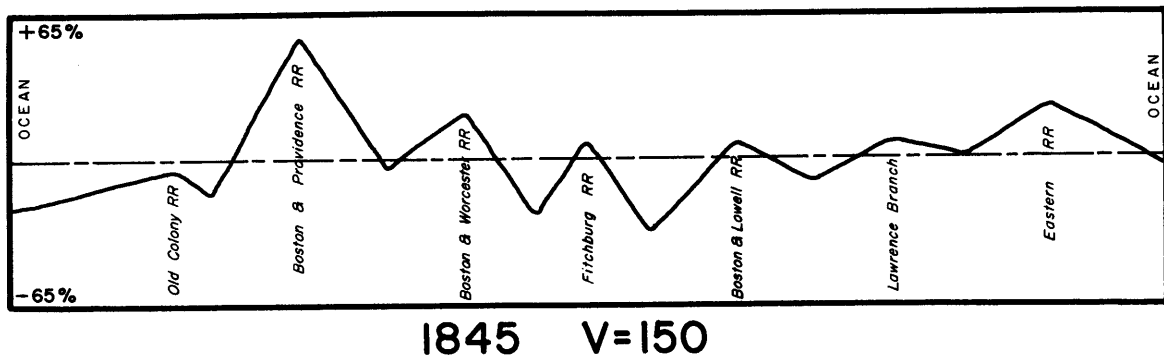
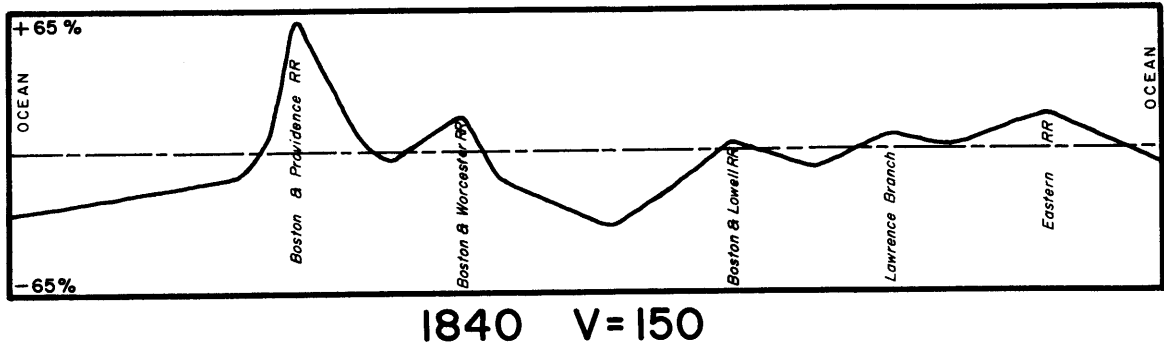
A second finding made from a study of these models is that the range of accessibility values is much narrower today than in 1840. In 1840 accessibility values ranged from 8 (Jaffrey) to 145 (Boston), the largest being 18 times the magnitude of the smallest. In 1959 the range is from 67 (Jaffrey) to 458 (Boston), the largest being less than seven times the smallest. Thus intercity differences in transportation advantage now have a narrower range than formerly.

A third finding, which is almost a corollary of the second, is that the

# ISOPOTENTIAL ACCESSIBILITY VALUES

PERCENTAGE DEVIATION FROM MEAN

FIGURE 10



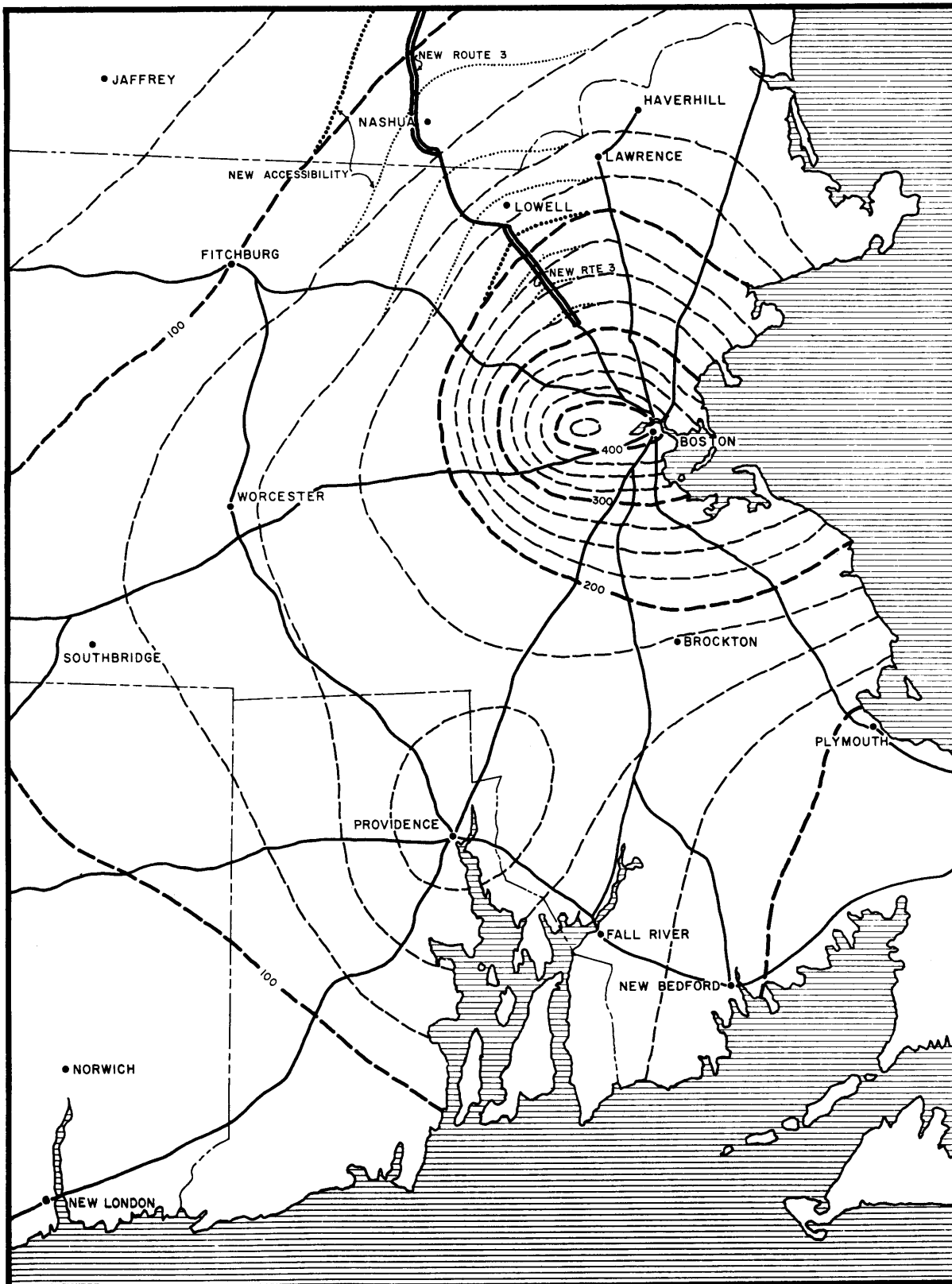
pattern changes produced by changes in the transportation network are likely in general to be less dramatic today than they were in the 1840's.

The construction of the two new rail lines between 1840 and 1845 sharply raised accessibility all along their routes, virtually doubled the accessibility of their terminus points, and left the rest of the pattern nearly unchanged, most of the change elsewhere resulting from improvements on the route to New York.

Pattern changes between 1950 and 1959, on the other hand, are hardly discernible, in spite of the greatest road-building program in history. The "nose" towards Worcester and Springfield has been accentuated, and a new one toward Lowell has been created, but the general picture is unchanged. This might be attributed to the fact that the system has been fairly uniformly developed in all directions, and that it follows roughly the old lines of best transportation. To test this, an approximation was made of the accessibility pattern if the only new road built during this period were route 3, the road from Boston to Lowell and north (see figure 11). This is a major road change, replacing an extremely poor road with a 55 to 60 miles-per-hour expressway. The result is still less striking than the addition of the Fitchburg Railroad or the Old Colony line (to Plymouth) in 1845.

The reasons for the relatively small change in accessibility produced by new expressways are, first, that the savings in time and cost via expressways as compared with the roads that they replace are far smaller than the savings in 1840 by railroad as against wagon. Second, the web of transport channels is far "finer" today than in 1840, with fairly good roads going virtually everywhere with a minor degree of circuitry. As it develops





CONTOUR INTERVAL = 25

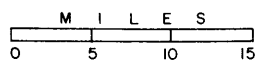


FIGURE 11  
CHANGE IN ACCESSIBILITY IF  
ROUTE 3 ONLY ROAD CHANGE

further and further, our transportation network approaches the assumptions of uniform service made in computing "potential;" as the accessibility pattern more closely approximates the potential pattern, the feasibility of using channel configuration as a planning tool is diminished.

Another finding is that, given ideal conditions, a new highway can raise the magnitude of accessibility of an area by about the same proportion as the new rail lines did in 1845, but that generally magnitude changes will be relatively small. The change in accessibility for Fitchburg and Plymouth between 1840 and 1845 is no more dramatic than the changes for New London and Southeastern Connecticut between 1950 and 1959. Both cases are extreme examples of change for the era.

New London typifies the type of location where new highway construction can make great changes in accessibility. It was poorly served with highways initially. It is in an area of low potential, with that potential being virtually all "contributed" by two cities - New York and Providence. This means that a single highway improving the links to those two cities is of greater relative importance than any single highway can be for, say, Worcester, which draws significant potential from a number of different directions, as well as from itself. Great changes in accessibility can be expected only when a new highway replaces a very poor one, when it leads out of a major population center (or centers), and serves an area of low potential dominated by the importance of the connected population center (or centers) (which excludes the possibility of massive change in accessibility of a major metropolitan area). Unlike the more "channeled" impact of the railroad, this will affect a broader area than the immediately contiguous towns and cities.

A "test expressway" not meeting all of the specifications required for maximum impact is shown in figure 12, indicating also the approximate changes in accessibility which it would produce. These would never be over 15 percent, as contrasted with the 90 percent change in New London. This is a highway of the type which might be proposed to aid the smaller cities which it links without aiding the metropolitan center.

The magnitude of change in New London and Norwich is an exceptional case, and except under special circumstances, like magnitude of change cannot be expected. A similarly "perfect" situation for change was never encountered in the 1840's models; had there been such a situation the change would have been even more dramatic than that of 1950.

Summarizing the findings made from these models, differences in locational advantage fall within a narrower range today than in 1840. Exact location with respect to the transportation network made greater differences in accessibility in 1840 than it does today, due to the "channelized" effect of railroad impact. Changes in the highway network today are less likely to make startling changes in the pattern of accessibility than did changes in the 1840's, but new construction may still produce great alteration in accessibility under special conditions.

#### Comparability of the Models

Accessibility comparisons between the 1840's and 1950's having been made, it is now fair to ask whether both sets of models measure aspects of locational advantage of about equal importance. The answer to this must be in two parts. First, what proportion of the total intercity transportation picture does each set of models represent? Second, of what relative

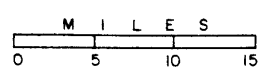
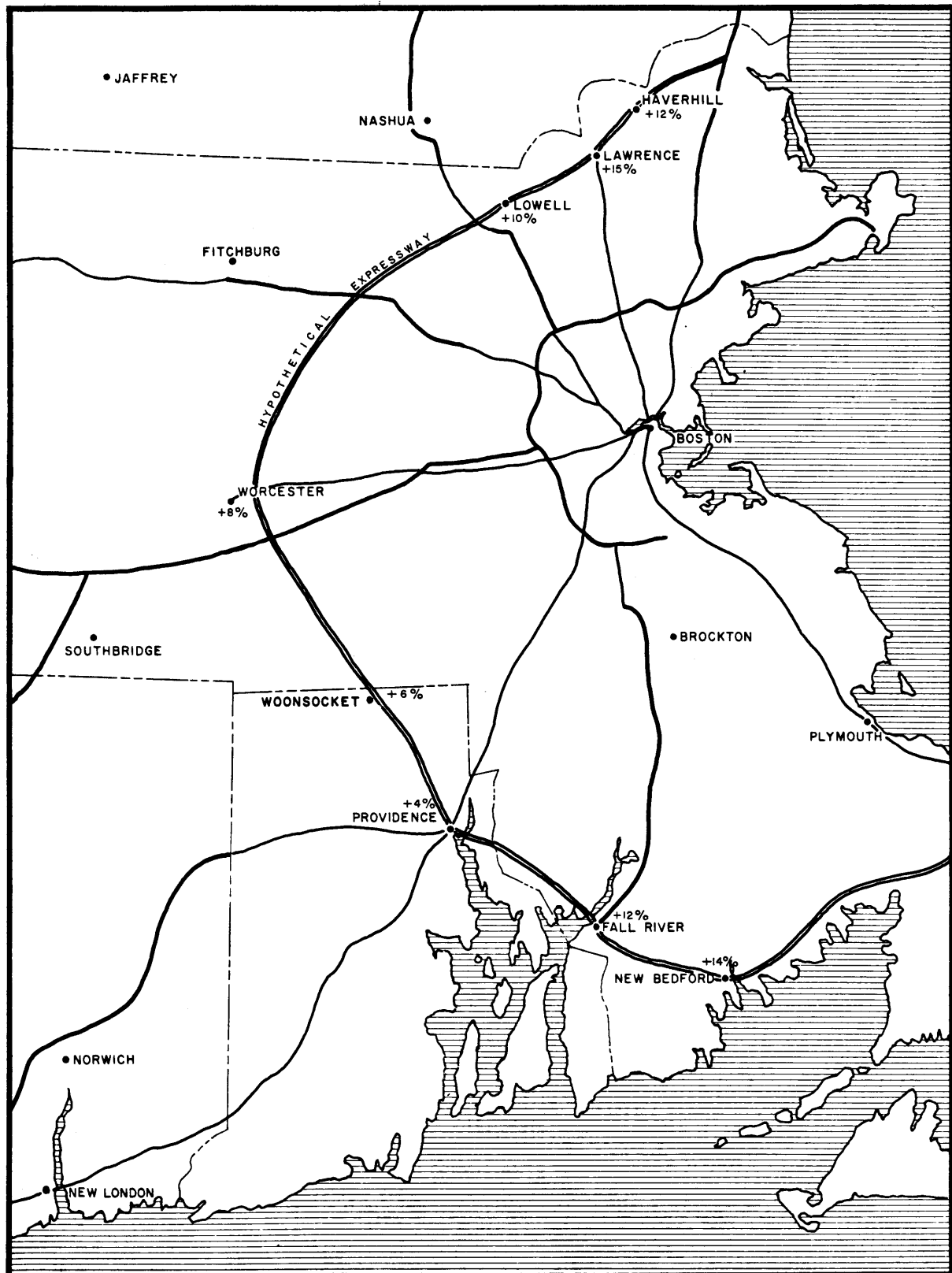


FIGURE 12  
"DEPRESSED AREAS" EXPRESSWAY  
CHANGE IN ACCESSIBILITY

importance in locational advantage was intercity transportation in 1840 compared with today?

Neither model is a "complete" one. The 1840's models omit canals and the coastwise shipping trade, the 1950's models omit railroads, airlines, and coastwise shipping. The question is whether or not these are comparable omissions.

It is impossible to determine the relative importance of water transportation to this area in 1840. The "coasting trade" nationally still carried nearly four times the tonnage that railroads carried in 1852,<sup>1</sup> but New England, with better developed railroads than most areas and with the barrier of Cape Cod, relied on overland transport to an unusual extent. In a sense, however, the accessibility of all port cities has been underestimated by the omission of water travel from these models. Canal travel was no longer of great significance in New England by 1840; its omission is of small significance.

Measured in tons, water transportation is still of surprising importance to New England, amounting to more than that moved by railroad, although considerably less than highway tonnage.<sup>2</sup> Again in this instance, omission of water transport from the models has caused underestimation of the actual accessibility of port cities. Omission of air transport is of small significance. The volume of air freight transport today is tiny, and even passenger traffic by air is less than 4 percent of the total intercity traffic, most of this on longer trips than those included in these models.

---

<sup>1</sup>Taylor, George R., The Transportation Revolution, New York, Rinehart & Co., 1951, p. 174.

<sup>2</sup>New England Governors' Committee on Public Transportation, Public Transportation for New England, Boston, New England Governors' Conference, 1957, reports nos. 5, 7, and 8.

Fortunately for the validity of this analysis, in New England rail traffic today accounts for only about half the overland ton mileage, or only about one-eighth of the total freight revenue. It accounts for about 3 percent of the intercity passenger business, a negligible amount.<sup>1</sup>

In each era, then, a fair-sized portion of the total intercity transport picture has been omitted. A more complete model would have shown higher accessibility for port cities in each case, and being more complete, would have been less altered by changes to highways or railroads only. For the inland portions, both models are essentially "complete." Although impossible to verify statistically, it would appear that the two models are comparable in measuring about the same proportion of the total intercity traffic picture.

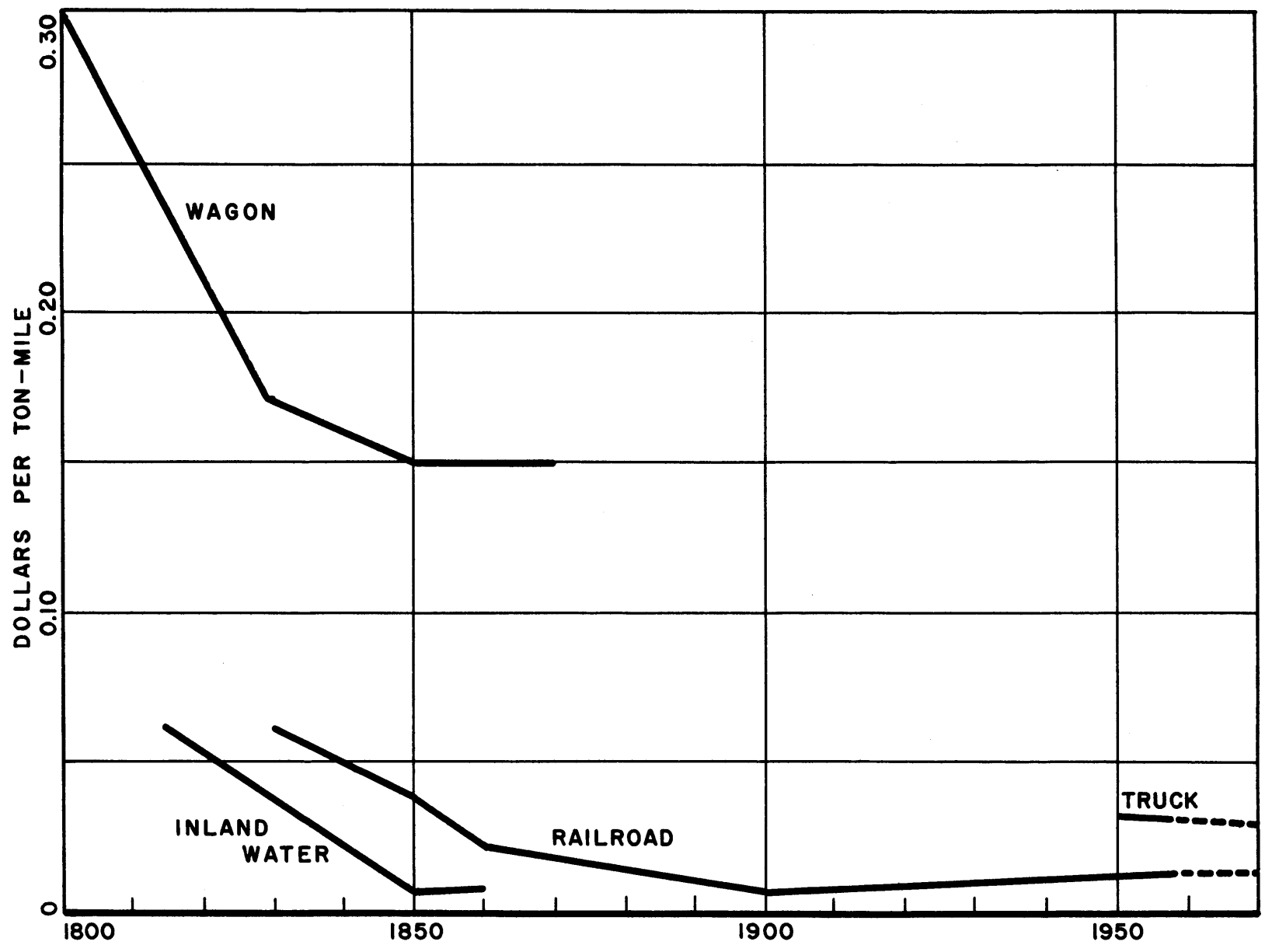
The second part of the question of comparability, that of the relative importance of intercity transportation to location economies, is also somewhat indeterminate. Three concurrent trends have been taking place in transportation for many years. First, rates have been dramatically lowered, dropping from thirty cents per ton-mile by wagon in 1800 to less than two cents per ton-mile by rail today, and speeds have been raised (see figures 13 and 14). Industry has therefore been permitted to centralize to take advantage of efficient locations and economies of scale, despite the lengthened freight hauls to markets or from resources that this necessarily entails. The third trend has been the technological one of requiring less bulk of materials for the same output. A ton of steel today requires a little over a ton and a half of materials for its production; in the

---

<sup>1</sup>Ibid., report no. 7.

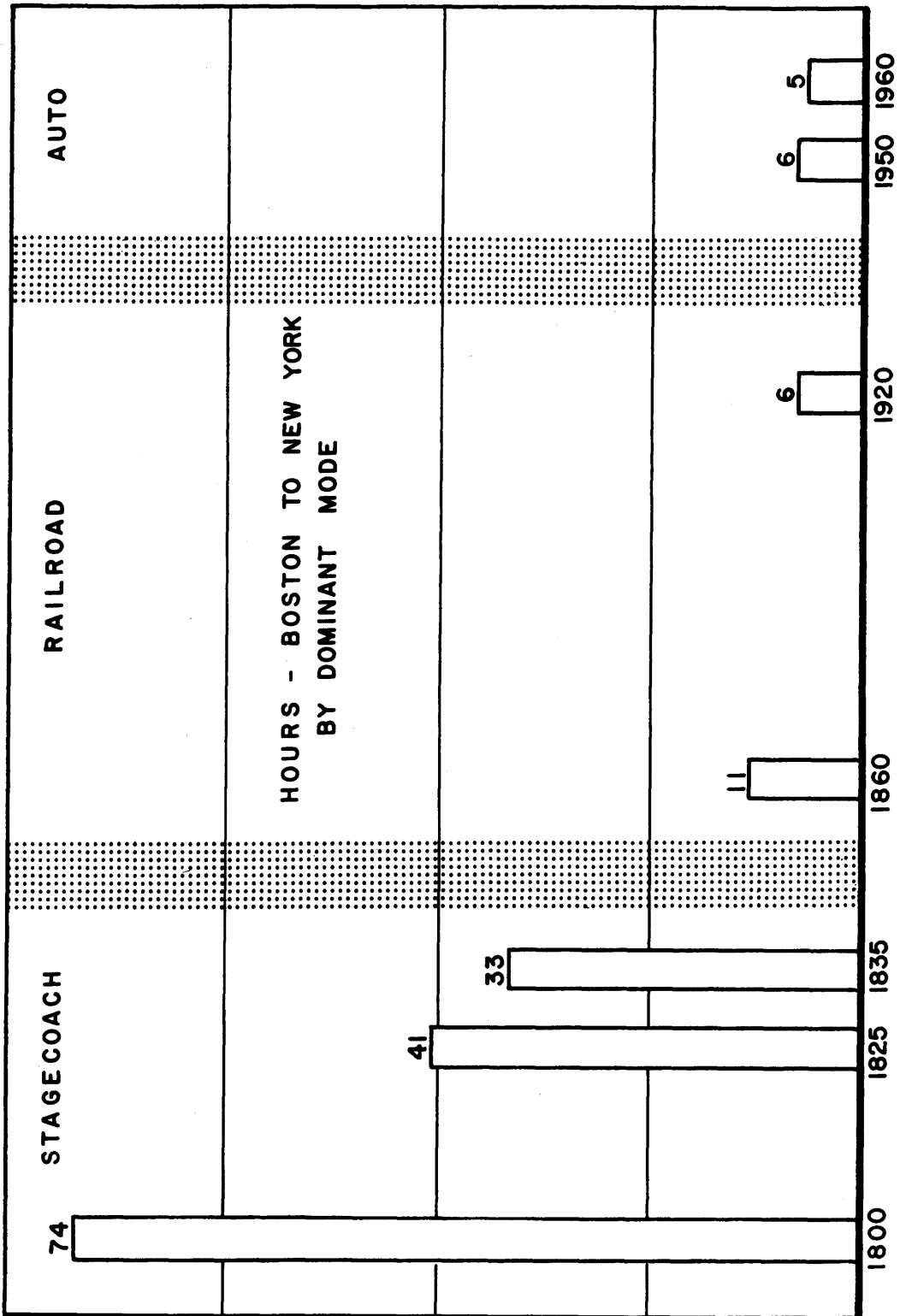
COST OF FREIGHT TRANSPORTATION 1800 - 1959

FIGURE 13



# PASSENGER TRAVEL SPEED 1800 - 1960

FIGURE 14





eighteenth century a ton of pig iron required 11 tons of material.<sup>1</sup>

Other factors are also at play. Tertiary or service output has represented a larger and larger proportion of total production. This type of production is largely market-oriented; it is located generally close to the point of consumption and involves relatively little intercity transportation. A higher standard of living, on the other hand, has made intercity travel more feasible for more people, and has increased the demands for "exotic" goods from distant parts of the nation.

Reliable evidence confirms that for the past thirty years the volume and cost of intercity transportation has about kept pace with the volume and value of production (see figures 15 and 16). This is hardly an adequate base for reverse extrapolation nearly one hundred years, but to do so indicates the reasonable conclusion that intercity transport is neither more nor less important today than in 1840.

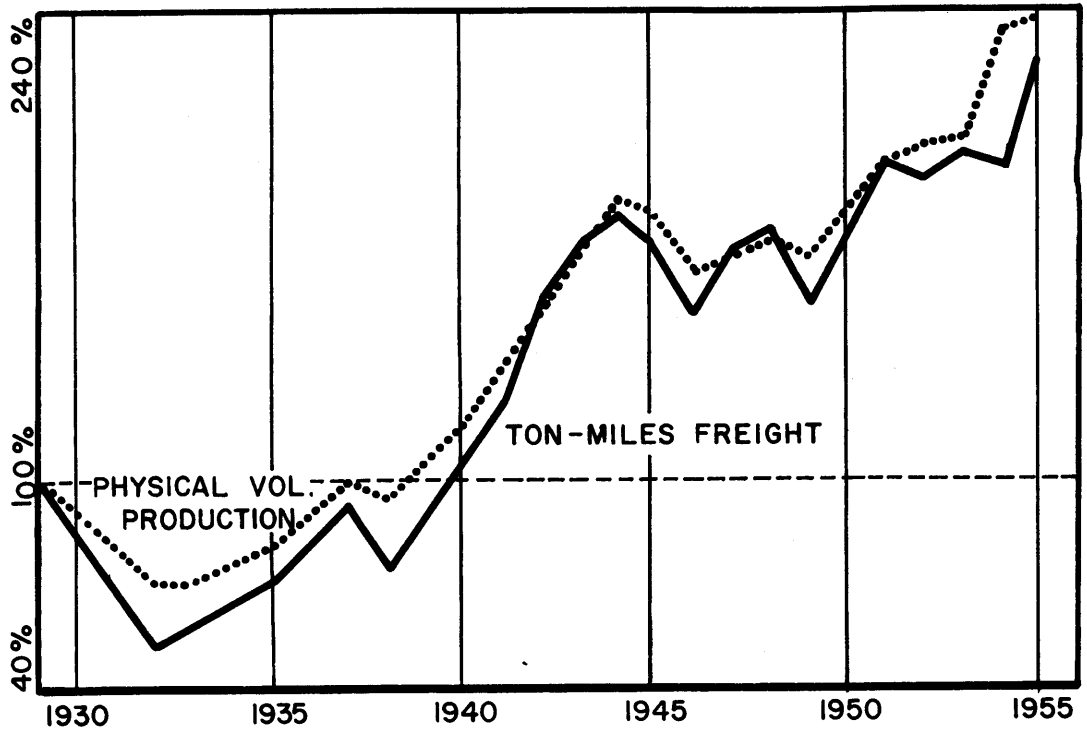
The actual size of the intercity travel bill for the nation is difficult to estimate today, let alone for 1840. National travel expenses, including the personal auto and all its services, have been estimated at \$75 billion for 1956<sup>2</sup> or about 18 percent of the gross national product. It can be inferred from various Bureau of Public Roads statistics<sup>3</sup> that less than half of the total vehicle miles are intercity miles; other modes would

---

<sup>1</sup>Harris, Chauncy D., "The Market as a Factor in the Localization of Industry in the United States," Annals of the Association of American Geographers, Vol. XLIV, No. 4, December, 1954, p. 315.

<sup>2</sup>Burck, Gilbert, "The Great U.S. Freight Cartel," Fortune, Vol. 55, No. 1, January, 1957, p. 102.

<sup>3</sup>U.S. Bureau of Public Roads, Highway Statistics, 1956, Washington, U.S. Printing Office, 1958.



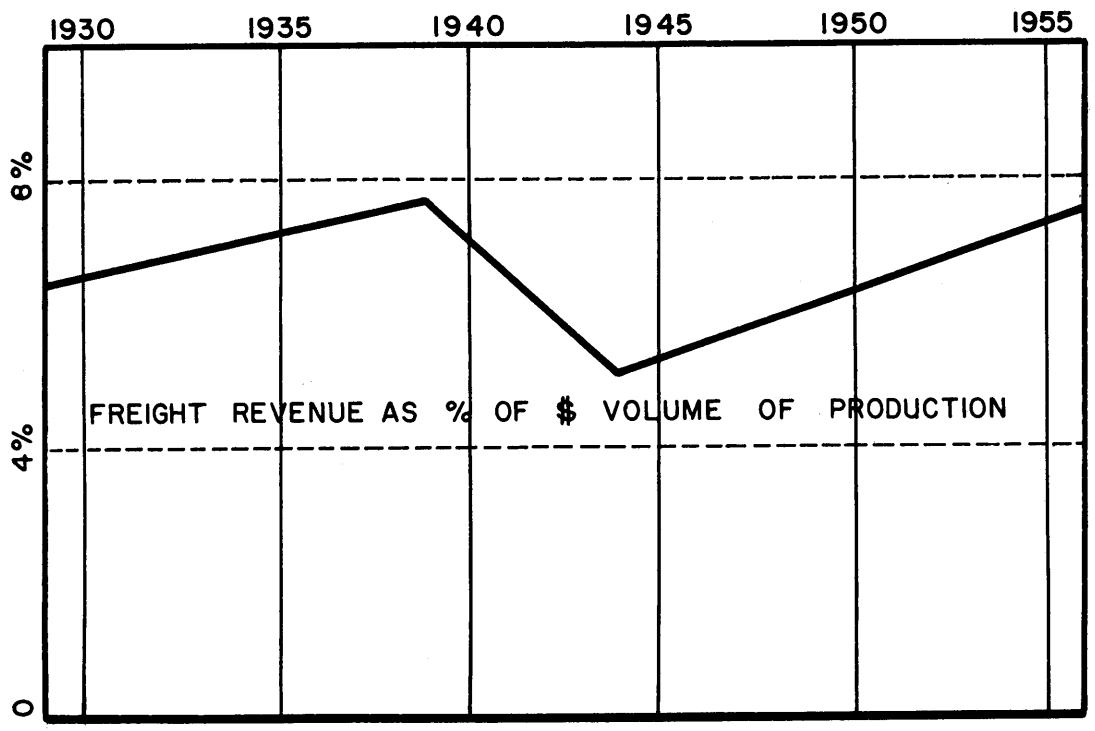
NATIONAL PRODUCTION AND FREIGHT VOLUME

FIGURE 15

Source: *Fortune*, January, 1957

FIGURE 16

NATIONAL PRODUCTION AND FREIGHT REVENUE



certainly have a higher percentage of intercity business, indicating a total of 10 percent or so of gross national product going into intercity transportation of all kinds. It seems unlikely that either very much more or very much less of the national product was spent on intercity transport in 1840.

This analysis indicates, then, that these models are comparable between eras in the completeness with which they cover the transport picture, and in the relative importance of transportation to the total national economy.

A note of caution on the comparability of the eras: the entire environment has not been abstracted and put into these models. So-called exogenous variables - factors beyond those under consideration - may have appreciable influence. For instance, if it could be demonstrated that intercity differentials in labor, capital, tax, and utility costs and problems had all been reduced through the years, then intercity differentials in transportation service would be of increased locational significance today even though they represent no larger a portion of the typical firms' or persons' budget. This trend towards equalization in non-transportation determinants of location in fact seems to be true, but is not easily demonstrable. This, along with the lowering of transportation costs in absolute terms, has led to a great increase in the number of "foot-loose" firms able to locate nearly anywhere, orienting to amenity or whimsy.

One fact which contributed to the transportation impact picture of the 1800's was the enormous overall reduction in overland transportation costs during this era, much of which had taken place within the area of this study before 1840. Although the accessibility of Fitchburg was nearly doubled between 1840 and 1845, in 1840 its accessibility was probably

already vastly greater than it had been prior to 1830, when the major "ribs" of the railroad system went into place. Railroad costs themselves were greatly lowered during these early years, and speeds were raised; even prior to the railroads wagoning costs had been slashed by improved roads and turnpikes.

No equivalent reduction in overall costs appears likely today. Operating costs at the same average speed are lower on expressways than on the roads which they replace, but these savings are spent on the additional cost of operating at the higher speeds permitted by the expressways. The major savings, therefore, are time (although some reduction in operating costs was assumed in these models) and to some extent distance through these straighter lines which make shorter distances between points. Even if time were assumed the only "cost" of separation, the differentials produced by new highways cannot generally compare with those through the period from 1800 to 1850.

### III POPULATION GROWTH AND ACCESSIBILITY

#### Empiric Evidence

Empiric evidence of the significance of differences and changes in accessibility can best be found by following population changes, since these are well recorded back to 1790, and are indicators not only of population movement but also of the economic health of the areas, as discussed in Chapter II.

Two hypotheses have been investigated. The first is the relatively simple idea that, since areas of highest accessibility have a transportation cost and hence economic advantage over areas of low accessibility, they should grow fastest; accessibility and net migration rates should be positively correlated.

This hypothesis was not upheld by correlation study for either the 1840's or the 1950's, and common-sense examination of growth patterns in the area tends to verify that this lack of correlation was not a failure of methodology but that at least at this scale accessibility and population growth are not strongly correlated.<sup>1</sup>

The second hypothesis is that rate of growth is related to change in accessibility; that an area having recently had a greater increase in accessibility than other areas around it will, other things being equal, grow faster than they. This was convincingly verified by data from the nineteenth century, and although it was impossible to test this hypothesis for the 1950's, it can be inferred from contemporary data that it holds

---

<sup>1</sup>For statistical method, see appendix, note 3.

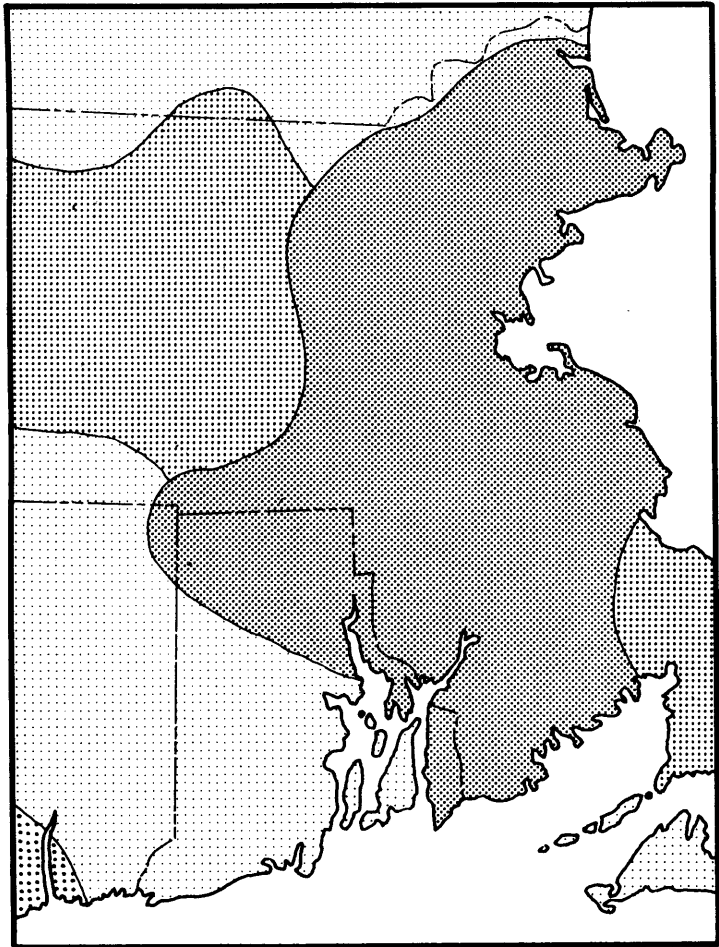
equally true today that change in accessibility and population growth are positively correlated.

The relationship between accessibility and population change can be explained in terms of the dynamic equilibrium which exists within regions. Accessibility, along with labor costs and availability, tax and utility costs, special features of some sites (water power, "prestige" location), and land costs and availability constitute an attractive set of forces "balanced" by migration rates. Sudden alteration of any one of these forces or components will cause a change in the resultant level of migration until "equilibrium" is again reached, in much the same way that unbalanced physical forces cause acceleration. The basic equilibrating forces are land costs and land availability, the first rising and the second declining, following increase in accessibility, until a density appropriate to the new level of accessibility and the other site features (taxes, utility costs, etc.) is reached.<sup>1</sup> Were land costs immediately and fully responsive to change in relative accessibility (or to change in the other factors), differential growth rates would exist only to the extent that high density uses normally prefer locations of high accessibility. The significance of change in accessibility lies largely in this lagging of land cost behind the use value of land following change.




This relationship between change in accessibility and population growth

---

<sup>1</sup>This suggests that density and accessibility (or roughly, potential) should be correlated, which has been demonstrated to be so by Stewart, Roether, and others. For this to hold true always, change in the accessibility of one area vis-a-vis others must be accompanied by extraordinary change in migration rate until density reaches a level again "appropriate" to the areas' accessibility, which is another explanation of the reasons for the observed relationship between changes in accessibility and population.



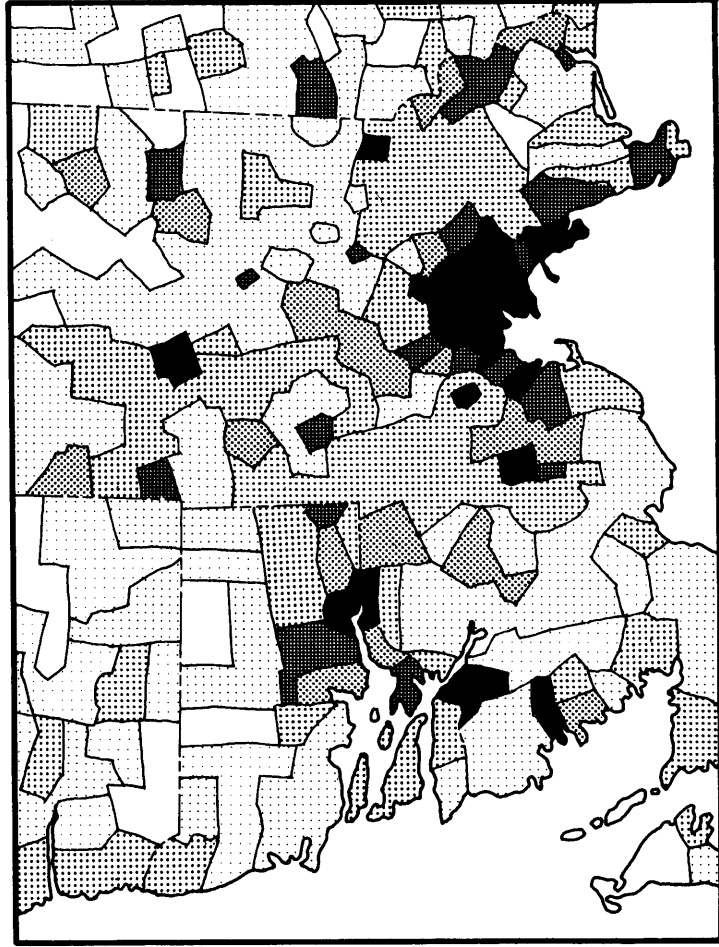
PERSONS PER SQUARE MILE

	125 +
	75 - 125
	40 - 75







1870

1850 SIMILAR

SOURCE: U.S. BUR. OF CENSUS



PERSONS PER SQUARE MILE

	2000 +		150 - 500
	1000 - 2000		50 - 150
	500 - 1000		0 - 25

1940

1950 SIMILAR

POPULATION DENSITY  
FIGURE 17

is a relatively short-term one (perhaps ten to twenty years) which modifies long-range trends of migration to the West and into urban areas, so that "equilibrium" in most cases is not zero growth but growth at some rate determined by secular trends. A long-range relationship between accessibility and population growth may exist at this scale, obscured in relatively short-range studies by the more dramatic population changes associated with change in accessibility.

The hypothetical relationship between change in accessibility and population change is illustrated by growth patterns of nineteenth century New England. The advent of the railroad changed accessibility patterns in two ways. First, the railroad sharply raised accessibility of all points that it served relative to those which it did not serve. Second, it sharply reduced the accessibility advantage which ocean and canal served cities formerly enjoyed over land-locked ones, by providing a superior alternative means of transport. Towns which were inland and rail-connected would have experienced the greatest increase in accessibility. Towns which were seaports and were not connected to the railroad would have experienced the least change, with inland non-rail connected and coastal rail connected towns experiencing an intermediate degree of change.

	Number	1850-1870 % change population	1850 <sup>1</sup> average access.
Inland rail connected	17	53.5	55.6
Inland without rail	16	30.6	35.2
Seaport rail connected	9	27.2	42.7
Seaport without rail	12	5.3	40.8
All rail connected	26	43.7	51.1
All without rail	28	18.5	37.7
All seaport	21	15.7	41.7
All inland	33	43.8	45.8
All towns	54	44.1	31.9

<sup>1</sup>Little relative change in accessibility between 1850 and 1870.



In this examination of fifty-four towns (between 1500 and 5000 population) within the study area, percentage change in population is clearly correlated with earlier change in accessibility, and is clearly not correlated with the static level of accessibility.<sup>1</sup>

The same conclusion is reached by examination of larger cities individually.<sup>2</sup> Fitchburg had its accessibility nearly doubled by the Fitchburg Railroad, and although it was still a location of fairly low accessibility, it grew at a rate two and a half times that of the general area for about ten years. Plymouth, whose similar gain in inland access was more than offset by the decline of its advantage as a seaport, grew even more slowly than before, following the construction of the railroads. Boston, tremendously favored as the "hub" of the newly formed railroad network, had always been tremendously favored as a transport center; it continued to grow at about the same rate in spite of system changes.

A lack of data on population change during the 1950's prevents testing the current relationship between accessibility change and population change, but an inference can be made from a study by Amos Hawley,<sup>3</sup> who found growth rates greatest in those sectors of metropolitan areas having highways but lacking railroads, precisely the areas with the greatest relative increase in accessibility following the advent of the automobile. It appears equally true today as in 1840; change in the accessibility of an area relative to the change in nearby areas is a prime factor in population growth patterns.

---

<sup>1</sup>For statistical discussion, see Appendix, note 4.

<sup>2</sup>For growth data on these and other cities, see Appendix, Figure 19.

<sup>3</sup>Hawley, Amos Henry, The Changing Shape of Metropolitan America, Glencoe, Illinois, Free Press, 1956, pp. 110-113.

To study accessibility at only one point in time or to study change in accessibility in a single area is likely to be meaningless.

#### Further Considerations

Additional observations about transportation impact can be made which are not clearly illustrated by model analysis. These are considerations of "break of bulk," minimum threshold of service, and "irrational" human reaction to transport system change.

Prior to completion of through rail transport to New York City, both goods and people traveling from Boston, Worcester, and points north normally moved by rail to Providence, Stonington, or Norwich, then transferred to ships for the remainder of the journey. This gave to those ports advantages in doing the handling of the goods, and as low-cost locations for processing. Since the goods are being unloaded and handled there anyhow, production at that point involves no additional terminal charges such as there would be at any intermediate location on either the ship or rail portions of the route. With completion of the rail connections to New York just prior to the Civil War, these points lost their special advantage, and their growth rates declined dramatically.

There is no equivalent "break of bulk" associated with a highway system, passengers and freight normally traveling in the same vehicle from origin to destination. The expectation of major impact at route junctions is largely based on a mental "hangover" from the former condition where different modes joined, and to that extent is a delusion.

Gloucester in the 1800's provides an example of the effect of provision of a "minimum threshold of service." Gloucester had all the requisites for

a thriving fishing business except quick access to a major market, which was ultimately provided by the railroad, whereupon Gloucester's trade and population grew all out of proportion to the change in accessibility. Overnight transport to Boston, a necessary minimum level of service for utilization of Gloucester's resources, had been provided.

Similar effects may be expected today in areas brought within overnight trucking or commuting distance of a major metropolis. Lowell, more than by general savings in highway costs, may be aided by being able now (because of a new highway) to offer residents reasonable commuting distance to Greater Boston jobs. Ski areas of southern New Hampshire have already been aided by being brought within "day trip" distance of Boston. The middle Hudson Valley is now as a result of the New York Thruway a suitable location for industries requiring "same day" deliveries to New York City.

Even where rational analysis would indicate that transportation impact should not be great, if there is a public expectation of impact it may occur just because of the expectation. Connection with the railroad was an event of great local importance in 1840, even when rationally unimportant. People expected great changes, so the "business climate" was good. Money was invested in facilities in anticipation of growth. Real estate promoters huzzahed the coming of the railroad in persuading people to locate there. The combination of "climate," stimulated investment, and promotion was probably enough to aid, at least for a while, the growth of some communities.

In the same way today new expressways are being eagerly awaited by numerous chambers of commerce and real estate promoters, ready to froth up a public enthusiasm that may lead to growth over and above that "rationally" expectable. This can be stretched too far, as evidenced by a number of

still vacant though loudly promoted tracts at junctions of major highways in the Northeast, in locations which, even well served with highways, cannot expect great growth.

Intercity highways will through intracity use, have effects not shown by any regional model. Within city or metropolitan areas intercity highways act as urban arterials, with the same expectation of impact as any urban expressway. In less populated areas, the effect of an intercity highway in bringing a larger labor force within commuting distance of any point along the highway may be significant. The relief of congestion caused by through traffic is of substantial benefit to cities and towns bypassed by new expressways, as evidenced by numerous studies.

#### IV CONCLUSIONS

##### General Applicability

The findings made here for Southeastern New England should be of general applicability, but regional differences in highway patterns and dependence upon highway transportation will affect the magnitude of impact which can be expected.

Many areas of the West and Midwest are served by fewer highways further apart than is the East, and traffic moves at speeds of sixty miles per hour and over. Accessibility patterns in such areas are probably more "distorted" along main highways than in the Northeast, but these patterns are also less likely to be greatly changed by new construction, which will do relatively little to raise intercity speeds, but will primarily aid travel through urban areas.

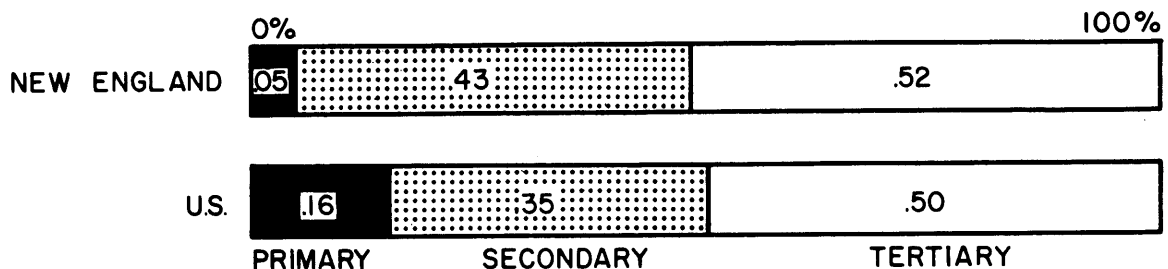
The dependence of areas upon highways also varies. New England is poorly located in a corner of the nation, with its industrial competitors between it and the rest of the country, so that through the years the industries which have prospered here have become "select" on the basis of not being heavily transportation-oriented. Extractive industries are of far less than average significance in New England, while manufacturing and service industries are of disproportionate importance. Distances between cities here are relatively short. All this suggests that in New England transportation generally would be of relatively low importance but that highways would carry a larger proportion of the traffic than in the "typical" area. This is borne out by the diagrams of figure 18.

Technical changes in the near future seem unlikely to affect transportation impact. A dramatic lowering of costs through gas turbine, free piston

## NEW ENGLAND - UNITED STATES COMPARISONS

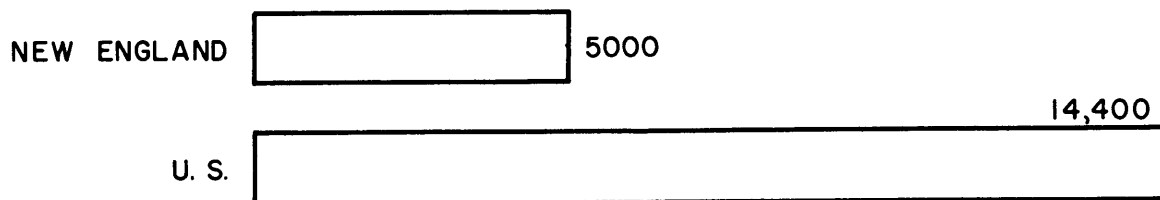
FIGURE 18

### LABOR FORCE BY INDUSTRY GROUP



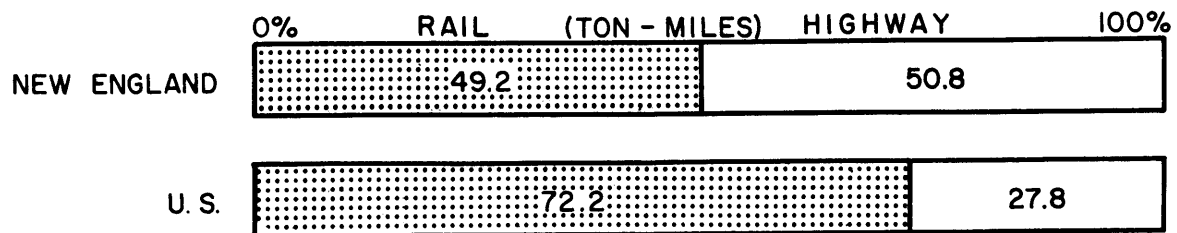
SOURCE: COMPUTED FROM 1950 DATA IN NPA, ECONOMIC STATE OF N.E.

### TON-MILES FREIGHT PER EMPLOYEE 1950



SOURCES: COMPUTED FROM NPA, ECONOMIC STATE OF NE; NE. GOVERNORS COMM. ON PUBLIC TRANSPORTATION.

### INLAND FREIGHT TRANSPORT



SOURCE: NE GOVERNORS COMM. ON PUBLIC TRANSPORTATION (1954)

engines or other motive development is doubtful. The greatest technical change that appears likely is an increase in the importance of "containerized" or "piggyback" freight, whose ultimate effect will probably mean more use of intercity roads for short hauls and less use of them for long hauls, but this effect will be slight. The well-documented, long-term increase in intercity highway travel seems the most significant future trend likely to affect highway importance and impact.

In summary, the general findings of this study seem applicable to all areas of the United States for at least the next decade, but highway location will be of varying importance to land use in different regions, depending upon highway pattern and industrial composition.

#### Land Use Implications

The results of this study indicate that the location of intercity highways will not be of the same significance as the location of railroads was in the 1840's. The differentials in transportation service created by highways are far smaller than those of the railroads in 1840. Much of the impact of the railroad was the result of an enormous overall reduction of transportation costs over a thirty-year period and the creation or removal of break-of-bulk points; neither of these effects can be expected with highway construction. Highway impact is less "channeled" than that of the railroad; towns missed by a few miles by new construction are not faced with the transportation tragedy such a miss involved in the 1840's, with the result that, at least outside of metropolitan areas, exact alignment of highways is of much less significance to city growth than is general highway configuration. Intercity highway impact on land use is therefore likely to be less locally pronounced than that of the railroad, but effective over a wider area.

The relative change in accessibility, and not its level, has been found to be the prime transportation influence on population growth. This means that new highways will have greatest impact where they replace especially poor roads and in areas dominated by population centers connected by the highway.<sup>1</sup> For this reason the likelihood of effecting major accessibility change for a city or metropolitan area declines with increasing city-size and nearness to other cities; while highways have their greatest local impact in large metropolitan areas, intermetropolitan highway configuration will have the least overall growth influence there.

Intercity highway influence will also depend upon the type of existing highway configuration, regional dependence upon highway transportation, and the public expectation of transport impact, as well as on a variety of purely local factors.

#### Planning Implications

Yes or no answers to the planning questions originally asked in this study cannot be made. Making one city a junction of major intercity highways and bypassing another will certainly benefit the former, but in most cases the benefit will not be great.

A policy of aid to depressed areas could be implemented in part through the location and programming of highway construction, but except in rare cases this alone would be insufficient to produce really significant change.

---

<sup>1</sup>"Impact" does not necessarily mean growth, but may mean only stemming of decline. New growth along highways, especially within metropolitan areas, may not be highway-induced growth but merely new building that would have occurred within the general area in any case. Failure to recognize these possibilities may cause failure to recognize highway benefits in the one case and cause overestimation of them in the other.



Directing population growth to or away from huge metropolitan areas by highway location is even less likely to be successful, such areas being especially insensitive to intercity highway configuration.

Both aid to depressed areas and direction of growth away from metropolitan centers often cannot reasonably be implemented at the same time through highway location. Fall River, New Bedford, Providence, Lowell, and Lawrence are depressed areas needing aid. According to these findings, the highway configuration which most quickly aids them is not one linking them together but a system of radials from Boston. This, on the other hand, will also reinforce Boston's position of dominance. This is a story as old as transportation: each area in aiding itself through transportation improvement almost inevitably reinforces the major urban area of the region.

In all probability, the location of interstate highways will continue to be on the basis of "highest density of service" and their programming on the basis of highest cost/benefit ratio, both costs and benefits construed relatively narrowly. The burden is on the planner to demonstrate that other considerations are of sufficient importance and predictable effect to change present methods of design. While the effects of highway location are to some extent both predictable and directable, highway location at the regional scale should not be considered a powerful tool for shaping the environment.

#### Further Studies

The use of the accessibility model technique could be of further value, both for operational planning studies and for academic research. It provides a relatively simple means of studying problems which involve the

overcoming of spatial separation, not only at regional, but also at national, metropolitan, and local scale.

Accessibility model studies of major highway proposals could aid the planner both in influencing the location of highways and in predicting the probable effect of such proposed highways upon urban growth. Used by a state or regional planning agency, this technique could relatively quickly identify areas which could be or are likely to be greatly affected by highway location and are therefore areas which should receive more detailed study.

An operational application of accessibility model technique at the metropolitan scale, which is a method of predicting rate of development on vacant land, has been derived by Walter Hansen.<sup>2</sup> A technique could be developed combining his techniques with that employed here which would include all modes of transport and the shifting "weight" to be given each through the course of time. This would, through revealing the changing patterns of accessibility, provide insights into growth patterns and changing rates of growth throughout the whole metropolitan structure, both for predictive planning information and for research into the growth process of the metropolis.

Another fruitful combination of techniques would be the use of freight rate matrices such as are now being developed by the Midwest Research Institute<sup>1</sup> for different transport types, in combination with a weighted summation process such as is used in gravity models, to determine locational

---

<sup>1</sup>Midwest Research Institute, A Study of Transportation as Related to Industrial Development in an Eleven State Area.

<sup>2</sup>Walter G. Hansen, "How Accessibility Shapes Land Use," Journal of the American Institute of Planners, Vol. XXV, no. 2, May, 1959, pp. 73-76.

advantage for different classes of land users by using different sets of weighting values, and studying how this correlates with actual locational trends.

This study has demonstrated the feasibility of historical research by means of gravity models. Further understanding of the relationships between accessibility change and population growth could be gained through further examination of the nineteenth century "transportation revolution," using models including all modes and covering a longer range of time.

The greatest frustration of this study was the lack of population data covering the period of greatest highway change. The 1960 census information will provide an opportunity to test rigorously the hypotheses suggested by this research.

APPENDIX: NOTES

NOTE 1. Two major assumptions beyond those stated in the text are made in this use of gravity models. One is the assumption of uniform productivity, income, and mobility, which is fairly true for the model area. The second assumption is that of uniform complementarity between points. This is not strictly true even in relatively homogeneous and resourceless New England, where it is probably truer than in most regions. Population in resort areas should have added "weight," as should population at ports serving more than local needs. The former effect was neglected, but an attempt was made to approximate the effect of external inputs at ports. For interactions between inland cities and ports, port population was weighted by the factor:

$$1 + \left( \frac{\frac{1}{2} \text{ tonnage movement by sea through port}}{\text{tonnage moved by other modes}} \right) (\text{"freight weight"})$$

(For explanation of "freight weight" see note 2.)

Only population in urbanized areas and cities of over 4,000 population for 1840 and over 25,000 population for 1950 was used in computing these models, resulting in the use of about forty "contributory points" in each case. 1840 census data was used for both 1840 and 1845, and 1950 census data was used for both 1950 and 1959. Accessibility and potential were computed for the same set of thirty control points for each model, with approximate calculations being made for additional locations where required.

"Potential" as defined by J.Q. Stewart and many others is a measure of the probable level of interaction with all surrounding points, but does not include distance as a "cost" excepting insofar as distance diminishes the

desire for interaction. Accordingly, "potential" in the sense that Stewart uses it was "weighted" by an inverse distance factor to obtain the measure of locational advantage used in these models:

$$V_i = P_i \sum_{j=1}^n \frac{P_j}{D_{ij}^2}$$

It was clear that the power of "D" should be greater than one in this instance, but it might have been better somewhat higher or lower than two, which was chosen for lack of a sound empirical test to obtain the power. Carroll<sup>1</sup> in a recent test at national scale and Anderson<sup>2</sup> in an earlier one both found the power "2" as good as or better than any others tested, and Isard determined a value of 1.7 for intercity rail freight.<sup>3</sup> This exponent is a measure of the social and economic impedance of distance, and therefore varies for different types and lengths of trip. For this reason, values obtained in metropolitan studies are invalid at the intercity scale.

Computing the potential of a city to its own population is essential in a model where the cities cover a wide range of population, as in this case. A method was devised to short-cut detailed computation for each city by deriving a single value of " $\bar{D}$ " to use in the standard formula along with the whole city population.

Roether made approximate computations of

$$V_i = \sum_{j=1}^n \frac{P_j}{D_{ij}}$$

for all cities and towns in the Boston Metropolitan Area.<sup>4</sup> The above

<sup>1</sup>Carroll, J. Douglas, "Population Projection by Means of Income Potential Models," Papers and Proceedings, Regional Science Association, Vol. 4, 1958

<sup>2</sup>Anderson, Theodore R., "Intermetropolitan Migration: A Comparison of the Hypotheses of Zipf and Stouffer," American Sociological Review, Vol. 20:3, June, 1955, pp. 287-91.

<sup>3</sup>Isard, Walter, and Merton Peck, "Location Theory and International and Interregional Trade Theory," Quarterly Journal of Economics, Vol. 68, February, 1954, pp. 97-114.

<sup>4</sup>Roether, Richard, Population Potential in Metropolitan Areas, Unpublished M.C.P. Thesis, M.I.T., 1949.

formula can be written:

$$V_i = \sum_{j=1}^n \frac{P_j}{\bar{D}_{ij}}$$

$$\bar{D}_{ij} = \frac{\sum P_j}{V_i}$$

where  $\bar{D}_{ij}$  is an "average" distance whose use produces the same potential as individual summation procedure. Values of  $\bar{D}$  were computed from Roether's data for Metropolitan Boston cities and towns and compared with city "diameter." The ratio of  $\bar{D}$  to observed "average" diameter of the built-up area of the town varied within a fairly narrow range from a little over a quarter to a little less than a fifth. For the metropolitan area as a whole the value was about one-tenth the "diameter" of the built-up area. With these values as a guide,  $\bar{D}_{ij}$  was estimated more or less individually for each city.

NOTE 2. Values of  $3\frac{1}{2}\phi$  per minute for autos and  $6\phi$  per minute for trucks were adopted as the fiscal equivalent value of time for the 1950's models. These were based on examination of "time value" studies made in a number of highway engineering surveys, all of which arrived at fairly comparable values by diversion curve analysis, surveys, and other methods of estimation.

For the 1840's an equivalent fiscal value for time can be imputed if one postulates that what brief life canals had following the advent of parallel railroads was because the difference between their rates was no less than the value of the time difference their speeds made. This analysis suggests a time value of a little over a tenth of a cent per ton per minute so this figure was adopted for all computations.

In order to solve "port weighting" and to establish appropriate cost figures for the models the "weight" to be given freight versus passenger costs had to be determined. Ideally this should be:

$$\text{Passenger weight} = \frac{\text{total area costs for passenger transportation}}{\text{total area costs for passenger and freight}}$$

$$\text{Freight weight} = \frac{\text{total area costs for freight transportation}}{\text{total area costs for passenger \& freight transport}}$$

For the 1840-1845 models the necessary information can only be approximated. "Passenger weight" varied on different lines from 80% to less than 50%. For the 1840's therefore an approximate value of 0.50 was used for both passenger and freight weight. For the 1950's models, national costs can be approximated by multiplying intercity vehicle miles totals for both trucks and autos by their respective costs per mile. New England costs were assumed to be in this same proportion, resulting in values of 0.68 for passenger weight, and 0.32 for freight weight.

"Cost" between points was computed from terminal cost, uniform line cost between points (including the value of time), transfer costs, and drayage costs for the 1840's models where involved. "Terminal costs" for passenger cars primarily consist of personal inertia and car warmup time.<sup>1</sup> The terminal cost used for highways in 1950 includes both "weighted" terminal costs and an extra allowance for clearing city traffic, speeds being estimated to the heart of each city on the basis of the roads just outside of it, an overestimate in each case.

In computing the accessibility contributions of a city's own population,

---

<sup>1</sup>Hansen has derived an empirical value for this. See Walter G. Hansen, "How Accessibility Shapes Land Use," Journal of the American Institute of Planners, Vol. XXV, no. 2, May, 1959, pp. 73-76.

"minimum" trip costs were established at \$1.00 in 1840, which was also high enough to cover the largest city, and at \$2.00 in 1950, with a \$3.00 maximum for Boston, values for other cities ranging in between.

NOTE 3. Correlation analysis of the hypothesis that population growth is a function of accessibility was attempted, using first the thirty "control points" for which accessibility was computed in drafting the accessibility maps, and later for a set of forty towns with 1850 population between one and five thousand. The general relationship tested was:

$$\frac{Pop_{t2} - Pop_{t1}}{k Pop_{t1}} = f(Y)$$

"Y" was taken variously as accessibility in 1840, 1845, and (estimated) 1850. Both arithmetic and logarithmic functions were tested, both numerically and graphically.  $Pop_{t1}$  and  $Pop_{t2}$  were taken as population in 1840 and in 1850, and then population in 1850 and 1870 were used in a "lagged" model. "k" is a constant equal to the rate of growth of the entire sample being used.

The highest correlation achieved was an r of 0.17 using the sample of forty towns, estimated accessibility in 1850, and population change between 1850 and 1870. This is far from 95 percent significance with this small a sample. All other correlations were below 0.10, also failing any realistic significance test.

Change in accessibility as measured by the incomplete models used tended to produce values within one or another of two fairly narrow ranges, a high range for those locations having been newly served by rail in 1845 and a low range for those either served or unserved at both test points in time.



The number of points in the first category was too small and the differences between values in the second category too low to permit valid correlation analysis. A proper test should cover a long-range of time and include all modes of transport.

NOTE 4. The fifty-six towns used in the investigation of accessibility change and population change (table, page 35) were randomly selected on the basis that population data was available for them. "Non rail connected" means that the town was not directly connected by rail before 1860 at the earliest, "rail connected" means connected by rail prior to 1850. Those towns connected 1850-1860, those very close to but not on either the coast or a rail line, and those clearly a part of a larger city complex were eliminated.

The statistical significance of the difference in average growth rates between the categories in the table was tested at the 95 percent confidence level. All differences were significant at that level except the difference between "inland non-rail connected" and "seaport rail connected," where little difference in growth rates could have been expected.

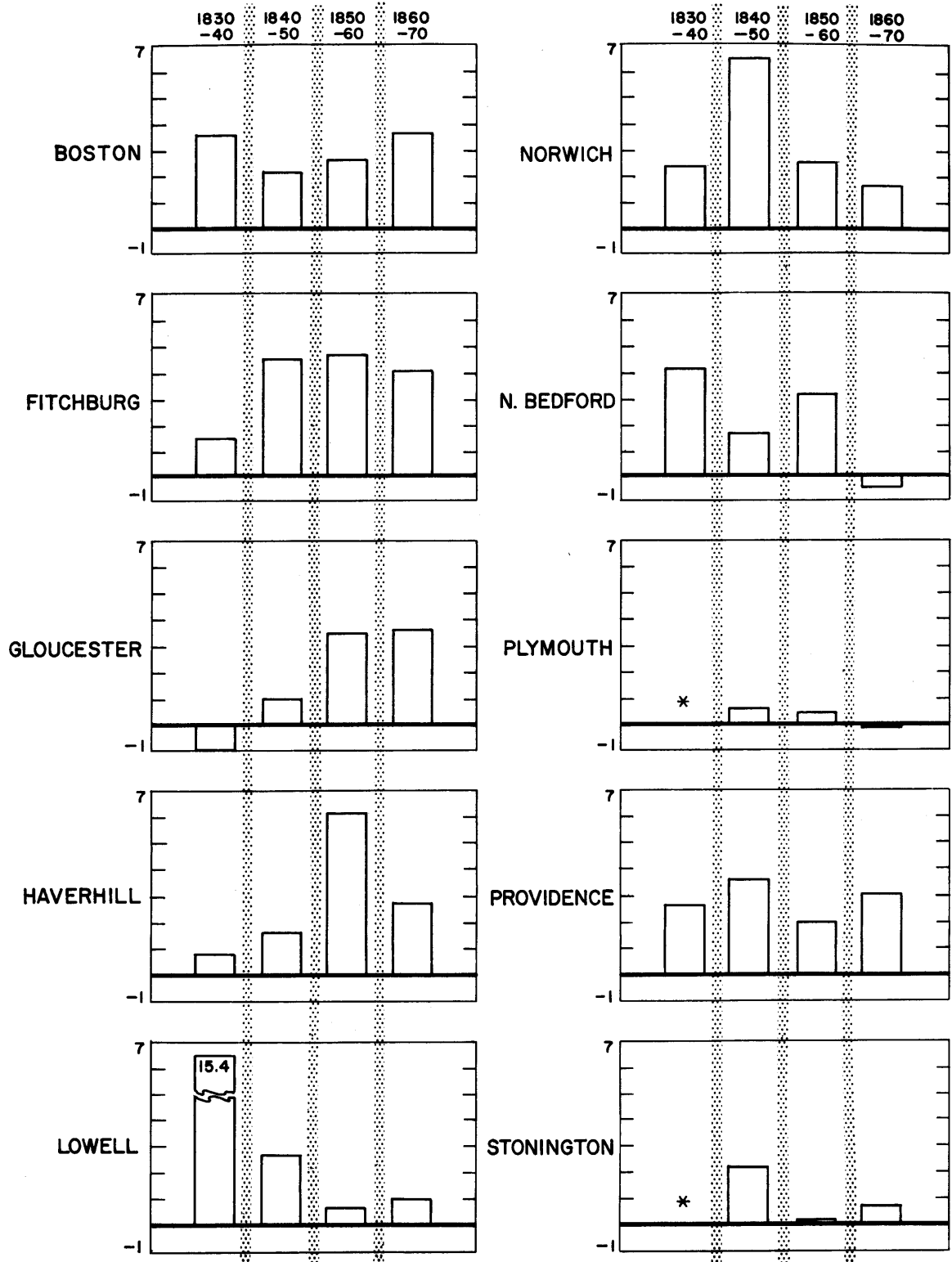
It should be noted that the argument used here bears little relation to the  $\frac{P_1 P_2}{D_{12}}$  probability model method of migration estimation out of which gravity models have been developed. It can be shown that, based purely on laws of probability, with all other things being equal, net migration should be slightly higher for locations of higher accessibility; level of accessibility and not change in accessibility would be the relevant variable. This assumes, however, all migrants coming from within the model area, uniform density of population, and equal advantages at all locations.

Since density is also a function of accessibility, the results of removal of the assumption of uniform density would depend upon the relation between the migration and density functions of accessibility, possibly even resulting in a negative relationship between migration and accessibility under realistic density assumptions. The concern of this study is with migration as a function of locational advantage and not as a function of a probability relationship.

# POPULATION GROWTH

FIGURE 19

RATIO OF LOCAL RATE OF GROWTH TO AVERAGE NEW ENGLAND RATE OF GROWTH



SOURCE: U.S. CENSUS

\* DATA NOT AVAILABLE

## BIBLIOGRAPHY

### Potential Models:

Anderson, Theodore R., "Intermetropolitan Migration: A Comparison of the Hypotheses of Zipf and Stouffer," American Sociological Review, V. 20:3, June, 1955, pp. 287-91.

Anderson, Theodore R., "Potential Models and the Spatial Distribution of Population," Papers and Proceedings of RSA, V. II, 1956, pp. 175-182.

Carrothers, Gerald A.P., "Population Projection by Means of Income Potential Models," Papers and Proceedings, Regional Science Association, V. IV, 1958, p. 121.

Carrothers, Gerald A.P., "An Historical Review of the Gravity and Potential Concepts of Human Interaction," Journal of the American Institute of Planners, Spring, 1956, pp. 94-102.

Dodd, Stuart C., "The Interactance Hypothesis," American Sociological Review, 15:2, April, 1950, pp. 245-256.

Hansen, Walter G., "How Accessibility Shapes Land Use," Journal of the American Institute of Planners, V. XXV:2, May, 1959, pp 73 - 76.

Isard, Walter, and Merton J. Peck, "Location Theory and International and Interregional Trade Theory," The Quarterly Journal of Economics, V. 68, February, 1954, pp. 97-114.

Roether, Richard W., Population Potential in Metropolitan Areas, Unpublished M.C.P. Thesis, M.I.T., 1949.

Stewart, J.Q., and William Warntz, "Physics of Population Distribution," Journal of Regional Science, V. 1:1, Summer, 1958, pp. 99-123.

Stewart, J.Q., and William Warntz, "Macroeography and Social Science," Geographical Review, V. 48, April, 1948, pp. 167-184.

### Historical Data on Transportation:

Gilmore, Harlan W., Transportation and the Growth of Cities, The Free Press, Glencoe, Illinois, 1953.

Kennedy, Charles J., "The Eastern Rail-road Company to 1855," The Business History Review, V. 31, Spring, 1957, pp. 92-114.

Kirkland, Edward Chase, Men, Cities, and Transportation, 2 Vol., Cambridge, Harvard University Press, 1948.

MacGill, Caroline E., et al., History of Transportation in the United States before 1860, Washington, Carnegie Institution of Washington, 1917.

Taylor, George R., The Transportation Revolution, New York, Rinehart & Co., 1951.

Taylor, George R., and Irene Neu, The American Railroad Network, Cambridge, Harvard University Press, 1956.

#### Highway Impact Studies:

Chase, Edward T., "The Hundred Billion Dollar Question," Architectural Forum, Vol. 107:1, September, 1956, p. 135.

"The Highway Billions," Fortune, Vol. LVII:3, September, 1958, p. 106.

Howard, John T., "The Impact of the Federal Highway Program," Planning, 1957, Chicago, ASPO, 1957.

Howard, John T., "Community Growth - Impact of the Federal Highway Program," paper read before 63rd National Conference on Government, National Municipal League, Cleveland, 1957.

Planning Advisory Service, Information Bulletin #71, "The Urbanizing Influence of the Expressway," Chicago, ASPO, February, 1955.

Warner, Arthur E., The Impact of Highways on Land Uses and Property Values, East Lansing, Michigan State University, 1958.

#### Other Transportation Materials:

Automobile Manufacturers Association, Motor Truck Facts, Detroit, Automobile Manufacturers Association, 1958.

Burck, Gilbert, "The Great U.S. Freight Cartel," Fortune, Vol. 55:1, January, 1957, p. 102.

Bureau of Public Roads, Highway Statistics, 1956, Washington, USGPO, 1958.

Cope, James, Wasted - \$3 Billion Yearly, Detroit, Automobile Manufacturers Association, 1953.

Daggett, Stuart, Principles of Inland Transportation, New York, Harper and Bros., 1955.

Federal Coordinator of Transportation, Freight Traffic Report, Washington, U.S. Government Printing Office, 1935.

Isard, Walter D., "Transportation Development and Building Cycles," Quarterly Journal of Economics, Vol. 57, November, 1942, pp. 90-112.

Kelley, Ray S., Jr., Origins and Destinations of New England's Traffic, Staff Memorandum #1, The Committee of New England, Boston, 1952 (unpublished manuscript).

Midwest Research Institute, Industrial Economics Division, A Study of Transportation as Related to Industrial Development in an Eleven State Area, Kansas City, Missouri (mimeoed manuscript), 1956.

Miernyk, William H., Railroad Transportation Charges to New England and Competing Shippers, Staff Memorandum #3, The Committee of New England, Boston, 1952 (unpublished manuscript).

Mossman, Frank H., and Newton Morton, Principles of Transportation, New York, The Ronald Press Co., 1957.

National Interregional Highway Committee, Interregional Highways, Washington, U.S. Government Printing Office, 1944.

National Resources Planning Board, Transportation and National Resources, Washington, U.S. Government Printing Office, 1942.

National Resources Planning Board, Industrial Location and National Resources, Washington, U.S. Government Printing Office, 1943.

New England Governors' Committee on Public Transportation, Public Transportation for New England, Boston, New England Governors' Conference, 1957.

Owen, Wilfred, The Metropolitan Transportation Problem, Washington, The Brookings Institution, 1956.

Schmidt, Robert E., and M. Earl Campbell, Highway Traffic Estimation, Saugatuck, Conn., The Eno Foundation for Highway Traffic Control, 1956.

"Transportation: Who'll be Carrying the Load and Why," Business Week, March 20, 1954, p. 102.

Ullman, Edward, American Commodity Flow, Seattle, University of Washington Press, 1957.

#### Other Related Material

Bogue, Donald J., Population Growth in Standard Metropolitan Areas, 1900-1950, Washington, Housing and Home Finance Agency, 1953.

Bogue, Donald J., The Structure of the Metropolitan Community, Oxford, Ohio, Scripps Foundation, 1958.

Bogue, Donald J., Components of Population Change, 1940-50, Oxford, Ohio, Scripps Foundation, 1957.

Bogue, Donald J., and Dorothy L. Harris, Comparative Population and Urban Research via Multiple Regression and Covariance Analysis, Oxford, Ohio, Scripps Foundation, 1957.

Bogue, Donald J., Siegfried Hoermann, and Henry Shrycock, Jr., Streams of Migration Between Subregions, Oxford, Ohio, Scripps Foundation, 1957.

Fulton, Maurice, and L. Clinton Hech, "Transportation Factors Affecting Locational Decisions," Economic Geography, Vol. 35:1, January, 1959, pp. 51-59.

Goodrich, Carter, et al., Migration and Economic Opportunity, Philadelphia University of Pennsylvania Press, 1936.

Harris, Chauncy D., "The Market as a Factor in the Localization of Industry in the United States," Annals of the Association of American Geographers, Vol. XLIV:4, December, 1954, p. 315.

Hawley, Amos Henry, The Changing Shape of Metropolitan America, Glencoe, Illinois, The Free Press, 1956.

Hewes, Laurence I., and Clarkson H. Oglesby, Highway Engineering, New York, John Wiley and Sons, Inc., 1954.

Hoover, Edgar M., The Location of Economic Activity, New York, McGraw-Hill Book Co., 1948.

National Planning Association, Committee of New England, The Economic State of New England, New Haven, Yale University Press, 1954.

Ullman, Edward L., "Amenities as a Factor in Regional Growth," The Geographical Review, Vol. 44, 1954, p. 119.