CHAPTER 4

THE AHS MAGLEV LAND USE TRANSPORTATION SYSTEM

4.1 Introduction

Transportation has always been a major force in determining the pattern of human settlements and activity. From the beginning of civilization of some six thousand years B.C. when our ancestors settled in fertile river valleys in half a dozen locations spread across the face of the earth to live by growing food rather than hunting for it, to the present century, in which the rural poor migrate to urban areas in search for jobs, man has continually sought a place where life was easier.

In a region of unproductive subsistence agriculture where it takes 1000 workers to produce enough food and fiber to provide for 1000 families, everyone is tied to the land. If agricultural productivity is doubled, half of population can move off the land to cities where they can both provide, and take advantage of, other services. Cities, then, are evidence that a society has reached a certain stage of “development.” Extending this simple proposition enables us to characterize three phases of development: (1) subsistence agriculture, (2) surplus agriculture/limited urbanization, and (3) an industrial-urban society. The third phase occurs with an after an “industrial revolution.” Indeed, this trend was so evident in the early 1800’s that this historical period is called the Industrial Revolution [42].

Development is the complex process by which a society moves toward greater control over its destiny. Obviously, phase 3 above represents a higher form of development because the surpluses reduce the vulnerability of the population to things beyond a society’s control, such as floods, drought, pests, epidemics, etc. Clearly, trade and its necessary correlate, the geographic division of labor, are intertwined with man’s pattern of settlement [47].

Why did the industrial Revolution suddenly cause the rural-to-urban migrations and growth of towns into cities and cities into metropolitan areas? The answer emerges when we realize that the Industrial Revolution comprised three, not one, revolution – a manufacturing revolution, an agricultural revolution, and a transportation revolution. Because, as we shall see, manufacturing and transportation are so dependent on transportation, we submit that the era of the technological progress that so changed the course of civilization, might more properly be named the Transportation Revolution [48].

The transportation revolution certainly encouraged urban agglomeration. Cities have, throughout history, tended to locate at economical transport points: at seaports, on navigable lakes and rivers, or at junctures of important overland trade routes. The transportation revolution of the nineteenth century consisted chiefly in the improvement in water-borne transport following the development of canals and the invention of the steamship and the even more radical change in overland transport made possible by steam railroads. These developments combined to increase enormously the transportation advantages of those points they served as compared with all other points. Both modes of transport operated, not ubiquitously, but along lines of movement that formed rather coarse-mesh networks. The point of service for the steamship network was the port – and the number of good ports is limited by topography. Later the railroad system was built, however, those points it served obtained decisive cost advantage over all other places, for overland travel apart from the railroad remained in the horse-and-buggy stage throughout the nineteenth century. Thus, port and points along the railroads and canals powerfully attracted industry and often become manufacturing towns or cities [49].

Indeed, so effectively did the railroad encourage villages to grow into towns and towns into cities that it proved to be the most powerful agglomerative invention of all time. To enjoy its benefits, one had to build directly along the right-of-way or on a short siding. Hence, nineteenth-century factories huddled next to one another in the familiar rail-side industrial districts still visible in every manufacturing town. Moreover, the railroad was relatively more efficient for long than for short hauls. It was miraculously economical for intercity movement of both goods and people.

In the second half of the 19th century the introduction of the "skyscraper" made possible still greater intensity of land use. The skyscraper, in turn, was the product of two interdependent innovations, the passenger elevator and the iron and steel frame method of building construction. The passenger elevator, a revolutionary means of urban transportation in the previously unexploited vertical dimension, was invented by Elisha Graves Otis, who personally demonstrated it at the Crystal Palace Exposition in New York in 1853. Within a few years the steel frame largely replaced masonry construction; the race toward the modern skyscraper was under way [50].

Meanwhile, escape outward from the crowded center was reserved for those who could afford, if they wished, to commute to the city on steam railroads. Toward the end of the century, commuter's suburbs grew up around the stations along the railroad lines leaving the principal cities. These suburbs were compact in form. Since local transportation was still by horse and buggy, commuters could not live far from the railroad station. Hence commuting towns were strung out like beads along the railroad lines that radiated from the city. By 1898 Harper's Weekly reported that more than 118,000 people arrived daily at New York City's Grand Central Terminal from Westchester and Connecticut alone [51].

Between 1870 and 1900 the "hoof-and-foot city" was rapidly transformed into the "city of the streetcar." In various ways rail transportation was adapted to serve urban needs. Horsedrawn streetcars had been in use since the middle of the nineteenth century. They were not fast enough or large enough, however, to influence urban size and form. Although the cable car was introduced in the 1870's its construction was expensive, and it remained for the electric streetcar, first operated on a large scale in the late 1880's, to alter matters by radically extending the distance city dwellers could conveniently travel to their workplaces. By the first decade of the twentieth century a web of streetcar lines crisscrossed every major city and made it possible for residential neighborhoods to spread far out from the old centers. Sometimes the new neighborhoods were more spacious than the old; sometimes they repeated the old high densities. In either case, vast new areas became accessible for housing, and cities were able to grow to unprecedented size [52].

In 1909, Henry Ford introduced his renowned “tin lizzie” Model T in “any color you choose so long as it’s black,” list price $940. In 1914, Ford open his revolutionary plant at Highland Park, Michigan, equipped with the first electric conveyor belt, which carried the gradually assembled car at a rapid speed past stationary workers, each equipped with the tools to perform his one simple mechanical task. By 1925, Ford was turning out a completed car every 10 seconds. In 1920, about nine million automobile were registered in the U.S.; by 1930, that figure had soared to 30 million [53].

Of all the technological innovations since the birth of the Nation, the automobile had the greatest impact on America and the American way of life. Within a few decades after its introduction, it had: driven horse-drawn vehicles out of use; destroyed the intraurban electric street railways, cut sharply into road traffic; vastly increased the mobility of people; and stimulated vast expenditures for highways. Additionally, the automobile: created great new manufacturing industries; upset the balance of population between town and country; reshaped the city and unleashed an explosion of the suburbs; changed people’s living habits; and created numerous social and government problems.

4.2 Intelligent Transportation Infrastructure (ITI)

The hottest topic in civil engineering is the concern of the deterioration of the nation’s roads, bridges, water pipes, storm and sanitary sewers and other public infrastructure. To attract and keep businesses, jobs and populations, cities must invest in the roads, transit systems, water supply systems and sewage systems – the major elements of urban infrastructure. The U.S. Bureau of Census polled more than 2,000 business firms to determine how these businesses chose locations for plants and facilities. In virtually all cases, the availability of infrastructure facilities emerged as a major factor. By creating inefficiencies in the generation of private firms, decaying infrastructure can greatly increase the cost of doing business, consuming capital that would otherwise be available for new investment in plant and equipment [54].

There are several interrelated demographic, fiscal, and social trends that help explain how the United States got into this mess. The post-war explosive growth in home ownership located in the suburb increase the demand for new infrastructure, particularly highways to accommodate suburban home to central city work trips. The 41,000 mile Interstate Highway System may have speeded intercity and commuter traffic but it also accelerated central city decline. Accompanying central city losses has been a massive regional population shit from the Northeast and Midwest to the South, the Southwest and the West – from the "Rustbelt" to the "Sunbelt" [50].

The real cause of the infrastructure crisis is the lack of leadership, especially in transportation. From politicians all over the world we hear a great deal about bridges to the 21st Century and the new millennium. In the U.S. this is a bridge to the 21st Century transportation that is suspended, if you will, from the bargain-basement philosophy embodied in the ISTEA legislation that empowered ITS. ISTEA and its follow-up policies, without the enabling infrastructure of ITI is like to suspend the Golden Gate Bridge without any towers. It is like AHS/Maglev without the guideway.

The financial difficulties of transportation seem to transcend national boundaries and seem to persist whether a nation is rich or poor. National airlines and railroads suffer large operating deficits as does public transportation in the world's cities. All forms of transport appear to lack the amount of money needed for maintenance and for modernization and expansion. One reason is that methods of privacy transport facilities and services fail to charge users for specific costs incurred. This is particularly ironic because transportation is perhaps the only activity in society that could easily "pay for itself". The American Highway Trust Fund probably considered more to the development of the U.S. than any other policy.

Politicians can be forgiven for vague promises because they are not believed, but transportation professionals have bought into the ideas that "intermodalism, seamlessness, and modally indifferent transportation" can be achieved without ITI. These promising and necessary concepts are simply empty rhetoric without the enabling infrastructure.

It is certain that infrastructure for a growing economy will require substantially more financial support in the future. Owen [53] lists among the reasons for expecting greater outlays the following: the mounting costs of airways modernization, the need for new roads in expanding suburbs, the growing importance of improve public transport, the modernization of intercity rail passenger service, expanding port and airport requirements associates with the growth of international traffic, and transportation requirements resulting from demographic shift and changes in the character and location of economic development.

Paying the bill for transportation facilities in the public sector is a problem primarily associated with road transport everywhere in the world. Part of the problem is reflected in the division of the highway transportation dollar between what is spent for roads and for vehicles. The owner of an intermediate-size car who incurs costs of 30 cents a mile willingly pays 28 cents for the car and its operation but often resists paying for the roads, which are “taxes.” The average motorist pays two and a half times as much per mile for insurance as for roads and streets. Given the congestion and obsolescence of many parts of the system, what is saved by keeping road payments low is lost in excessive fuel consumption, accidents, and time spent in traffic congestion. Payments for roads need to be viewed not as taxes but as charges for a public service.

The U.S. National Council on Public Works Improvement, reporting to the president and Congress in 1987, suggested that if the nation invested $20 billion more per year for highways, motorists could save $100 billionmore per year in vehicle operating costs. Increasing users tax from 2 cents a mile of driving to 3 cents is all that would be required to generate another $20 billion in revenue [55].

Economist Lester Thurow’s latest book “ The Future of Capitalism”, makes a compelling argument for more public sector investments as America becomes integrated in the global economy. His argument that a de facto industrial policy has always existed in the United States offers a serious challenge to conservative economists who argue that market forces, not the government, should be the primary determinant of the nation’s economic outcomes. To the citizen who is concerned about taxation policy and government spending, Thurow offers empirical evidence that government investment, not private-sector research and development, has historically been the catalyst for much of America’s economic growth.

In capitalist societies, Thurow contends private firms have a six- to seven-year planning horizon. If profits are not predicted in that time period, businesses are not likely to invest the necessary funds to produce new products and services.

Conversely, government’s economic-planning horizon is usually 18 to 20 years. Once research-and-development fund are invested, and the product or service matures, the enterprise is usually taken over by private business. Government monies provide the long-term research-and development financing that private-sector organizations are unwilling to chance until there is a virtual guarantee of profitability.

ISTEA which assumes that the next transportation paradigm can be implemented by the private sector through “smart car”, rather than by the public sector through a policy of smart infrastructure, is a flawed policy that will, unfortunately, may not be exposed as such for a decade during which time the transportation problem in the U.S. will become critical.

4.3 Sustainable Development

For 6000 years, from the beginning of civilization to the eighteenth century, there was little change in the quality of life for the average person. Progress for ancient man meant protection from the elements; for medieval man, it meant salvation of his soul; for Renaissance man, it meant progress in the quest for knowledge. The Industrial Revolution ushered in the modern age with progress being measured in economic terms, whether used to describe national power or personal prosperity. Surely, eighteenth-century believers in progress would be both astounded at our technological capabilities and dismayed at what we have done with them.

Not until the middle of this century did the protest against progress begin to manifest itself seriously, first by liberal intellectuals with their indictment of poverty, blight, and the excesses of capitalism, ad later by the environmentalists with their concern for growing population and resource depletion. The first environmentalists were probably the World War II scientists who sensed that the development of nuclear weapons posed a grave threat to the human race. Two events in the early 1960s formalized the growing concern for the environment: (1) the signing of the treaty by the nuclear powers prohibiting above the ground testing and (2) the publication of Rachel Carson's book, Silent Spring, documenting the misuse of pesticide [56].

In 1965 Barbara Ward [57] used Space Ship Earth as the title of a book in which she discussed the international power struggle, the widening gap between rich and poor countries and the conflict of ideologies. Architect-philosopher Buckminster Fuller, and economist, Kenneth Boulding seized on the metaphor and addressed it to the earth's fragile environment. On April 22, 1970, Gayland Nelson, a former U.S. Senator and Wisconsin Governor, founded "Earth Day" as a way to heighten national awareness of environmental issues [58].

In 1972, environmentalist protest against pollution and against economic growth as it chief cause received formidable endorsement in the form of a report, the Limits of Growth, commissioned by the Club of Rome and prepared by a team of scientists at the Massachusetts Institute of Technology [59]. The system dynamics methodology used in the Limits of Growth study provides the conceptual foundation for the sustainable development paradigm.

The advent of sustainable development is new compared to the established economic theories, and even compared to the environmental movement which is also partly responsible for its criterion. The concept that the term sustainable development embodies is simple. It is the reconciliation of economic development with protection of the environment, or the knowledge that infrastructure, the economy, and the environment, instead of being discrete and separate entities, are interconnected in fundamental and crucial ways [60].

The need for maintaining an environmental balance, first articulated in the Space Ship Earth metaphor, was next interpreted in terms of the "steady-state economy," where steady state meant constant inventories of capital and people. The problem is that zero population growth is, realistically, a long term goal at best and without it zero capital growth would only serve to reduce the quality of life.

Environmental issues are of abiding interest to a broad swath of the worldwide, public. If not unanimity, there is at least widespread consensus that environmental protection is one of government's most important roles. Moreover, environmental and related studies have become a major specialty in scientific research. The acquisition of knowledge that has both made mankind aware of problems it hitherto didn't know existed and help us find ways to solve or contain them. Research interest in the environment isn't confined to life scientists and environmental engineers. Sustainable development has been proposed for addition to the canons of the Code of Ethics of the American Society of Civil Engineering (ASCE) [61].

The crisis approach to infrastructure and to the environment have common issues of funding, priorities, politics and the well-being of society [60]. Funding for environmental projects comes from the federal government principally because they are federally mandated; whereas funding for infrastructure has historically been distributed among federal, state and local governments. The political system also has a common influence on these issues that is reflected by the involvement of different branches and levels of government and special interest groups. Interesting responses to both the environmental and infrastructure crisis have served to unify citizens. In the case of the environment, the groups have been formalized and are better organized whereas the anti-infrastructure movements have tended to coalese around slogans such as "not in my backyard."

The number of motor vehicles in the world has grown more than ten-fold since 1950. There are now about 700 million vehicles. While the U.S. has the largest motor vehicle fleet, its rate of growth is only about 2% per year. On the other hand, many newly industrialized countries are experiencing a rapid rate of motor vehicle fleet growth.

For example, in recent years China, India, Korea, and Indonesia experienced an average annual vehicle growth rate of 10% or more. More alarming is the rate of increase in automobile use relative to rate of population growth. Since 1960, the number of automobiles worldwide has increased more than twice as fast as the population. The OECD countries which include the U.S., Canada, West European countries, and Japan, have the highest rate of per capita vehicle ownership. The U.S. has about 780 vehicles per 1,000 people. However, other countries are rapidly increasing their vehicle ownership as well, and without the benefit of appropriate infrastructure. The adverse effects of motorization are much more severe in these countries than in developed countries [62].

Although a motor-vehicle-dominated transportation system may not be entirely safe and environmentally sustainable, there are no equivalent alternatives. It is the most flexible and reliable form of transportation, representing a free and democratic society. To assume that the current trend of increasing motorization can be significantly reversed is irresponsible. The experience of Singapore over the past two decades indicates that even when strict measure are taken, automobile ownership and use continue to grow, although at a slower rate than what could be expected without the measures. We must therefore search for ways to make road transportation safe, as well as environmentally sustainable [53].

The long-term sustainability of transportation systems can only be achieved through careful strategies combining technological innovations such as AHS/Maglev and rational urban and regional development policies.

4.4 Creating Accessible Cities

The continuing growth of urban activities and the expanding dimensions of city and suburbs are making it difficult to move between and within population centers, rendering urban areas less accessible and reducing the quality of urban living.

America’s inner cities and cities in the developing world may find relevant ideas in efforts around the world to view transportation as an integral means to improve human conditions. As an example, considered Singapore, a formerly poor country that overcame many obstacles and emerged as one of the world’s richest nations.

In 1960 Singapore confronted its intense traffic problems in the larger context of supplying housing, jobs and income security for its people. It launched a massive program of urban redevelopment and simultaneously creates new plan communities on the out skirts to accommodate industrial and population growth [53].

Transportation became one of several means for moving out of wretched living conditions and into decent urban settings. Through redesign and relocation, old city slums were transformed by scenic boulevards, waterfront parkways, and allocation of space for housing and industrial estates parks, schools, and various urban amenities.

A tiny island nation may not be the first model one would turn to for an American city, but Singapore’s unique experience nevertheless demonstrates how transportation can provide means for achieving a society’s goals. The goals in this case were economic and human development; the means were jobs, education, and training, modern housing, and the creation of transportation services and city-building industries that, in turn, would help to fuel further economic development.

Congestion everywhere has reached a destructive level that demands better use of transportation and communication – not to increase concentration, but to disperse the population in an orderly manner and to stop random spillover into the surrounding countryside [62].

If the world is to accommodate its population growth over the next 50 years, there must be a three-pronged attack: (1) rebuild and reorganize existing cities, (2) rationalize suburban growth, and (3) build new cities and towns. Taking the United States as an example: assume that by the middle of the next century, the guideway freeway system described in this paper is implemented throughout the entire Interstate Highway system. The population of the U.S. will have increased by at least 100 million persons. The new transportation paradigm requires that this new AHS/Maglev system act as a structuring device for achieving sustainable development. The Magway system can be used to provide a point focus. While the Magway is visually a line, the accessibility is from points on the line. In a sense, it is a high-speed railroad without rails, and it has all of the advantages of this type of high-speed surface transportation, but it combines with these the flexibility of a highway. The location of Magway interchanges determines the focal points for new urban development.

These new developments, or “Magway Towns” would be distinct from past new towns or satellite towns in that they would have the following characteristics:

(1) They would be located in the path of the heaviest projected population growth and would be served by Magway interchanges.

(2) Each unit would have between 100,000 and 300,000 population.

(3) Each would contain varied employment and services; a wide variety and price range of housing; and government, cultural, educational and recreational facilities.

Each town would be comprised of hexagonal modules of from one to three kilometers on a side so that the Magway Towns would consist of various modules combined according to topographic conditions and demographic demands located at guideway interchanges (see Fig 4.1).

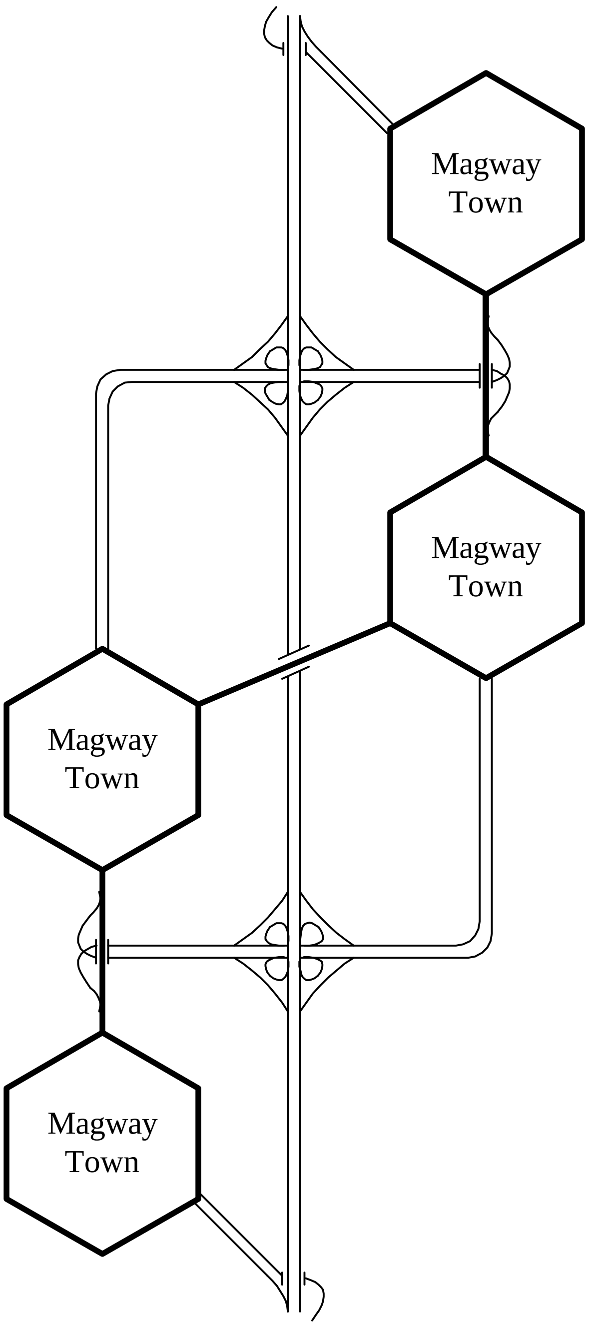

Figure 4.1 Magway metropolitan structure

4.5 The Land Use and Transportation Subsystems

The planning profession is developing along two related lines: (1) the process of planning – the comprehensive aspects, the systems view etc. and (2) the subject matter of planning – the town, the urban area, the depressed region, or the underdeveloped nation. These are the means and ends of planning.

In the United States the terms “city planning”, “urban planning”, and sometimes, “metropolitan planning” are used; in England it is unassumingly referred to as “town planning”. Recently, the appreciation of the inseparability of the “market center” from the “homogeneous plain” has led to the increasing reference to “urban and regional planning” in the U.S. and to “town and country planning in Britain [63]. The purpose of these aspects of planning is to provide pleasant surroundings for people to live and work in. For the most part this objective has been pursued in many countries through legislation under which private land use and building development are regulated by local government. The rationale lies in the desire to preserve a balance between the competing claims made on available land by homes, industry, commerce, recreation, etc.

Ideally the urban region should be conceived and planned as a comprehensive system of inter-related activities which are directed to achieving certain community objectives. Such a system might be thought of as a group of elements containing various types of human activity connected together by communication elements.

One of the elements in this systems is the land use subsystem. Traditionally the city planner has been concerned with the activity elements and the expression of these efforts to achieve community goals is the three-dimensional land use plan. Another element is the transportation subsystem. At the same time, the civil engineer has been concerned with the transportation phase of the communication requirements and the physical expressions of his efforts to contribute to these goals is the transportation subsystem. The particular objectives associated with these two subsystems must be regarded as intermediate steps to the overall community goals in order to develop appropriate and compatible objectives for the transportation subsystem.

The traditional view point of urban planning is physical in nature and its centers on the allocation of land to different types of activities. Methodological approaches to land use planning should be based upon theories of urban spatial structure and interaction. Let us consider the lists of the following organizing concepts for the city (1) communications theory in which the city is conceived as a response to man's need to maintain communication with his fellowman; (2) the human interaction theory involving three related perspectives – the flow of people and goods, the space adopted for various human activities, and the special distribution of various types of activities; (3) the focus on urban form; (4) accessibility concepts – the community effort to overcome distance; (5) the economic model approach; and (6) a values behavior patterns – consequences framework. From these concepts, two guiding considerations concerning land use can be formed: (1) land use planning means more than existing or proposed improvements on the ground and (2) land use planning is dynamic [64].

During the past 25 years a procedure for performing Urban Transportation Planning has evolved. Basically, the UTPP consists of 10 steps comprised of various field studies to obtain information and a series of mathematical models to utilize this information rationally. These are

1. Coding and Zoning: The urban study area is broken down into homogeneous spatial units called "zones". Each zone is given a number. In addition each modal network is coded numerically as a series of "links". Each link begins and ends at a node.

2. Inventory Studies: Each zone is classified according to land use. Information is collected regarding Land Use Intensity, Zonal Socioeconomic characteristics, and the capacity and condition of all links.

3. Travel Studies: The most important of these is the O-D survey which includes a transit terminal survey, a transit route survey, an external cordon survey, an internal cordon survey, and a home interview survey. The O-D identifies where and when trips begin and end, the land use at the trip ends, the purpose

of the trip, the mode and route of travel and the socioeconomic characteristics of the trip-maker.

4. Forecast for the Horizon Year: This requires an estimation of the intensities and spatial distribution of the population, employment, land use and the economic and social activity that the transportation system is to be designed.

5. Trip Generation Analysis: The purpose of this phase is to develop equations that allow the trip end of a particular trip type generated by each zone to be estimated from a knowledge of the land use properties of those zone.

6. Trip-End Modal Split Analysis: Trip ends estimated in the trip generation phase are partitioned into two groups – Transit captive trip ends and choice rider trip ends – based on socioeconomic characteristic such as age, income, sex and auto ownership.

7. Trip Distribution Analysis: For each zone, a determination is made of the zone to which itst produced trips will be attracted based on the attractiveness of the potential destination points and the cost or impedance of travel.

8. Trip Interchange Modal Split Analysis: The purpose of this step is to determine the proportion of trip makers traveling between each origin and destination pair that will choose competing modes, based on the time and cost of travel.

9. Network Assignment Analysis: Assignments are made for each mode to alternate routes based on relationships between travel times volumes, and capacities for the routes.

10. Evaluation: Alternatives are compared on the basis of systems performance and social, economic and environmental impacts.

The concept of equilibrium is tied to the system-oriented view of urban transportation. The traditional approach taken in many engineering analyses is to isolate a component of a system and analyze this component individually, be it small changes in the transportation or a particular step of the UTPP process. There has been a general tendency to emphasize and analyze each step of the UTPP in very great detail and in the process the system as a whole is lost sight of. Each of these steps is interlinked with the others. These should be equilibrium within the network assignment and also equilibrium with between this step of UTPP and the other elements of the demand function. A comparison should be made between the travel times based on the outputs of traffic assignment and the travel rime used as inputs for the allocation of residential growth and activity. And if these travel times are not the same, the sequence of travel time dependent steps in the UTPP must be repeated until equilibrium is achieved between the equilibrium travel time from the network assignment step and the input travel time taken in the trip generation step.

The notion of equilibrium in this context parallels the physical notion of stable equilibrium, which is the state in which there are no net forces that try to push the system to some other state. Furthermore, when the system is not in equilibrium, there are forces that tend to direct the system towards the equilibrium state. In the case under consideration, the flows are being “pushed” towards equilibrium by the route switching mechanism. At equilibrium, the flow will be such that there is no incentive for route switching.

As the examples above indicate, the equilibrium flow pattern associated with a given scenario may involve unanticipated flow levels and congestion in various parts of the network. This bears directly on the question of who is affected under this scenario. Where as some travelers will be better off, other may be worse off. A consideration of the entire system is therefore necessary in order to account for the wide spectrum if effects associated with a particular scenario. In other words, the equilibrium flow pattern that would prevail under each scenario can be found only by analyzing simultaneously all elements of the transportation network.

4.6 Application of the UTPP

If we accept the semantically double negative, development is negative entropy [48]. Development is a difficult goal because it represents the least probable state. This raises an important philosophical and methodological query: should one plan to predict the future or to influence the future? For example, we have seen how the gravity model is used in transportation planning to describe future spatial organization because as an entropy maximizing approach, it provides the only unbiased situation which can be assumed. While the maximum entropy solution to a problem is the most natural solution, it is not the most desirable solution. Whereas the gravity model posses the rationality of deductive rather than projective planning, it has been subjected to such tight calibration that it has degenerated to a simple projective tool. In summary, what we have today is a case of transportation engineers trying to minimize entropy through the use of such tactical ploys as freeway control (minimizing entropy in transportation supply) while transportation planners are locating new transportation facilities according to entropy maximizing criteria at the strategic level. This is obviously a mismatch. It is apparent that the next generation land transportation and the communities that they serve must be designed in concert.

Assume by the middle of the next century that the entire 40,000 mile Interstate Highway System has been converted to the cross-section shown in Figure 4.2. Assume, for planning purpose, that this 40,000 mile Magway Corridor will be the home for 400 million American at the end of the 21st Century, which means an average of 10,000 persons per mile. If the average spacing between Magway Interchange is 10 miles, these nodes represent ingress-egress points for 100,000 persons; if a 20 miles spacing is used then 200,000 persons. Many of these interchanges would be the focal points for new city modules as explained in Section 4.4.

The forecast of corridor land use and travel for the horizon year begins with the location and intensity of industrial activity as measured by J_j, the number of jobs in module

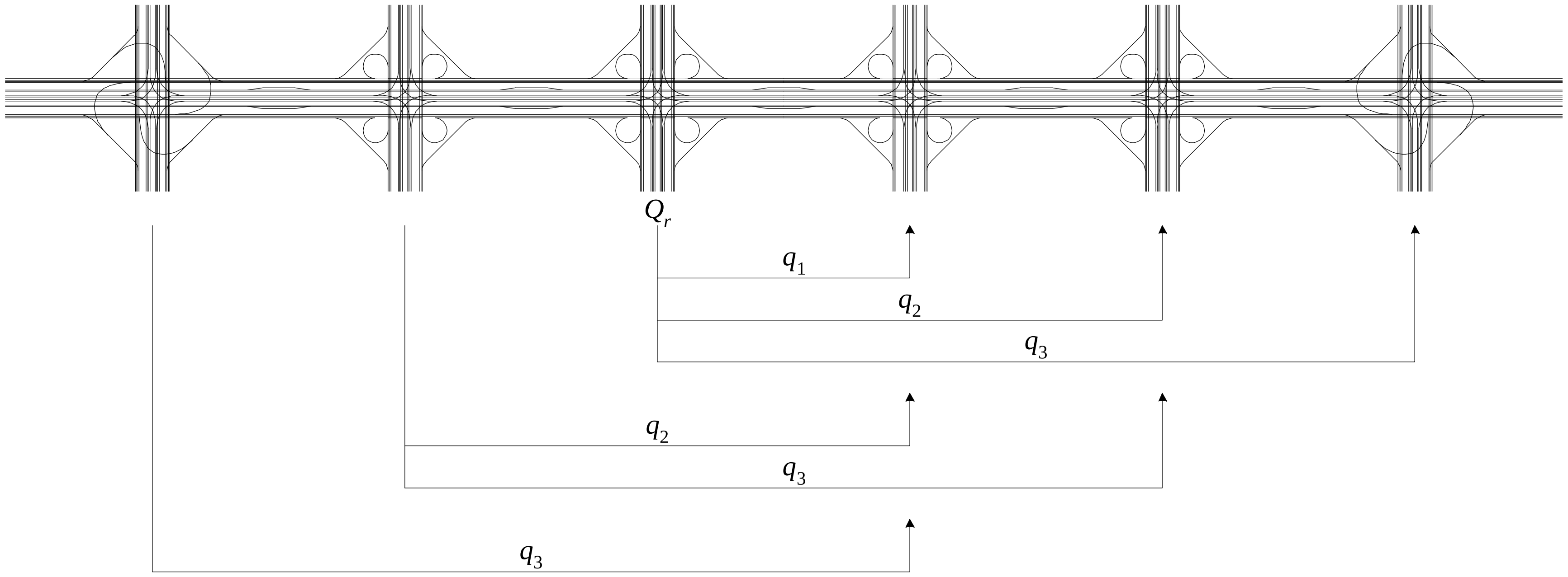

Figure 4.2 Application of UTPP

j. Knowing where the laborforce will work, the next step is to determine where the laborforce will live L_i using the gravity-accessibility model:

$$L_i = \frac{A_i H_i}{\sum_{i=1}^{n} A_i H_i} \sum_{j=1}^{n} J_j \tag{4.1}$$

where A_i is the accessibility factor and H_i is the holding capacity of the module. The expression for A_i, the accessibility of workers in module *i* to jobs in module *j* is

$$A_i = \sum_{j=1}^{n} J_j / t_{ij}^{x} \tag{4.2}$$

where t_{ij} is the travel time from *i* to *j* and *x* is a measure of the importance of proximity.

Trip generation analysis is used to find the number of trip ends, O_i and D_j, from the land use intensities, L_i and J_j, and other socioeconomic variables using regression analysis. The number of trips from module *i* to module *j*, V_{ij}, is obtained using trip distribution analysis. A gravity model formulation is

$$V_{ij} = K O_i D_j / t_{ij}^{x} \tag{4.3}$$

where *K* is a factor for satisfying the following constraints:

$$\sum_{j=1}^{n} V_{ij} = O_i \qquad (i = 1, \ldots, n) \tag{4.4}$$

$$\sum_{i=1}^{n} V_{ij} = D_j \qquad (i = 1, \ldots, n) \tag{4.5}$$

To convert from person-trips per day, V_{ij}, to vehicle trips per hour, q_{ij}, we employ the fraction of daily work trips during the peak hour, *FDWTPH* and *AVO* the average vehicle occupancy to obtain

$$q_{ij} = (FDWTPH / AVO) \times V_{ij} \tag{4.6}$$

To complete the demand function, it is necessary to find the link volumes q from the intermodule volumes q_{ij}.

Considerable insight can be gained by modeling the assumption that all modules are identical. Summing (4.1) over i gives

$$\sum_{i=1}^{n} L_i = \sum_{j=1}^{n} J_j \tag{4.7}$$

and since $L_i = L$ and $J_j = J$,

$$nL = nJ \tag{4.8}$$

and

$$L = J \tag{4.9}$$

for each module.

Likewise, summing (4.6) over j and substituting in (4.4)

$$\sum_{j=1}^{n} q_{ij} = (FDWTPH / AVO) \times O_i \tag{4.10}$$

Assuming $O_i = L_i$ (realistic for work trips during the morning peak hour), then

$$\sum_{j} q_{ij} = (FDWTPH / AVO) \times L_i \tag{4.11}$$

Noting that L is the module population, P multiplied by the labor participation fraction, LPF,

$$\sum_{j=1}^{n} q_{ij} = \frac{FDWTPH \times LPF}{AVO} \cdot P \tag{4.12}$$

The number of vehicles originating in the module i during the morning peak hour is $\sum_{i=1}^{n} q_{ij}$ of which it can be assumed that the fraction a are intramodule and 1-a are intermodule ((1-a)/2 in each direction). Let $\sum_{k=1}^{n} q_k$ equal the vehicles per hour entering the magway in each direction. Then

$$\sum_{k=1}^{n} q_k = \frac{FDWTPH \times LPF \times (1-a)}{2 \times AVO} \cdot P \tag{4.13}$$

If there is to be compatibility between the land use and transportation subsystem, $\sum_{k=1}^{n} q_k$ should not exceed the interchange ramp capacity Q_r. Therefore, referring to Figure 4.2

$$Q_r = q_1 + q_2 + q_3 + ... + q_n = \sum_{k=1}^{n} q_k \tag{4.14}$$

where (in terms of q_{ij}) $q_1 = q_{12}$, $q_2 = q_{13}$, etc.

Consistent with the gravity model concept, the number of trips that exit at each interchange is inversely proportional to the number of interchanges, k, between i and j, expressed mathematically as [65]

$$q_k = \frac{q_1}{k^x} \tag{4.15}$$

Substituting (4.15) into (4.14) and solving for q_1,

$$q_1 = \frac{Q_r}{\sum_{k=1}^{n} k^{-x}} \tag{4.16}$$

The link volume q between adjacent interchanges, as seen in Figure 4.2 can be expressed as

$$q = \sum_{k=1}^{n} k q_k \tag{4.17}$$

Then by substituting (4.15) into (4.16)

$$q = q_1 \sum_{k=1}^{n} k^{1-x} \tag{4.18}$$

Substituting (4.16) into (4.18) gives the desired result:

$$q = Q_r \frac{\sum_{i=1}^{n} k^{1-x}}{\sum_{k=1}^{n} k^{-x}} \tag{4.19}$$

4.7 The Supply Function

The final step in the transportation forecasting process is to determine the traffic volume expected in each segment of the network, referred to by such term as network assignment or route choice. To carry out this task, we need to know the demand function and the supply performance function for the available routes on each link. Both of these functions contain route travel times expressed in terms of traffic volume. Secondly, we need to know the decision rule that states the criteria by which users select or are assigned to alternative routes.

For the magway corridor, traffic assignment means splitting the directional peak hour vehicle trips originating at each module which we have designated Q_r into the entrance ramp volume for the freeway roadway Q_r^f, the entrance ramp volume for the weaving lane of the guideway $Q_r^{g,w}$, and the entrance ramp volume for the through lane of the guideway $Q_r^{g,t}$, so that

$$Q_r^{g,w} + Q_r^{g,t} + Q_r^{f} = Q_r \tag{4.20}$$

The supply performance function for the freeway is based on the traditional linear speed-density model and is written

$$T^f = \frac{T_f^f}{.5 + .5\sqrt{1 - q^f / n^f Q^f}} \tag{4.21}$$

where T^f is the link travel time between module interchanges, T_f^f is the free flow travel time, q^f is the link volume, Q^f is the link capacity, and n^f is the number of freeway lanes. For cars, $T_{f,c}^f$ = 15 min and for trucks, $T_{f,t}^f$= 20 min assuming 20 miles between modules. The capacity values are Q_c^f = 2400 veh/hr and Q_t^f = 1200 veh/hr.

The supply performance function for the guideways is based on the analysis that will be presented in Chapter 8 in which

$$Q_T = a\left[\frac{5280(2 - b)NV_0}{S_p}\right] \tag{4.22}$$

and

$$Q_W = a\left[\frac{5280bNV_0}{S_p}\right] \tag{4.23}$$

where $a = N/N_{max}$ and $b = n/N$. Substituting for a and b in Q_w gives

$$Q_W = \left[\frac{5280NV_0}{S_p}\right] \times \frac{n}{N_{\max}} \tag{4.24}$$

where $N_{max} = S_p/2S$ and $S_p \sim 0.783V_0 + NS$ for Case 1 (Equation 8.9). As operating speed V_0 on the guideway increases, the ability to form platoon decreases, so it is not unreasonable for the term NV_0/S_p to remain fairly constant, and therefore replaced by K. In order for the weaving guideway lane to exactly replace 5 freeway lanes

$$\frac{5280Kn(2S)}{0.783V_0 + NS} = 5Q_c^f \tag{4.25}$$

For example if $n = N = 3$, $S = 20$ ft and V_0 is 200 mph

$$K = \frac{(12000)(156.6 + 60)}{(5280)(3)(40)} = 4.1 \tag{4.26}$$

Therefore the supply performance function for the weaving guideway becomes

$$Q_W = \frac{5280Kn(2S)}{.783V + NS} \tag{4.27}$$

For cars, $S = 20$, $K = 4.1$ and using $n = N = 3$

$$Q_{W,c} = \frac{2600000}{.783V + 60} \tag{4.28}$$

Expressed as travel time as a function of traffic volume,

$$T_{W,c} = \left(\frac{20 \times 60 \times Q_{W,c}}{2600000 - 60Q_{W,c}} \right) \times .783 \tag{4.29}$$

Likewise, for the through guideway lane for cars,

$$T_{T,c} = \left(\frac{20 \times 60 \times Q_{T,c}}{2600000 - 60Q_{T,c}} \right) \times .783 \tag{4.30}$$

Repeating the analysis performed from (4.22) to (4.29) for trucks, in which $S = 60$ ft and $V_0 = 150$ mph, yields

$$\frac{5280Kn(2S)}{0.783V_0 + NS} = 4Q_t^f \tag{4.31}$$

Again if $n = N = 3$

$$K = \frac{(4800)(117.5 + 180)}{(5280)(3)(120)} = .75 \tag{4.32}$$

The equation for trucks corresponding to (4.29) and (4.30) for cars are:

$$T_{W,t} = \left(\frac{20 \times 60 \times Q_{W,t}}{1425600 - 180 Q_{W,t}} \right) \times .783 \tag{4.33}$$

$$T_{T,c} = \left(\frac{20 \times 60 \times Q_{T,c}}{1425600 - 180 Q_{T,c}} \right) \times .783 \tag{4.34}$$

Three supply performance functions are plotted in Fig 4.3, 4.4 and 4.5 correspondingly to the following:

1. Do-nothing Alternative: 4 freeway lanes in each direction

   2 lanes for work trips (Fig 4.3)

   1 lane for non-work trip (Fig 4.4)

   1 lane for trucks (Fig 4.5)

2. Expansion Alternative: 18 freeway lanes in each direction

   7 lanes for work trips (Fig 4.3)

5 lane for non-work trip (Fig 4.4)

   6 lane for trucks (Fig 4.5)

3. AHS Maglev Alternative: 4 guideway and 4 freeway lanes each direction

   1 guideway weaving lane and 2 freeway lanes for short trips (Fig 4.3)

   1 guideway through lane for long trip (Fig 4.4)

   1 guideway weaving lane and 2 freeway lanes for short-haul trucks, and 1 guideway through lane for long-haul trucks (Fig 4.5)

For Alternative 3, the minimum length of trip on the guideway weaving lane is $a = a_1$ and on the guideway through lane is $a = a_2$. Repeating the analysis of (4.15) through (4.19) for a, we have:

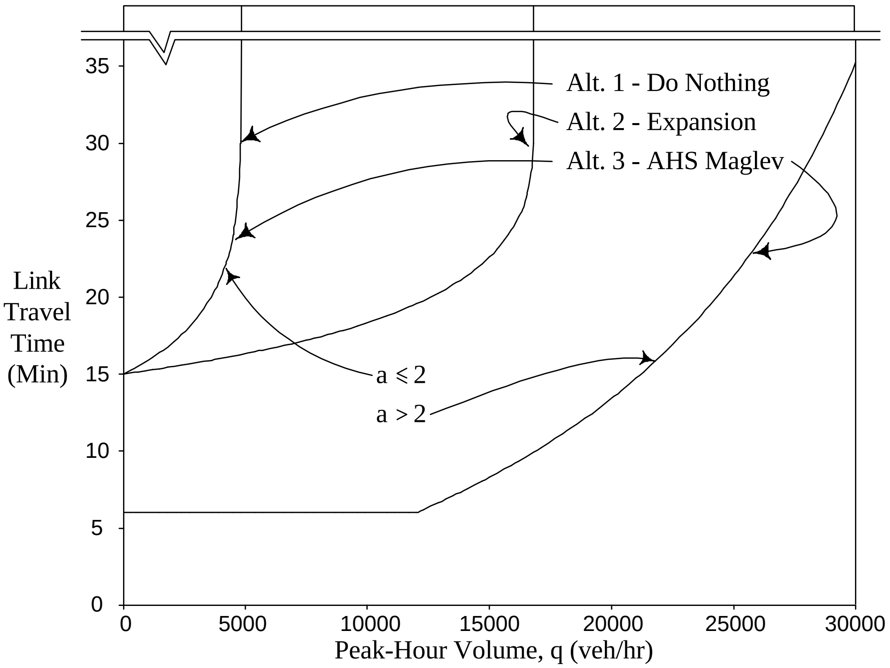

Figure 4.3 Supply performance functions for work trips

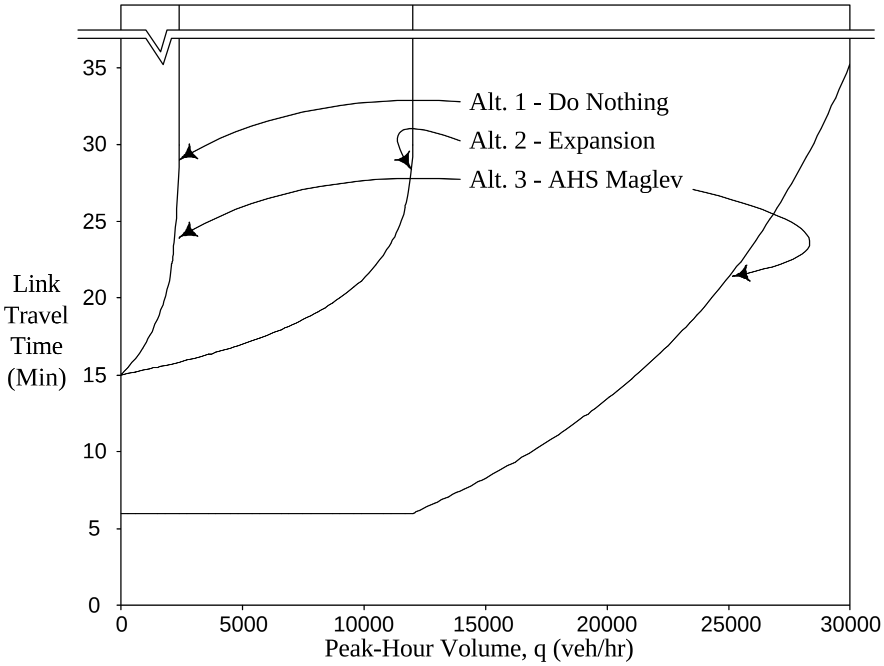

Figure 4.4 Supply performance functions for long trips

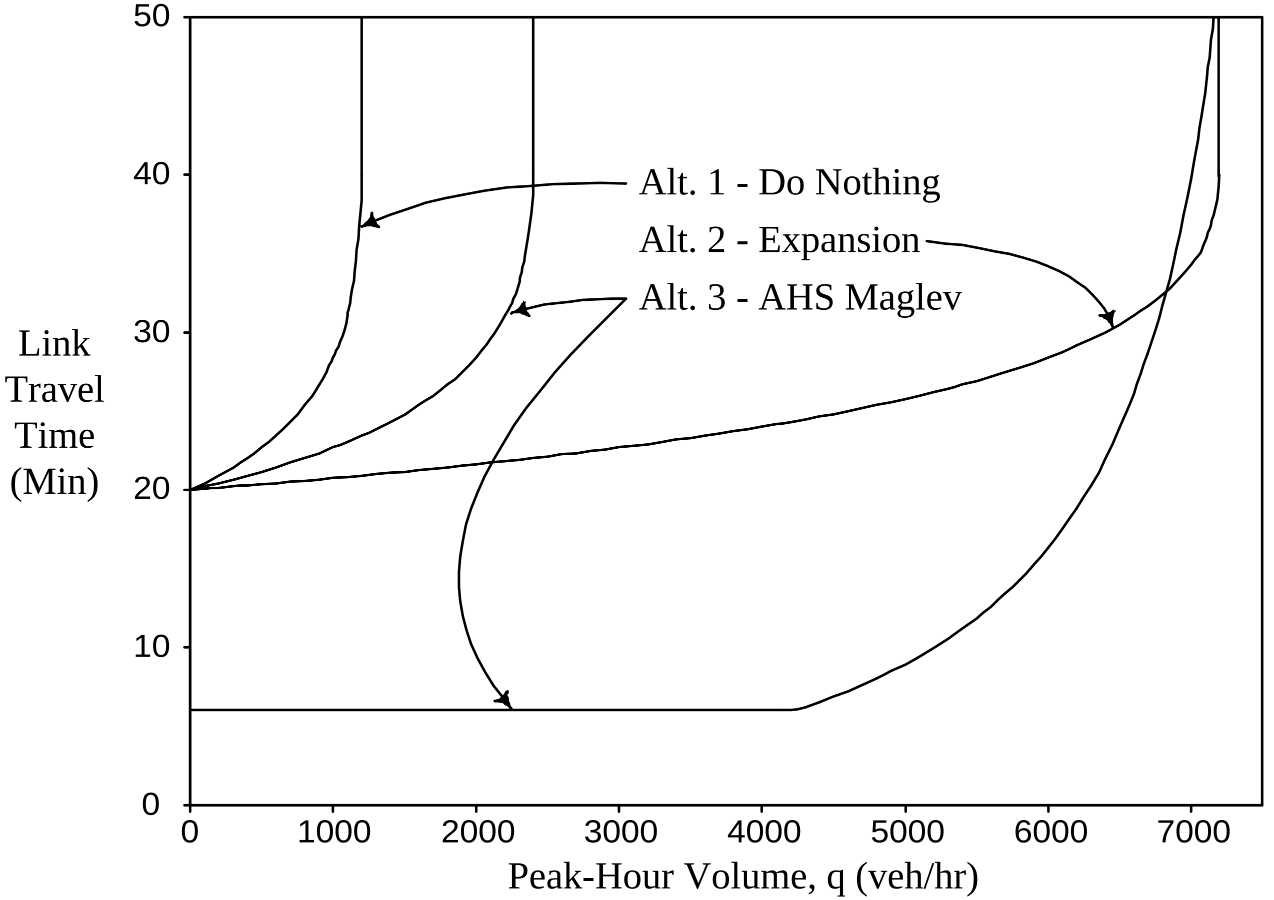

Figure 4.5 Supply performance functions for trucks

$$Q_r = q_a + q_{a+1} + q_{a+2} + \ldots + q_n = \sum_{k=a}^{n} q_k \tag{4.35}$$

where

$$q_k = \frac{q_a}{\left((k-a+1\right)^x} \tag{4.36}$$

Substituting Equation (4.36) into Equation (4.35) and solving for q_a:

$$q_a = \frac{Q_r}{\sum_{k=a}^{n} \left(k-a+1\right)^{-x}} \tag{4.37}$$

Then the link volume, q, between interchanges can be expressed as

$$q = \sum_{k=a}^{n} k q_k \tag{4.38}$$

By substituting Equation (4.42) into Equation (4.44)

$$q = q_a \sum_{k=a}^{n} \frac{k}{\left(k-a+1\right)^x} \tag{4.39}$$

Substituting Equation (4.43) into Equation (4.45) finally gives

$$q = Q_r \frac{\sum_{k=a}^{n} \frac{k}{\left(k-a+1\right)^x}}{\sum_{k=a}^{n} \left(k-a+1\right)^{-x}} \tag{4.40}$$

4.8 Economic Analysis

We have identified three alternatives identified as (1) Do-Nothing, (2) Expansion, and (3) AHS Maglev. An important issue has to do with the selection of the most appropriate method for ranking several scenarios, with cost-benefit analysis being the most frequently used. In the transportation field, this analysis is frequently employed for user impact analysis. Historically, the factor of cost was dealt with in a straightforward manner, usually taken to mean the amount of investment. In the concept of "sustainability", the meaning of cost needs to be expanded. The value systems of transportation impact analysis will be addressed in two parts: user impact analysis and nonuser impact analysis.

In the transportation field, benefit-cost analysis is often used for describing user impacts. The primary benefits of transportation improvements are time savings, cost savings, and savings due to accident reduction. Price-volume curves will be used as a conceptual framework for the process of pricing the benefits related to the following traffic components: 1) benefits to existing traffic; 2) benefits to generate traffic; 3) benefits to diverted and transferred traffic; 4) benefits to developed and normal growth traffic; and 5) pricing benefits to community traffic.

In the simplest case from Fig 4.6, the formula for consumers' surplus or net user benefit is:

$$UB = \frac{(P_0 - P_n)(V_0 + V_n)}{2} \tag{4.41}$$

where UB = user benefits, P_0 = original price of travel, V_0 = original travel demand (original annual volume), P_n = new price of travel, and V_n = new travel demand, (new annual volume).

The user-price of travel can be computed by the following equation:

$$P = n \times T \tag{4.42}$$

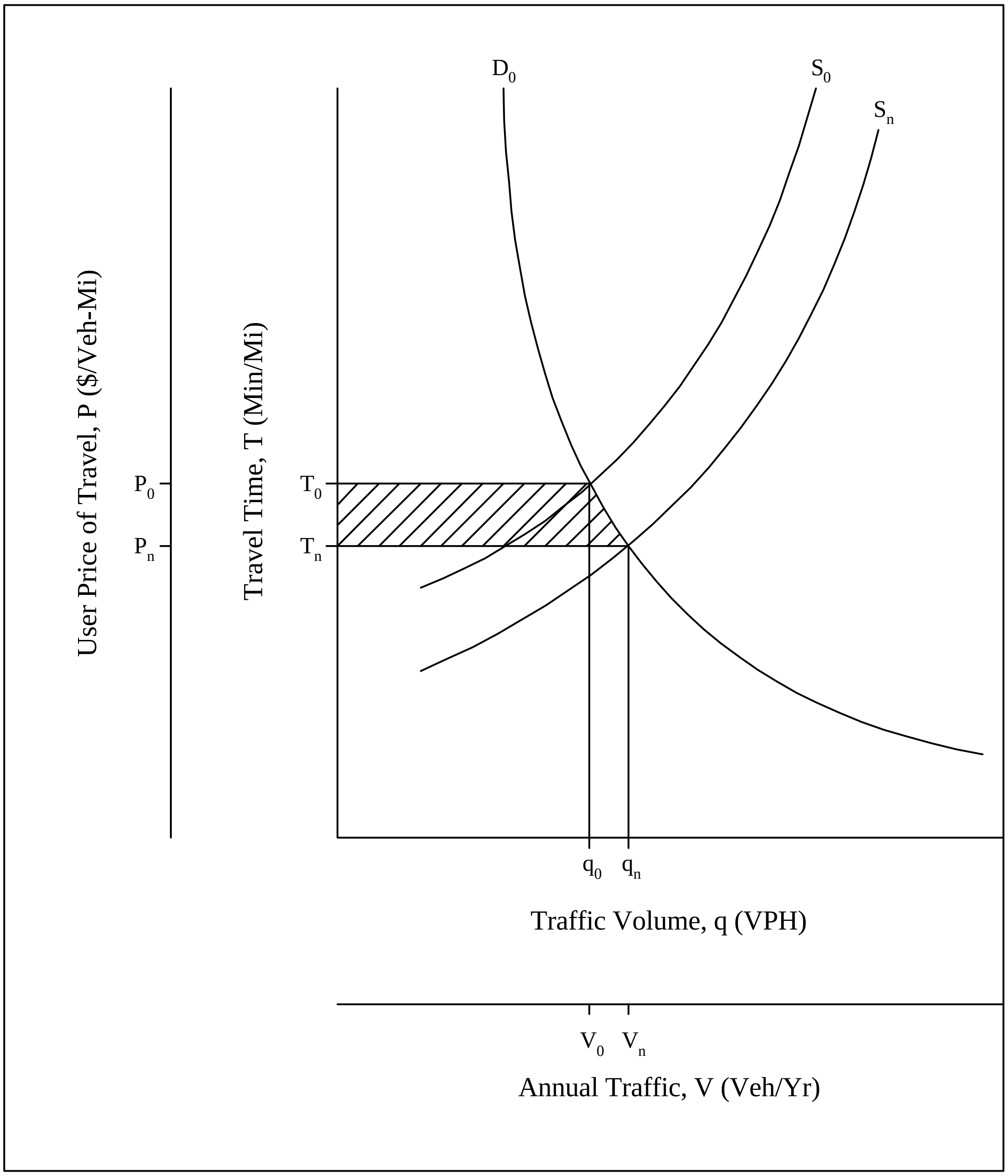

Figure 4.6 Determination of user benefits in transportation improvement

where P = price of travel, n = value of travel time, and T = travel time per unit length of road (min/mi).

The following equation is used for the computation of B/C ratio in infrastructure developments, which is shown in a simple form:

$$BCR = \frac{R - E}{C \times r}\left(1 - e^{-rt}\right) \tag{4.43}$$

where BCR = B/C ratio, R = annual revenues, E = annual expenses, C = capital costs, r = annual interest rate, and t = life span of the project.

Since the benefit-cost ratio, as the term implies, is the ratio of net annual benefits to net annual capital costs, any alternatives whose BCR is above 1.0 is economically feasible and the alternative having the highest BCR is indicated as the preference. In the transportation project evaluation, the benefit/cost ratio method is applied to pairs of alternatives and in this study the null alternative (do-nothing alternative) serves as the basis for comparison. In other words, the benefit/cost ratio of the first alternative is taken to be 1.0.

Taking the supply curves of Figs 4.3 and 4.4, four user benefit graphs are presented in Figs 4.7, 4.8, 4.9 and 4.10 using the format of Fig 4.6. Superimposed on the graph of the supply curves are the demand curves. A demand function illustrates what price different volumes of trip makers will be willing to pay for the trip in question. Different people wanting to make trips between a given set of origin and destination points will value the trips differently due to differences in income and ability to pay for the trip, differences in urgency of the trips, differences in the value of getting to their destination, and so forth. In general, as the price (or cost) of travel increases, less trips will be made, everything else being equal. In other words, the demand curve will usually be downward sloping. This is the case for demand curves involving freeway roadways for the three alternatives. These demand curves were chosen to intersect the freeway supply curves for the Expansion Alternative giving the following mathematical forms:

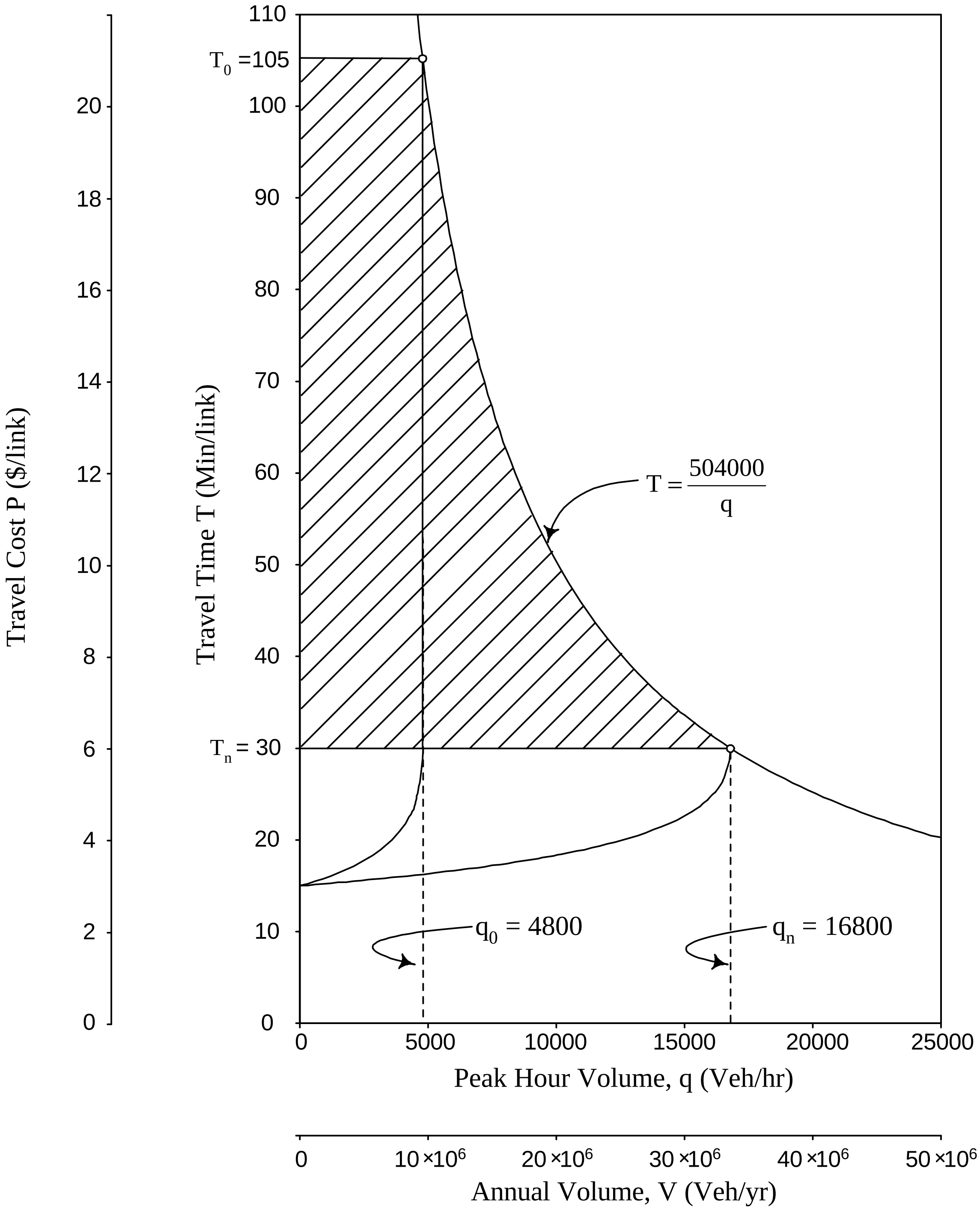

Figure 4.7 User benefits for Expansion Alternative (work trips)

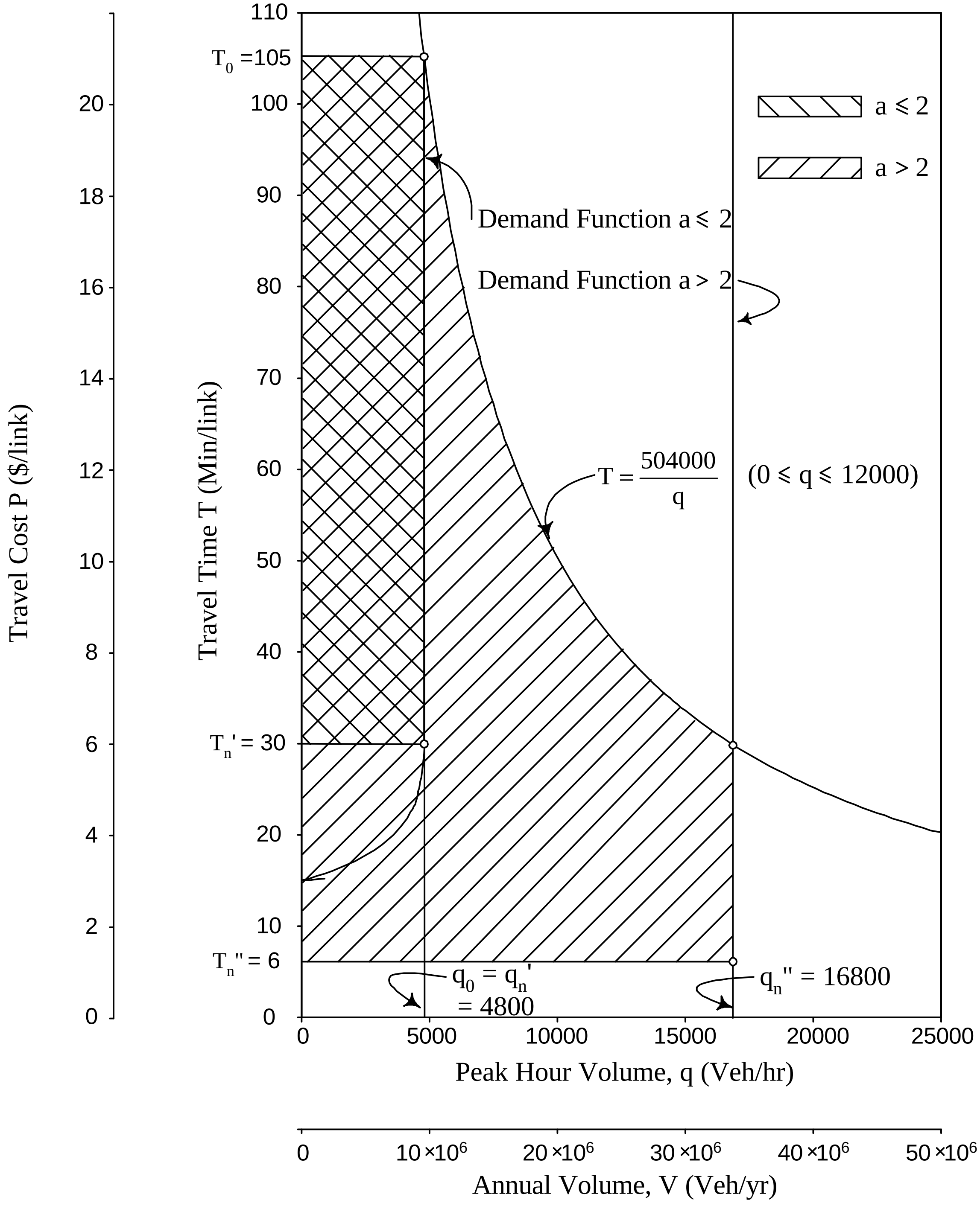

Figure 4.8 User benefits for AHS Maglev Alternative (work trips)

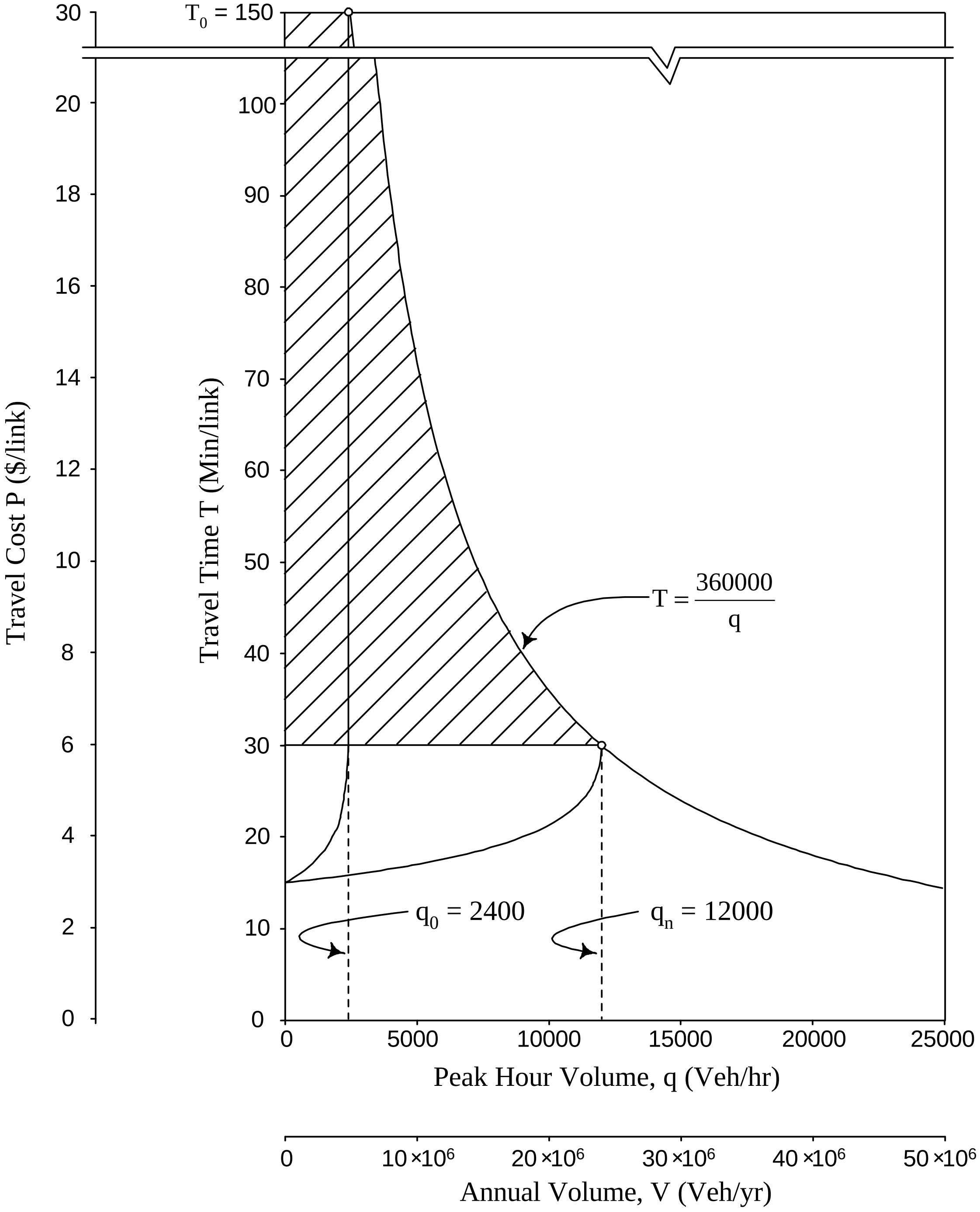

Figure 4.9 User benefits for Extension Alternative (long trips)

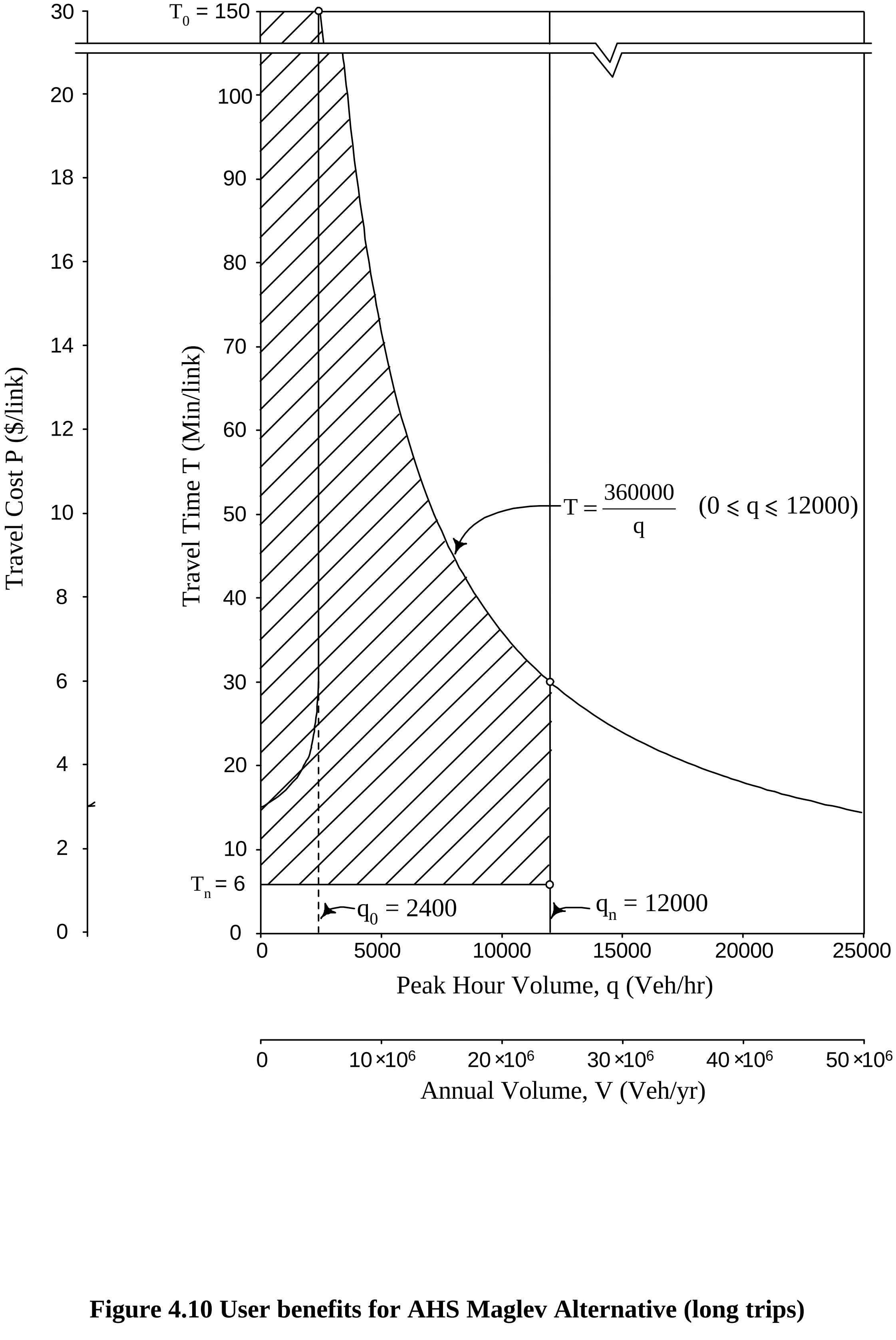

Figure 4.10 User benefits for AHS Maglev Alternative (long trips)

$$T = 504000/q \text{ in Figs 4.7 and 4.8} \tag{4.44}$$

and

$$T = 360000/q \text{ in Figs 4.9 and 4.10} \tag{4.45}$$

In this approach an important assumption is that the demand for travel depends only upon travelers' perceived costs. However, it has been argued that an improvement on a roadway will not only yield measurable travel cost savings, but it will also shift the demand curve due to changes in non-costable qualities such as comfort, view and convenience. For our user benefit computation this shift in the demand curve was utilized for the AHS Maglev guideways. The demand functions for these situation in Figs 4.8 and 4.10 are constants because the whole idea is that the link volumes are tied to module land use (See Sections 4.6 and 4.7).

The interplay between the supply and the demand relationships will determine the level of actual use which the roadway facility will experience and the price which trip makers should pay. In other words, at the equilibrium point (q_{kl}, T_{kl}) which is the intersection between the supply and demand curves, the peak hour volume q_{kl} and the link travel time T_{kl} will be determined, so that the system user cost and further, the user benefit in annual terms can be computed. For this purpose, the peak hour volume is converted into the annual volume V by the following equation:

$$V = 2000 \times q \tag{4.46}$$

where V is the annual volume and q is the peak hour volume.

The user price of travel P is found by Eq. 4.42. The converted equilibrium point (V, P) is substituted into Eq. 4.41 to find the unit user benefit for a 20-mile link and the result is multiplied by 2,000 to find the user benefit based on the assumption that 40,000 miles of the Interstate Highway System will need improvements. The user benefits for Alternatives 2 and 3 are calculated in Table 4.1.

Table 4.1 Calculations of user benefit

Alternative	**Original Price** P_0 (\$/veh)	**New Price** P_n (\$/veh)	**Original Demand** V_0 (10^6 Veh/yr)	**New Demand** V_n (10^6 Veh/yr)	**User Benefit** UB (10^9 \$/yr)
Work Trip					
Alt. 2	42000	12000	9.6	33.6	648.0
Alt. 3 (a < 2)	42000	12000	9.6	33.6	648.0
Alt. 3 (a > 2)	42000	2400	9.6	33.6	855.4
Long Trip					
Alt. 2	60000	12000	4.8	24.0	691.2
Alt. 3	60000	2400	4.8	24.0	829.4

Sample Calculation

Work Trip: Alternative 2

Value of time = 0.20 $/min, and a network of 2,000 links.

Original Price: $P_0 = 105 \times .2 \times 2000 = 42{,}000 \text{ \$/veh}$

New Price: $P_0 = 30 \times .2 \times 2000 = 12{,}000 \text{ \$/veh}$

Original Demand: $V_0 = 2000 \times 4800 = 9.6 \times 10^6 \text{ Veh/yr}$

New Demand: $V_n = 168000 \times 4800 = 33.6 \times 10^6 \text{ Veh/yr}$

User Benefit: $\frac{(42000 - 12000)(9.6 + 33.6)(10^6)}{2} = 648 \times 10^9 \text{ \$/yr}$

Table 4.2 Calculations of costs for Alternative 3

Design Speed (mph)	Facility Cost (10^9 $)	Land Cost (10^9 $)	Capital Cost (10^9 $)
200	1960	233	2193
250	2117	233	2350
300	2263	233	2496

Sample Calculation

Design speed 200 mph

Facility Cost: Assuming Construction Cost $40,000,000 per mile.

Construction cost increases as the design speed increases as shown.

$$FC = 40 \times 10^6 \times L \times \left[1 + \frac{V - 100}{300 - 100}\right]^{1/2}$$

$$= 40 \times 10^6 \times 40000 \times \left[1 + \frac{200 - 100}{300 - 100}\right]^{1/2} = \$1960 \times 10^9$$

Land Cost: Assuming $200,000/acre in year 2010.

$$LC = \frac{(540 - 300)}{5280} \times 40000 \times 640 \times 200000 = \$233 \times 10^9$$

Total Cost: $TC = FC + LC = \$2193 \times 10^9$

Table 4.3 Calculations of Benefit Cost Ratio

Design Speed (mph)	Travel Price P_n (\$/veh)	User Benefit (10^9 \$/yr)	Capital Cost (10^9 \$)	B/C Ratio
200	2400	829.4	2193	5.53
250	1920	836.4	2350	5.08
300	1600	841.0	2496	4.71

In order to calculate the benefit-cost ratios, Capital Costs C and Expense E in Eq. 4.41 must be determined for the two Alternatives. Capital costs include costs of advance planning, preliminary engineering, final design, rights-of-way acquisition and preparation, and construction. For our purpose, the capital costs are divided into fixed facilities costs (FC) and the land cost (LC) and thus can be expressed as follows:

$$C = FC + LC \tag{4.47}$$

This portion of the analysis is summarized in Table 4.2 based on the assumed condition for Alternative 3 shown in Fig 4.11. The facility cost for Alternative 2 is assumed to be the same as for Alternative 3 (Base Case). The right-of-way requirements for the three alternatives are 300 ft for 1, 780 ft for 2, and 540 ft for 3. The results of the user benefit-cost analysis for alternative 3 are presented in Table 4.3 assuming that annual expenses, E, are ten percent of C, an annual rate of 5% and a project life of 100 years. The benefit cost ratio for Alternative 2 is 3.67.

4.9 Nonuser Benefit Analysis

Information about nonuser social, economic and environmental consequences – community impacts for short – of transportation investment is frequently of crucial importance, due to the existence of the desire to achieve the highest possible state of economic efficiency, the trend to impose the cost of highways upon the beneficiaries thereof and the concern about the effect of highway location upon land use pattern, land value, population location, business activity, social disruptions and environmental disruptions.

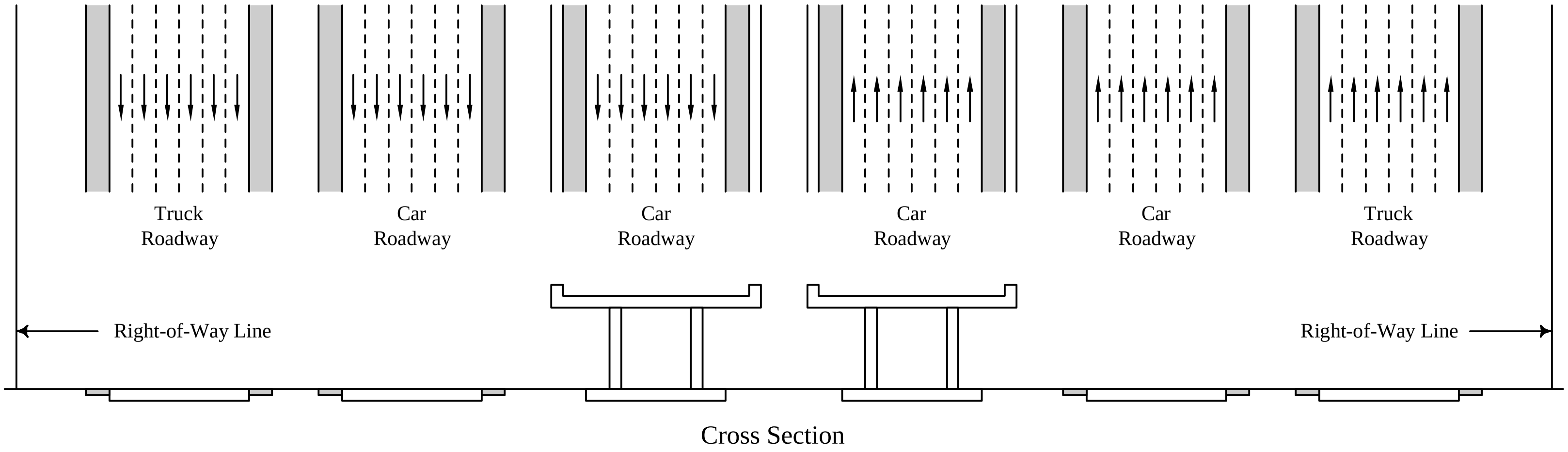

Figure 4.11 (a) Assumed condition for Alternative 2

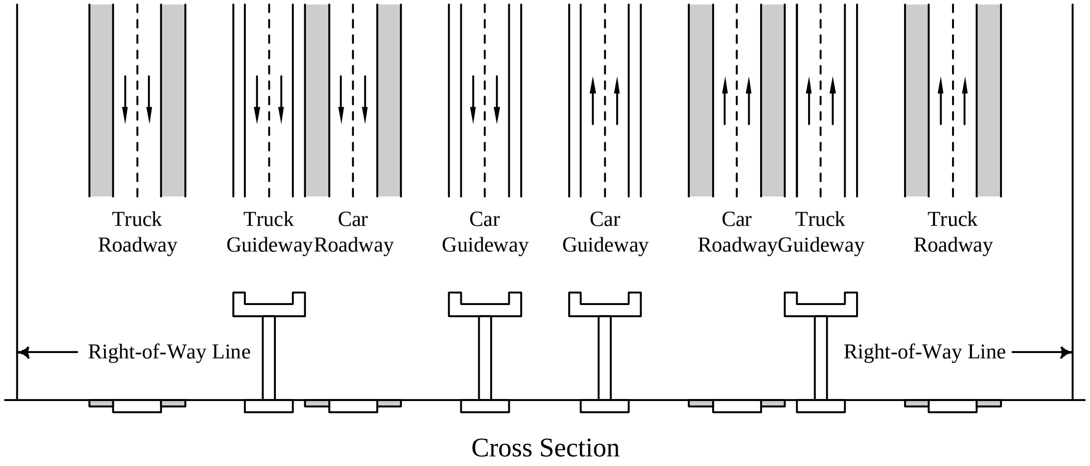

Figure 4.11 (b) Assumed condition for Alternative 3

Harris Associates, Inc. [66] refers to the benefits of the highway systems: 1) construction expenditures; employment and income in other sectors of the economy, 2) reduction of the interregional transportation costs, an effect on the location of industries, 3) reduction of the amount of traffic congestion within a region, making it more attractive as a location for industry and people. Perera [67] classified nonuser consequences into the following economic categories:

1) Spending for highway construction
   - Expenditure on labor and materials
   - Secondary effects induced by direct expenditure
2) Land use and land values
   - Loss of land due to right-of-way (R-O-W) acquisition
   - Redistribution of jobs and services due to relocation attraction of people and business
   - Land use changes
   - Land value changes
3) Business activity
   - Adjacent highway-oriented businesses
   - Local general trade, and tourism and recreation
4) General industry
   - Expansion of manufacturing, distributing, warehousing, and service types of industry, both light and heavy
   - Attraction of basic, export industries classified as (1) fabricating or processing and (2) orientation to markets, resources or labor
   - Business serving and household serving industrial induced growth

5) Agriculture
   - Increase in productivity and profit
   - Conversion of land to other uses
6) Mining and forestry
   - Improved accessibility to markets
7) Energy
   - Consumption associated with direct, indirect and induced effects.

For our purpose we will limit nonuser benefit analysis to a comparison of the impacts of the Alternatives on (1) the national economy and (2) the air transportation system.

Economically speaking, transportation investments positively affect a nation as a whole and its gross national product (GNP). Indeed, it requires the most imaginative mind to describe our economic society as it would be now without the motor vehicle. The main contribution of transportation investments to the economy of a nation comes from lowering the transportation cost of materials, supplies and products, reducing the cost of doing business, enhancing employment opportunity, increasing business activities, and making it possible to reach new land and obtain new natural resources.

Based on the above argument, it is obvious that the implementation of the most promising ITS technology, the original objective of which is to meet the challenge in the future mobility of the United States, will make a substantial contribution to the nation's gross national product. In other words, the dramatically improved mobility will reduce the proportion of industrial output allocated to the transportation service of raw materials, supplies and products, resulting in the increase of GNP since GNP is computed by subtracting a certain portion of the industrial output used to pay for raw materials, transportation service, energy supply, and etc. from the output.

To evaluate the savings in the transportation service cost, which are called the nonuser benefit of the AHS Maglev investment, the simple system dynamics model expressed in the causal diagram of Fig 4.12 and the equations of Fig 4.13 is proposed.

The analytical solution of the model is instructive. Considering the industrial sector first,

$$\frac{dIC_t}{dt} = ICI_t - ICD_t \tag{4.54}$$

Repeat substitution in the right hand side yields

$$\frac{dIC_t}{dt} = IC_t\left[\frac{(1 - FIOI)\times FGNPI}{COR} - \frac{1}{LIC}\right] \tag{4.55}$$

Separating variables and integrating yield

$$IC_t = ICN \times e^{\left[\frac{(1-FIOI)\times FGNPI}{COR} - \frac{1}{LIC}\right]t} \tag{4.56}$$

Solving for GNP_t gives

$$GNP_t = GNP_0 \times e^{\left[\frac{(1-FIOI)\times FGNPI}{COR} - \frac{1}{LIC}\right]t} \tag{4.57}$$

Now, considering the population sector, we form the differential equation of the system from the level equation

$$\frac{dP_t}{dt} = B_t - D_t \tag{4.58}$$

Repeated substitution in the right hand side gives

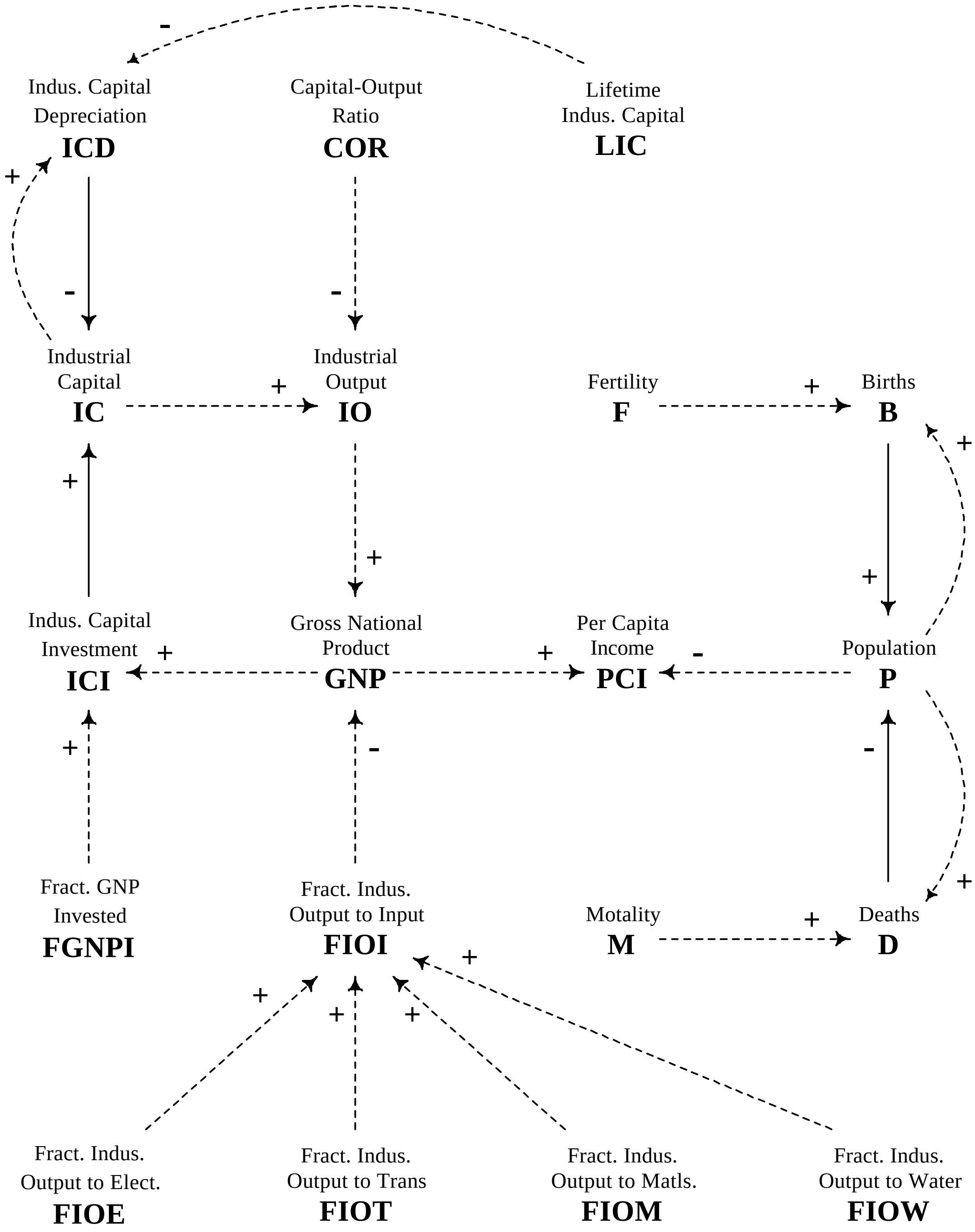

Figure 4.12 Causal diagram for nonuser benefits

```
       **************************************
NOTE NONUSER BENEFIT MODEL
**************************************
L IC.K=IC.J+(DT)(ICI.JK-ICD.JK)
N IC=ICN
NOTE IC-INDUSTRIAL CAPITAL ($)
C ICN=3.5E11
NOTE ICN-INDUSTRIAL CAPITAL INITIALLY ($) (YEAR 2000)
R ICI.KL=GNP.K*FGNPI
NOTE ICI-INDUSTRIAL CAPITAL INVESTMENT ($/YR)
A GNP.K=IO.K*(1-FIOI.K)
NOTE GNP-GROSS NATIONAL PRODUCT ($/YR)
C FGNPI=.25
NOTE FGNPI-FRACTION GNP INVESTED (DIM)
A IO.K=IC.K/COR
NOTE IO-INDUSTRIAL OUTPUT ($/YR)
C COR=1.25
NOTE COR-CAPITAL OUTPUT RATIO (YR)
R ICD.KL=IC.K/LIC
NOTE ICD-INDUSTRIAL CAPITAL DEPRECIATION ($/YR)
C LIC=20
NOTE LIC-LIFETIME INDUSTRIAL CAPITAL (YR)
A FIOI.K=CLIP(FIOT+FIOE+FIOM+FIOW,FIOTN+FIOE+FIOM+FIOW,TIME.K,10)
NOTE FIOI-FRACT INDUS OUTPUT TO INPUT (DIM)
C FIOE=0.2
NOTE FIOT-FRACT INDUS OUTPUT TO ELECTRICITY (DIM)
C FIOM=0.2
NOTE FIOI-FRACT INDUS OUTPUT TO MATERIALS (DIM)
C FIOW=0.1
NOTE FIOI-FRACT INDUS OUTPUT TO WATER (DIM)
N FIOT=
NOTE FIOI-FRACT INDUS OUTPUT TO TRANSPORTATION (DIM)
NOTE FIOT=.25 ALTERNATIVE 1
NOTE FIOT=.20 ALTERNATIVE 2
NOTE FIOT=.175 ALTERNATIVE 3
C FIOTN=.25
NOTE FIOTN-INITIAL VALUES OF FIOT DURING FIRST TEN YEARS
L P.K=P.J+(DT)(B.JK-D.JK)
N P=PN
NOTE P-POPULATION (PERSONS)
C PN=275E6
NOTE PN-POPULATION INITIALLY (PERSONS) (YEAR 2000)
R B.KL=P.K*F
NOTE B-BIRTHS (PERSONS/YR)
C F=.025
NOTE F-FERTILITY (1/YR)
R D.KL=P.K*M
NOTE D-DEATHS (PERSONS/YR)
C M=.018
NOTE M-MORTALITY (1/YR)
S PCI.K=GNP.K/P.K
NOTE PCI-PER CAPITA INCOME ($/PERSON-YR)

SPEC DT=1/LENGTH=100/PLTPER=5/SAVPER=1
SAVE GNP,P,PCI
PLOT GNP=G(0,20E12)/P=P(0,6E8)/PCI=I(0,36E3)
```

Figure 4.13 DYNAMO program for nonuser benefits

$$\frac{dP_t}{dt} = P_t\left(F - M\right) \tag{4.59}$$

Separating variables and integrating yield

$$P_t = PN \times e^{(F-M)t} \tag{4.60}$$

The measure of effectiveness is the Per Capita Income, PCI, which is

$$PCI_t = GNP_t \,/\, P_t \tag{4.61}$$

Substituting (4.57) and (4.60) in (4.61) provides the expression

$$PCI_t = PCI_0 \times e^{\left[\frac{(1-FIOI)\times FGNPI}{COR} - \frac{1}{LIC} + F - M\right]t} \tag{4.62}$$

The computer output for the model of 4.12 and 4.13 are presented in Figs 4.14, 4.15 and 4.16 for the three alternatives. In Fig 4.17 the three alternatives are arranged to facilitate comparison. The areas between the alternatives in Fig 4.17 are quantitative measures of difference in nonuser benefits. For example, the cumulative difference in GNPs between Alternatives 2 and 3 over the next century amounts to about 150 trillion dollars. The reason for this difference projected by the model is the difference in travel times and costs, FIOT (the fraction of industrial output to transportation).

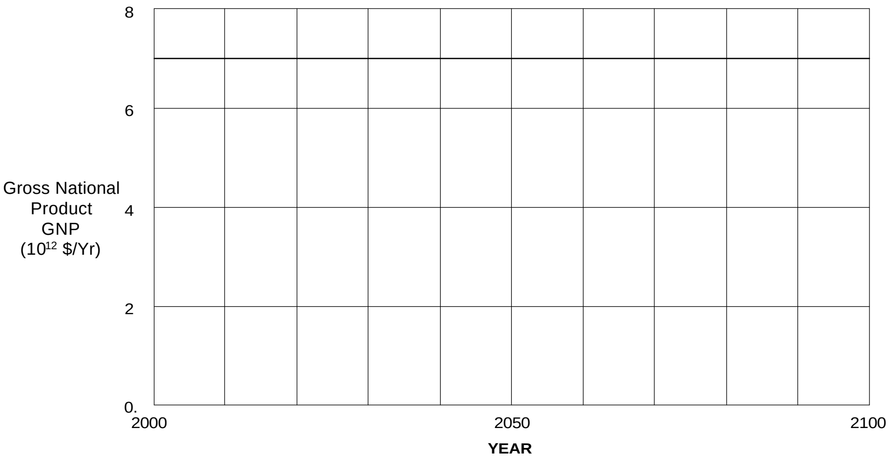

Figure 4.14 Gross National Product for Alternative 1

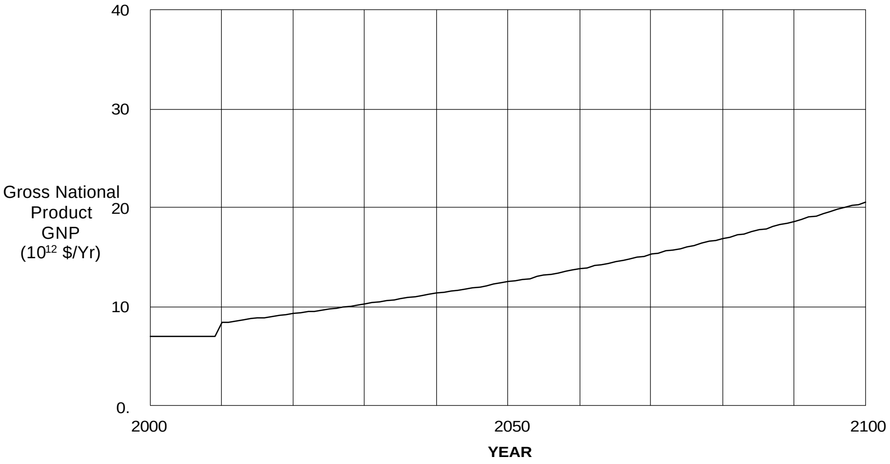

Figure 4.15 Gross National Product for Alternative 2

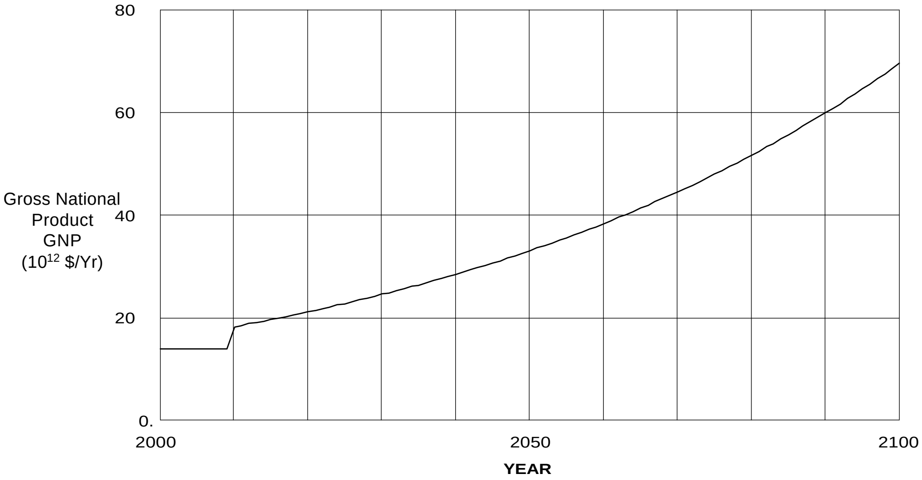

Figure 4.16 Gross National Product for Alternative 3

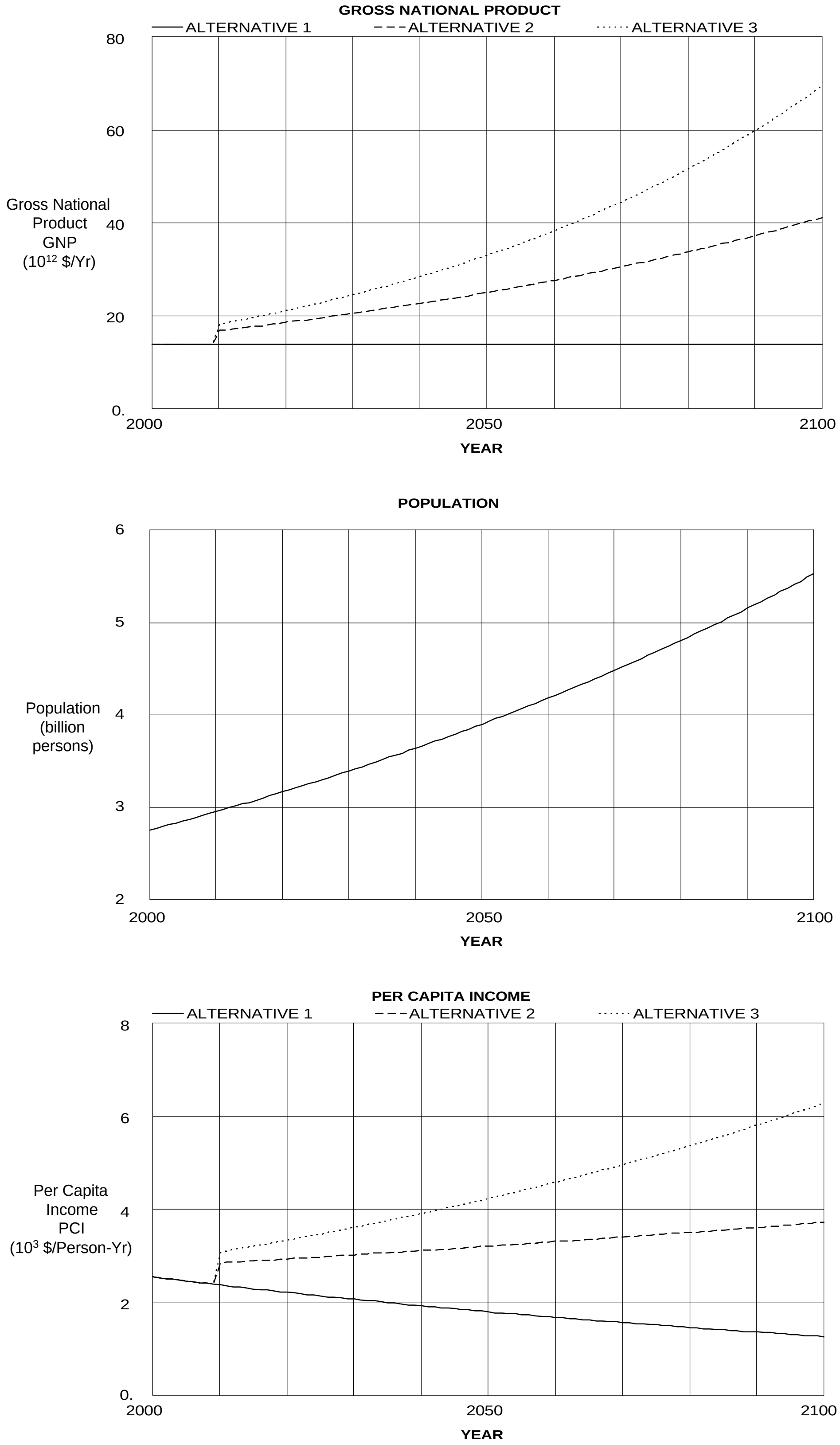

Figure 4.17 Summary of comparison of nonuser benefits

4.10 Impact on Air Travel

The worldwide growth in air travel over the past decade is 6% per year. The major explanation for this growth is the speed and convenience provided by this mode. The advantages are fast terminal-to-terminal transportation, reliable service, relative safety and customer services. Limited frequency of flights, capacity restrictions, and poor service to small cities are disadvantages. Also, factors that increase overall travel time are long trips to and from the airport as well as long wait times to check-in and retrieve baggage.

The choice of mode for intercity travel is heavily dependent on the sensitivity of the traveler with respect to time and cost. By and large, business travel is time sensitive, vacation travel is price sensitive, and travel for personal reason may be either or both. Key modal attributes are schedule, speed, cost and service.

The land transportation systems described in this dissertation, AHS Maglev, would significantly alter the modal split for intercity travel. Air travel on short and intermediate length trips would be greatly reduced. Regional carriers would probably not be needed and airport expansion at many hubs would not be needed.

Consider door-to-door service for air transportation. The respective time components are [68]:

- Access origin terminal = 30 minutes
- Check-in, walk to gate and wait = 30 minutes
- Board and time until plane leaves gate = 15 minutes
- Taxiing and stops until takeoff = 10 minutes
- Landing and taxiing to gate = 5 minutes
- Exit plane and walk to baggage claim = 15 minutes
- Wait for luggage = 10 minutes
- Walk to exit terminal = 5 minutes

- Access destination point = 30 minutes

Hence the total nontrip time by air is about 2 ½ hour long. Figure 4.18 compares air travel to AHS Maglev service assuming 500 mi/hr for jet aircraft, 200 mi/hr for the maglev automobile and zero access and wait time for the auto. The break-even point occurs at 833 miles and 4.17 hours.

In Figure 4.19, the modal split between air travel and AHS maglev is presented based on the multinomial logit model. The probability that a traveler faced with the choice of flying or driving decides to fly is given by the following equation:

$$P(A) = \frac{e^{-Z_A}}{\left(e^{-Z_A} + e^{-Z_M}\right)} \tag{4.63}$$

where Z_k is the generalized cost of travel for mode K as measured by

$$Z_K = g\left(C_K + vT_K\right) \tag{4.64}$$

with C_K being the travel cost, T_K the travel time, v is the value of time, and g is the utility coefficient. Multiplying (4.63) by e^{Z_A} and collecting terms gives

$$Z_K = \left(1 + e^{\Delta Z}\right)^{-1} \tag{4.65}$$

where $DZ = Z_A - Z_M$. The utility coefficient g is calibrated from data, but here will be assumed to be 25 ÷ distance traveled. The value of time is taken as \$20/hour. The cost of air travel is taken as 15 cents per mile and 30 cents per mile for AHS Maglev with an average occupancy of two persons per auto.

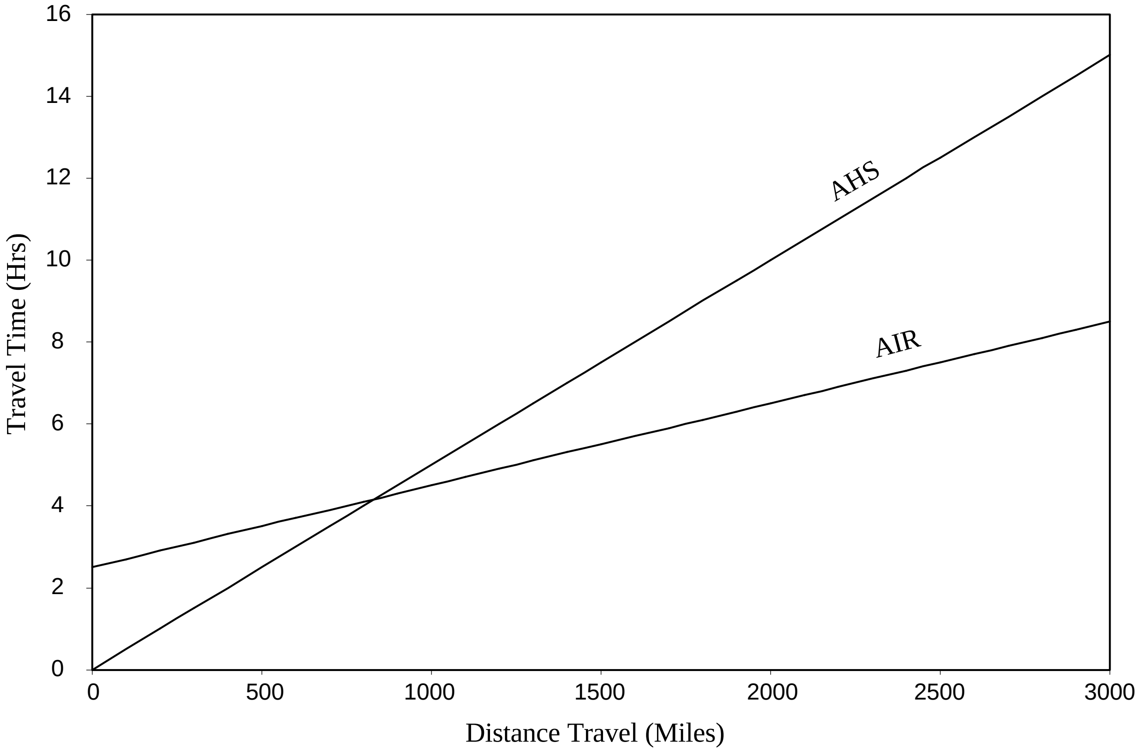

Figure 4.18 Mode competitiveness based on travel time

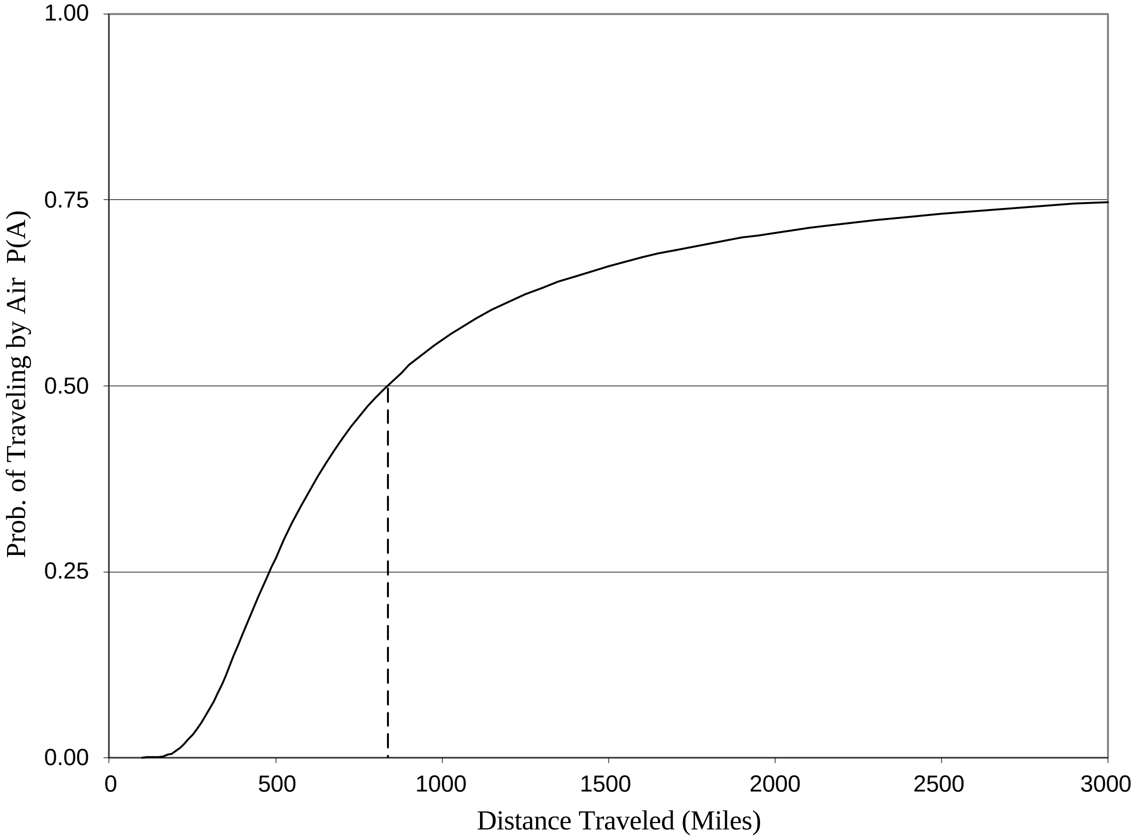

Figure 4.19 Modal split between air travel & AHS Maglev