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Final Report

ALTERNATIVE LAND USE PATTERNS TO MINIMIZE CONGESTION

Volume 1: Comparative Analysis of Mixed Land Use and Separated Land Use Neighborhoods

Amica Bose
Jon Fricker

December 2008

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Volume 1
Comparative Analysis of Mixed Land Use and Separated Land Use Neighborhoods

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16. Abstract

Urban sprawl creates serious traffic congestion. Alternative land use patterns may be the best solution. New Urbanists claim that, by placing frequently-visited sites within walking distance of homes and creating a pleasant walking environment, people are more willing to choose non-motorized transportation mode to do such activities.

Part I of this study investigated the ability of travel demand models to estimate the impacts of alternative land use patterns. Part II conducted an economic viability analysis for a mixed land use neighborhood and collected land use preferences at meetings of neighborhood associations. The objective in Part III was to evaluate the feasibility of implementing mixed land use neighborhood, based upon public acceptance, actual impacts on travel behavior and observed trip making patterns. Surveys were conducted and analyzed for this report.

A brief summary of the principal findings of this study will be posted on a website – either JTRP or INDOT. The findings will include brief numerical examples of the analyses that led to the report's conclusions. Figures and photos will be used to illustrate the alternatives and performance measures that support the project's findings.

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CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Land use patterns affect travel patterns, and vice versa. As congestion increases in many areas, a variety of strategies are being considered. While many of the congestion management strategies involve travel demand management (TDM) or traffic control measures (TCMs), shaping land use to fit travel habits and preferences may offer longer-lasting solutions. However, changing land use patterns will take more time and coordination with various stakeholders.

In Southern California, slow growth ordinances (SGOs) have been adopted. In Portland, Oregon, urban growth boundaries (UGBs) have been established (Metro, 2001). In the San Francisco area, transit-oriented design (TOD) has guided the development of several new BART stations (Transit Station Communities, 1999). In scattered locations across the US, neo-traditional neighborhood design (NTND) is being implemented (New Urban News, 2000). The SGO and UGB strategies have had unintended negative consequences. Urban containment policies retard growth processes and cause house prices to rise sharply. Inflexible growth constraints can cause artificial land scarcities and reduce affordable housing. The TOD and NTND ideas have not yet been applied in a large number of locations. Quite likely, other, less publicized ideas regarding the land use-transportation connection are being tried with varying degrees of success or failure.

The need for this research is guided by Indiana Department of Transportation's (INDOT) objective of developing a "toolkit" for use by planners, developers and public officials in Indiana, presenting the alternate land use patterns and mechanisms that would bring about the most desirable outcomes, in terms of congestion mitigation. Currently INDOT has no influence over decisions regarding what types of developments are allowed, where are they are placed, how large they are, and how they are configured. Previous INDOT projects were designed primarily to guide INODT's reactions to land use changes. While INDOT cannot dictate land use decisions in the private sector, or even by other public agencies, INDOT can assume a leadership role in educating all interested parties as to the consequences of certain development decisions on the transportation system, the development itself, and the community.

1.2 Scope of Research

The purpose of this research is to study generic land use-traffic relationships at the neighborhood level based on travel patterns and trip making behavior. The purpose is to develop and test a “modular” land use pattern designed to accommodate most of the non-work trips at reasonable distances from home. Existing land use strategies like neo-traditional/new urbanist and Euclidean models that are currently in use will be studied. Finally, an attempt will be made to make a comparative assessment of the measures of effectiveness (MOEs) between the developed “modular” land use pattern and the existing land use alternatives. The proposed research has two main components:

A. A review of the land use control strategies and existing forms of neighborhood design currently in use in the United States. In the inventory study, neighborhood design principles conforming to Euclidean (characterized by separated land uses; looks like conventional suburban development prevalent in various towns in the United States), new urbanist (mixed-use, compact development) and transit-oriented (mixed use development along a transit line) designs have been investigated.

B. The development of a “modular” land use pattern designed to accommodate most non-work trips within an acceptable travel distance from home, based on generic data. The neighborhood “module” will be analyzed using appropriate measures of effectiveness (MOEs), and will be compared with a Euclidean design. This component draws from the lessons of Component A, alternate models of travel behavior, and data on trends in travel patterns to determine the circumstances under which neighborhood “modules” can succeed.

1.3 Analysis Package

The modeling implicit in Component B has been accomplished using standard software in the form of Excel spreadsheets. For the four-step travel demand modeling procedure, a geographic information system (GIS) based transportation planning package "TransCAD: Transportation GIS Software", Version 4.0 (Caliper Corporation MA, 2001) has been used.

1.4 Applicability and Benefits of the Study

This study looks into the aspects of organizing land uses so as to affect local travel patterns. It is aimed at educating planners, public officials, developers and citizens as to the potential benefits of such alternatives as long-lasting solutions, to minimize congestion. The monetary costs of implementation are rather small. Most of the "costs" of implementation would be in terms of creating conditions or enacting regulations that will make implementation more likely. The benefits will begin as the desired land use patterns are instituted. Because much of this transformation will take place as new developments are built, the benefits will begin slowly. There is the possibility, however, for existing land use patterns to be modified to capture the benefits of a better match with personal travel preferences. For these reasons, the potential benefit-cost ratio is very high.

CHAPTER 2. LITERATURE REVIEW

The development of the "module"—the neighborhood design that will satisfy most of the non-work tripmaking needs at reasonable distances from residences -- is largely drawn from existing concepts, taking into account their ability to produce desired outcomes. This phase of the study is "information collection", creating an inventory and classifying the various land use strategies currently in use or proposed. In this phase, much emphasis has been placed on the concepts of traditional neighborhood development, new urbanism, livable communities, transit oriented development, and smart growth, as a means of building human-scale neighborhoods in place of single-use subdivisions, shopping centers and office parks.

The following sub-sections give broad outlines of the major findings from literature.

2.1 Christopher Alexander and "A Pattern Language"

The book "A Pattern Language" (Alexander, Ishikawa, Silverstein, 1977) presents a complete working alternative to our present ideas about architecture, building and planning. It provides a coherent picture of an entire region by describing about 253 patterns for towns, neighborhoods, houses, gardens and rooms. Each pattern has a format and no pattern is an isolated entity. The following paragraphs give brief descriptions of some of the patterns, paraphrased from the book, that are applicable to neighborhood design concepts. The title of the pattern is the section heading and the number between parentheses gives the index of each pattern as it appears in the book.

2.1.1 Scattered Work (# 9)

Separation of houses and work creates rifts in people’s lives. Prohibit large concentrations of work without family life around them and large concentrations of family life without workplaces around them.

2.1.2 Local Transport Areas (# 11)

Break the urban area into local transport areas, keeping main roads for long-distance traffic, but not for internal local traffic. Discourage the use of private vehicles within local roads. Lay footpaths and bike paths within local streets. Build major roads that make it easy for cars and trucks to get to and from a ring road (Fig. 2.1), but place roads to make internal trips slow and inconvenient.

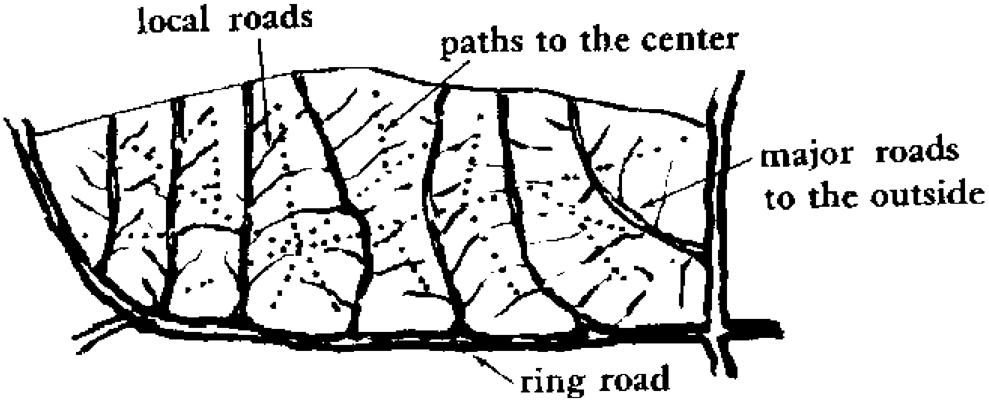


Fig. 2.1 Local Transport Areas (Alexander, Ishikawa, Silverstein, 1977)

2.1.3 The Sub-Culture Boundary (# 13)

A rich mix of sub-cultures can be created when they are separated by land that is not residential. Here, Alexander introduces the idea that a mix of land uses is possible when separated by man-made or natural physical boundaries. A physical barrier (Fig. 2.2) between the adjacent sub-cultures (this boundary may be natural--wilderness, farmland, water—or man-made--roads, parks, schools, housing, etc.) leads to development of indistinguishable traits between members of the same species.

Natural boundaries: water, pools and streams.

Artificial boundaries: ring roads, parallel roads, work communities, parking, etc.

Boundaries should be accessible to both the neighboring communities.

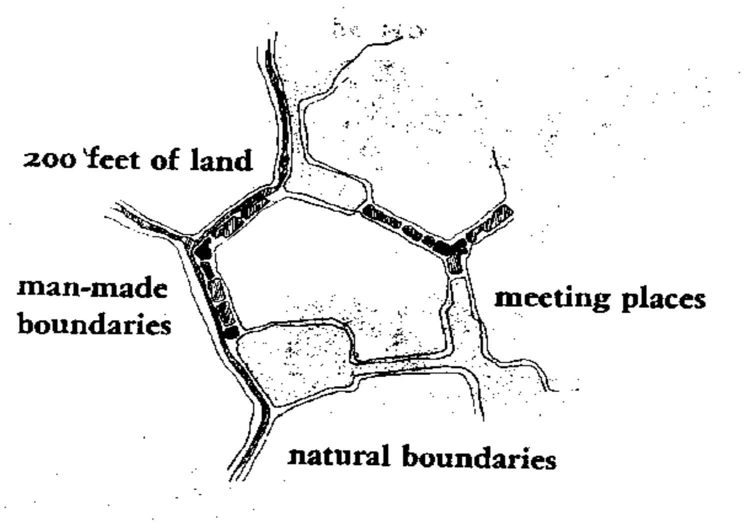


Fig. 2.2 Sub-Culture Boundary (Alexander, Ishikawa, Silverstein, 1977)

2.1.4 Identifiable Neighborhood (# 14)

A neighborhood can have a strong identity if it is protected from heavy traffic. The issue of traffic is fundamental--major roads become barriers to free pedestrian movement. People tend to view those neighborhoods as less personal and tend to think of them less as their home territory. Encourage people to define neighborhoods in which they live, not more than 300 yards across, with no more than 400 to 500 inhabitants.

2.1.5 Neighborhood Boundary (# 15)

The single most important feature is restricted access to a neighborhood. Encourage formation of a boundary around each neighborhood--by closing down streets and limiting access to the neighborhood.

2.1.6 Web of Shopping (# 19)

Shops of similar nature to be located further away from each other so that they serve those areas where there are potential customers. Identify location of potential consumers. Look for the biggest gap in the existing web of shops and within the gap in the web of similar shops, then locate the shop next to the largest cluster of other kinds of shops.

2.1.7 Four Story Limit (# 21)

High-rise buildings actually destroy people’s minds and feelings. They destroy townscape, wreck open spaces near them, promote crime and are difficult to maintain. Keep the majority of buildings four stories high or less. Even if certain buildings exceed the limit, they should never be for human habitation.

2.1.8 Discussion

The present research draws on Alexander’s idea that each “pattern” can exist in this world only to the extent that it is supported by other patterns: the larger pattern in which it is embedded. In many ways, this research incorporates the ideas proposed in the patterns listed above to create a coherent picture of a community. The patterns listed below are also worth mentioning in the present context.

- City-Country Fingers (# 3)
- Country Towns (# 6)
- Magic of the City (# 10)

- Local Transport Areas (# 11)
- Web of Public Transportation (# 16)
- Ring Roads (# 17)
- Network of Learning (# 18)
- Nine Percent Parking (# 22)
- Parallel Roads (# 23)

2.2 New Urbanism and Traditional Neighborhood Development

This trend is gaining momentum and has captured the interest of planners, architects, public officials, developers, engineers and citizens. Ten years ago, only a handful of projects were underway nationwide. Now, there are more than 250 new towns and neighborhoods, and at least 160 "infill" projects (New Urban News, 2000) that are planned under construction in the U.S. using the principles of the New Urbanism.

The New Urbanism calls for a different approach to just about every aspect of land planning and real estate--blocks and street networks, building design, transportation, retail, employment centers, zoning and codes, inner city revitalization.

A traditional neighborhood development (TND) is a new urbanist project built on a neighborhood scale, or larger. TNDs, also called new urbanist neighborhoods, can be as big as conventional modern master planned communities, but are radically different in design. In place of segregated private pods of suburban housing, TNDs mix uses and housing types. Cul-de-sacs are prohibited; instead, streets are interconnected and narrowed. In place of stand-alone shopping centers, town centers and "main streets" are built. Some of the major principles of New Urbanism are highlighted below:

- All development should be in the form of compact, walkable neighborhoods and/or such districts. Such places should have clearly defined centers and edges. The center should include a public-space (such as a square, green or an important street intersection), public buildings (such as a library, church, or community center), a transit stop and retail businesses.

- Neighborhoods and districts should be compact (typically no more than one-quarter mile from center to the edge) and with a mix of retail/commercial and residential uses, to encourage pedestrian activity without excluding automobiles altogether. Streets should be laid out as an interconnected network (usually in a grid or modified grid pattern), forming coherent blocks where building entrances front the street rather than parking lots. Public transit should connect neighborhoods to each other, and to the surrounding region.
- A diverse mix of activities (residences, shop, schools, workplaces and parks, etc.) should occur in proximity. A wide spectrum of housing options should enable people with a broad range of incomes, ages and family types to live within a single market neighborhood/district. Large developments featuring a single use or serving a single market segment should be avoided.
- Civic buildings, such as government offices, churches and libraries should be sited in prominent locations. Open spaces such as parks, playgrounds, squares, and greenbelts should be provided in convenient locations throughout the neighborhood.

TNDs have grown at a steady pace. Seaside, Florida, an 80-acre new town development, designed by planners Andres Duany and Elizabeth Plater-Zyberk, was the first TND, and it remains one of the best-known examples of New Urbanism.

Table 2.1 lists some projects that are representative of the TND trend. All projects share the design characteristics of a TND, yet are substantially different in density, appearance and specific planning features.

Table 2.1 Examples of TND Projects (New Urban News, 2000)

State (Name/Location)	Status (% Complete)	Acres	Characteristics
California 1. Hughes-Fullerton/Fullerton	Advanced planning	270	Mixed use neighborhood
Florida 1.Celebration/Osceola County	Construction (50%)	4900	8000 homes, office park
2. Haile Village Center/ Gainesville	Construction (50%)	50	200 homes, 200,000sq ft retail
3. Seaside/Walton County	Construction (90%)	80	350 homes, village center
Indiana 1. Coffee Creek Center/Chesterton	Construction (1%)	640	1200 units, town center, employment center
Maryland 1.Kentlands/Gaithersburg	Construction (90%)	352	1700 homes, school, retail district
2. Pleasant View Gardens/Baltimore	Built	21	Public housing redevelopment into neighborhood, 228 row houses, 110 apartments for elderly
Massachusetts 1. Mashpee Commons/Mashpee	Construction	140	New village connected to existing shopping center
North Carolina 1. Southern Village/Chapel Hill	Construction (60%)	312	1200 units, 200,000 sq ft office/retail
Oregon 1. Orenco Station/West Portland	Construction (20%)	190	1850 units, town center, live/work units
South Carolina 1. I'On/ Mount Pleasant	Construction (20%)	243	850 units, commercial
Tennessee 1.Lemoyne Gardens/Memphis	Planning	40	400 units, mixed use, public housing redevelopment
Texas 1. Triangle Square/Austin	Planning	22	Mixed use infill development
Washington 1. North West Landing/Dupont	Construction (15%)	3000	3500 residences, stores, industrial
Wisconsin 1.Midtown Commons/Madison	Advanced Planning	79	750 units, main street retail

2.2.1 Comparing New Urbanism and Conventional Suburban Development

The heart of New Urbanism is in the design of neighborhoods, and there is no clearer description than the 13 points developed by town planners Andres Duany and Elizabeth Plater-Zyberk (New Urban News, 2000). An authentic neighborhood contains most or all of these elements (see Fig. 2.3):

1) The neighborhood has a discernable center. This is often a square or a green, and sometimes a busy or memorable street corner. A transit stop would be located at this center.
2) Most of the dwellings are within five-minute walk of the center, an average of roughly 2000 feet.
3) There is a variety of dwelling types -- usually houses, row houses and apartments -- so that younger and older people, singles and families, the poor and the wealthy may find places to live
4) There are shops and offices at the edge of the neighborhood, of sufficiently varied types to supply the weekly needs of a household
5) A small ancillary building is permitted within the backyard of each house. It maybe used as a rental unit or place to work (e.g., office or craft workshop).
6) An elementary school is close enough so that most children can walk from their home.
7) There are small playgrounds near every dwelling – not more than a tenth of a mile away.
8) The streets within the neighborhood are a connected network, providing a variety of pedestrian and vehicular routes to any destination, which disperses traffic.
9) The streets are relatively narrow and shaded by rows of trees. This slows down traffic, creating an environment suitable for pedestrians and bicycles.
10) Buildings in the neighborhood are placed close to the street, creating a strong sense of place.
11) Parking lots and garage doors rarely front the street. Parking is relegated to the rear of buildings, usually accessed by alleys.

12) Certain prominent sites at the termination of street vistas or in the neighborhood center are reserved for civic buildings. These provide sites for community meetings, education, religious or cultural activities.

13) The neighborhood is organized to be self-governing. A formal association debates and decides matters of maintenance, security and physical change. Taxation is the responsibility of the larger community.

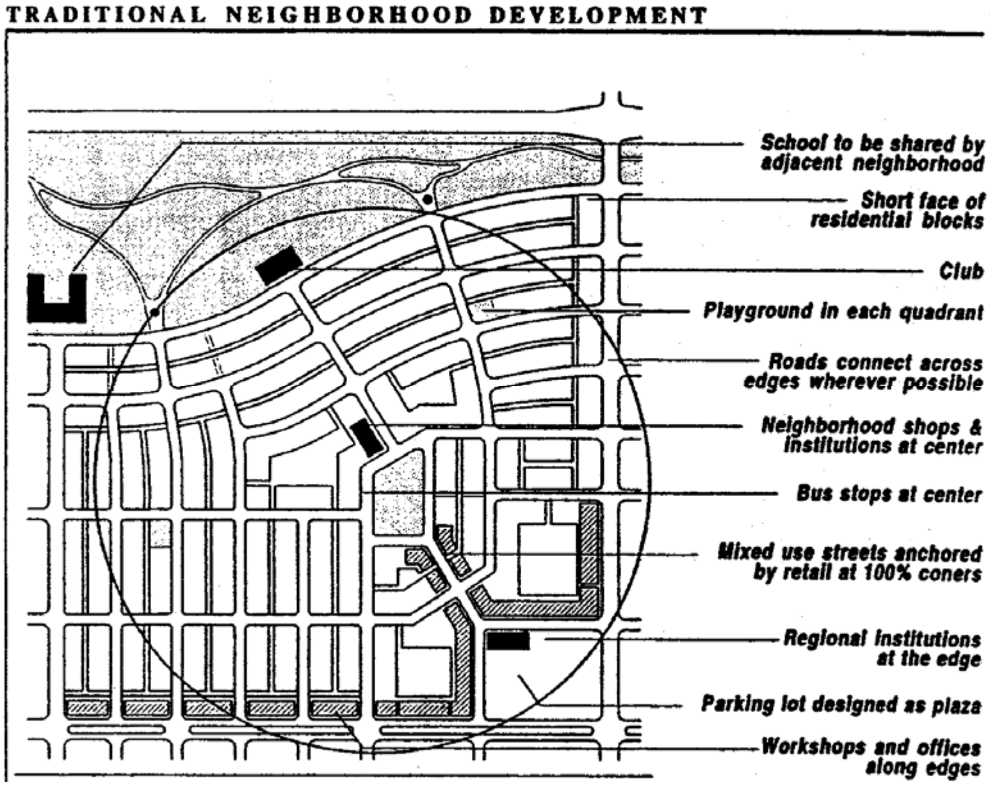


Fig. 2.3 Elements in a New Urbanist Development (New Urban News, 2000)

In comparison, conventional suburban development has the following characteristics:

1) Conventional suburban development consists of housing subdivisions, shopping centers, business parks, stand alone commercial stores, open space and civic uses such as schools, libraries and municipal buildings.
2) All uses are kept separate, in district pods. Even housing types, such as townhomes, duplexes, apartment buildings, and single homes are usually built in separate pods. Transportation between separate pods is generally by automobile.
3) The street pattern is dendritic, rather than interconnected. Housing pods, shopping centers and business parks feed into arterial roads that carry most of the traffic. To move between pods, one generally has to travel by automobile on an arterial road. Use of cul-de-sacs in residential areas is common.
4) There is no distinct center.
5) It is less compact than historic or neo-traditional neighborhoods. Because uses are kept separate and there is no distinct center, conventional suburban development tends to spread out, hence the term “sprawl”. The main selling point is privacy and security, so lots tend to be bigger.
6) Streets are designed on an automobile scale. Pavement is wide, and setbacks of buildings from the street are large. Infrastructure intended for the automobile is given the most prominent placement – e.g., garages, driveways and parking lots are closest to the street. Arterial roads, which connect separate uses, are designed for rapidly moving traffic. These characteristics create a pedestrian environment that is both boring and threatening for those who venture beyond the cul-de-sac. The large distances between the uses and the housing types poses an additional barrier to pedestrian traffic.
7) The low density and spread out nature of conventional suburbia discourages the use of public transit.

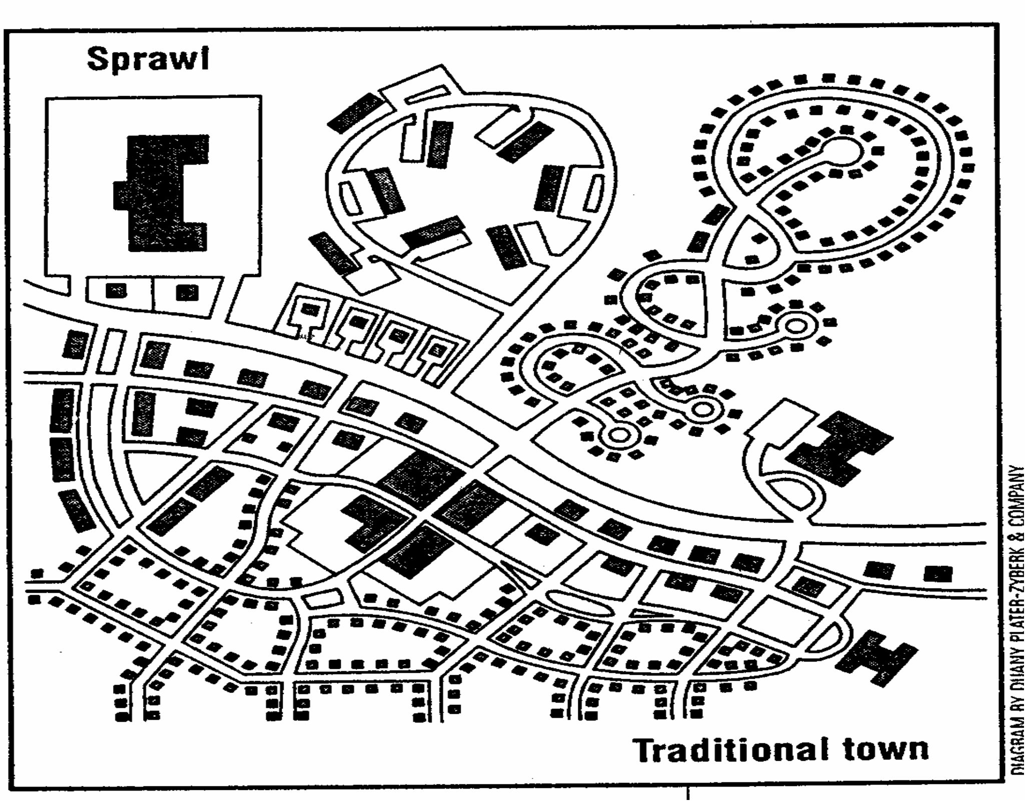


Fig. 2.4 Comparing Traditional Development and Urban Sprawl
(New Urban News, 2000)

2.3 James Howard Kunstler and "Home from Nowhere"

In the book "Homes from Nowhere", writer and social activist Kunstler echoes the sentiments of neo-traditionalism in creating more sustainable and livable communities. He focuses on the idea that the basic unit of planning is the neighborhood. Kunstler proposed that the neighborhood be limited in physical size, with well-defined edges and focused center. The size of a neighborhood can be defined as a five-minute walking distance (or a quarter mile) from the edge to the center and a ten-minute walk from edge to edge (Atlantic Monthly, 1996). Human scale should be the standard for proportions in buildings and their accessories. Kunstler, in fact reiterates the concept of the

Neighborhood Unit, which was formulated in the First Regional Plan of New York in 1929. In the 1920s, Clarence Perry, in his writings on the neighborhood unit, suggested that schools be placed within walkable residential communities so that a child would never have to cross a heavily trafficked street.

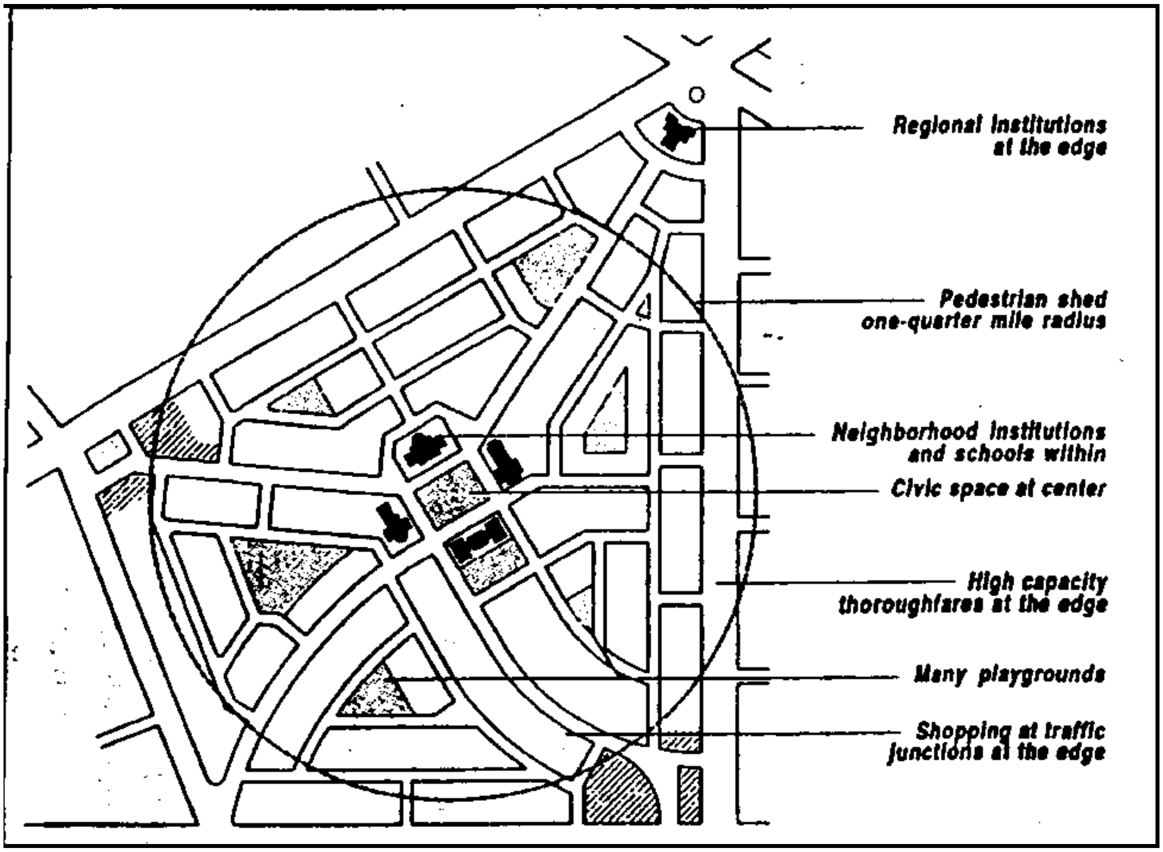


Fig. 2.5 Traditional Neighborhood Unit (Clarence Perry, 1920)
(New Urban News, 2000)

2.4 Urban Growth Boundaries

Urban growth boundaries (UGBs) have been looked upon as an essential tool for meeting the growth management challenges of the 1990s. They offer a better way to resolve the conflict between conservation and development. They encourage appropriate development inside the boundary and enhance long-term ecological, agricultural and other uses of natural lands outside the boundary.

The main characteristics of UGB are:

- They establish lines around metropolitan areas outside of which growth is discouraged or prohibited.
- They are intended to encompass an adequate supply of buildable land that can be efficiently provided with urban services to accommodate the expected growth during a 20-year period. By providing land for urban uses within the boundary, rural lands can be protected from urban sprawl.
- They encourage development inside the boundary and augment long term ecological, agricultural and other uses of natural lands outside of the boundary.

A UGB is more than just a line separating cities from the countryside. It is a “pro-active growth management tool that seeks to contain, control, direct or phase growth in order to promote more compact, contiguous urban development. The other key purposes are to protect farmland and other resource lands -- like watersheds or wildlife habitat -- from scattershot or low-density development.

2.4.1 Issues with UGBs

- UGBs may have unintended social and economic consequences. By restricting the land available for new housing, growth boundaries could increase the price of land and, ultimately, housing. Inflexible growth constraints can cause artificial land scarcities and reduce affordable housing. The price of housing will necessarily rise where the finite resource--developable land--is made much less available. As land for development becomes scarcer inside the boundary, the increased competition for developable land inside the growth boundary appears to contribute to higher land prices.
- The burden of the impacts are likely to affect low-moderate and middle-income households because their housing choices will be severely constrained, thus working against their interests. The higher property taxes result in forced sales of property and

their dislocation from the UGB to other neighborhoods or urban areas in search of cheaper housing.

Some say that UGBs create artificial land economics. Others point to the typical sprawl found within many UGBs as evidence that drawing growth lines does not equate with good planning or necessarily result in more sustainable development, either within or outside the line. The proponents argue that, where development is concentrated and higher density housing is built with smaller lots, the land will be better used and housing located on smaller lots with existing infrastructure will permit lower sales prices per housing unit (Greenbelt Alliance, 1993).

The best place to look for evidence of how UGBs have performed is Portland -- Oregon's 15 years of experience has shown UGBs to be highly effective. "Metro" is the agency that manages the regional UGB for the Portland Metropolitan Area. The Metro UGB has approximately 369 square miles of area (Metro, 2000). On the whole, it has been a huge success. It has helped to protect large swaths of forest and farmland at the region's edge. It has helped increase the amount of housing planned inside the UGB -- from 129,000 homes to 300,000 homes. And it has helped revitalize Portland's downtown.

2.5 Urban Land Institute: The Community Builders Handbook

This handbook (Urban Land Institute, 1977) is accepted as a practical reference manual for residential and commercial land development, and has guidelines for directing community growth and its correlated land development projects.

The handbook gives some general land use measurements applicable to preliminary planning for a satellite community, which is listed below. These indicators have been utilized as general points of departure in several places in the "module" development phase.

- Commercial Land Use (retail shopping): 2 to 3 acres per 1000 population

- Residential Land Use: single-family areas -- 100 acres gross required to house 1000 population; multi-family -- 15 to 30 acres gross required per 1000 population for apartments.
- Recreational and park land: 15 acres per 1000 population

In general, areas allocated to non-residential uses within the neighborhood tract should not exceed 35 percent; 20 percent is a norm for the area devoted to streets; 10 percent in public open space, including schools and churches; and 5 percent in commercial use. In terms of lot sizes, street layout, school and other public areas, land use allocations will be realistic in the neighborhood scale if residential use approximates 60 percent of the area, with the other 40 percent assigned to ancillary uses. The ancillary uses include any form of non-residential land development, such as, retail/commercial, schools and other public institutions, parks, open spaces and streets.

CHAPTER 3. THE MODEL

3.1 Methodology: Reverse Engineering

The Reverse Engineered Neighborhood (REN) model is designed to accommodate most non-work trips within an acceptable travel distance from home. The methodology followed is what one would term as “reverse engineering”. The concept is that, rather than start from a defined set of land uses and study the travel characteristics, instead shape land use patterns to fit the travel patterns of people. The intent is to start with the existing trip making behavior and identify land use configurations that would satisfy the most common trip making purposes.

3.2 Trip Purposes

Trip making is highly varied, reflecting the diverse activities pursued by people in their work and non-work activities. For purposes of this analysis, trips have been grouped in terms of categories or purposes. While this may disguise the variety of activities pursued, it simplifies the model development.

For the analytic purposes of the current research, generic trip making purposes as available from NPTS has been used. Table 3.3 lists the 11 major tripmaking purposes as categorized by NPTS. In the REN model, several sub-categories have been included in each category, to provide insight into the different land uses that might be associated with these trip purposes and to also facilitate calculation of land areas devoted to these land uses. Relevant calculations for the area requirement and development of the model have been discussed in Sections 3.3, 3.4 and 3.5 of this chapter.

3.3 Trip Frequency and Land Use Types

To start with, in the Reverse Engineering methodology, two aspects of trip making behavior have been considered: 1) trip frequency and 2) trip rates. The frequency of trip making by trip purpose gives an idea of the type of land uses that would be required in the REN. The trip rates, on the other hand, lead to the land area required for these chosen land uses. In order to address the trip frequency issue, a list of the most commonly visited land uses was made from the Yellow Pages in the telephone directory. A subjective estimation of the frequency of trip making by average households to these land uses was made. The levels of trip frequency considered were:

> 1 trip / week
1 – 4 trips / month
< 1 trip / month

Each land use type was placed into one of these trip frequency categories.

Table 3.1 lists the land uses that were considered. The general idea was to generate a comprehensive list of land uses that would fulfill a majority of the non-work trip making needs of the people living in the REN. The land uses have been further grouped into the broad major categories compatible with NPTS (Nationwide Personal Transportation Survey) trip making categories for which data are available. The Trip Rate column of the table gives the frequency, which is based on a subjective evaluation of the number of trips that would normally be made by members of a household. The broad categories based on trip frequency have already been mentioned above. Table 3.1 lists the trip frequency for the specific trip purposes that have been considered for the model development. However there is no such detailed database that lists these detailed trip purposes. The above-mentioned exercise of categorizing land uses by trip frequency attempts to relate the trip making frequency to the land use types that might be included in the model prototype. It was considered reasonable to include those land uses in the REN that had a trip frequency of at least one trip per month. Particular attention was paid to those land uses that had trip frequencies of about one per month. In reality, these land uses could also have a frequency of just a few trips per year or in some cases, even less than one trip per year. For example, trips to attorneys, accountants and consultants would probably be made at a rate of less than a one trip per year on a per household basis.

However, it seems still reasonable to include these land uses in the REN from a standpoint of self-sufficiency and sustainability in terms of satisfying most of the non-work trip making needs of its residents. Due consideration was also given to striking a balance between the type of land use and its effect on the size of the REN. A systematic attempt has been made to determine an optimum and acceptable size for the model neighborhood, consistent with the type and number of land uses and also with their dependence on the neighborhood size.

Table 3.1 Land Use Types by their Trip Frequencies

Category	Land Use	Trip Rate (per household)
Shopping	Grocery (Supermarket)	> 1 trip/week
	Convenience Store	> 1 trip /week
	Clothing	< 1 trip/month
	Hardware store	< 1 trip/month
	Shopping center and Mall	1-4 trips/month
	Specialty retail center	1-4 trips/month
	Bakery	> 1 trip/week
	Furniture Store	< 1 trip/month
	Electronics Store	< 1trips/month
	Sporting Goods- retail	< 1 trip/month
Doctor/Dentist	Doctor	< 1 trip/month
	Clinic	< 1 trip/month
	Hospital	< 1 trip/month
	Vet Clinic	< 1 trip/month
Other Family	Post Office	1-4 trips/month
Business	Banks	1-4 trips/month
	Credit Union	1-4 trips/month
	Gas Station	> 1 trip/week
	Car Wash	1-4 trips/month
	Auto repair center	1-4 trips/month
	Drugstore	1-4 trips/month
	Copying services	<1 trip/month
	Books & Magazine Center	< 1 trip/month
	Florists	1-4 trips/month
	Barber Shop	< 1trip/month
	Beauty Salon	<1 trip/month

Table 3.1 Continued

Category	Land Use	Trip Rate
Other Family	Attorney	< 1 trip/month
Business	Accountant	< 1 trip/month
	Engineering Consultant	< 1 trip/month
	Insurance Office	< 1 trip/month
	Real Estate	< 1 trip/month
	Dry Cleaners	1-4 trips/month
	Commercial Washers, Dryers	1-4 trips/month
	Plumbing repair and service	1-4 trips/month
School/Church	Elementary School	> 1 trip/week
	Day Care Center	> 1 trip/week
	Church	1 – 4 trips/month
Other Social &	Sit-down Restaurant	1-4 trips/month
Recreational	Fast –Food Restaurant	> 1 trip/week
	Drive-in Restaurants	> 1 trip/week
	Coffee Shop	1-4 trips/month
	Ice Cream & Confectionary	1-4 trips/month
	Pizza Place	1-4 trips/month
	Community Center	< 1 trip/month
	Fitness Centers/Health Club	1-4 trips/month
	Soccer Fields	1-4 trips/month
	Parks	1-4 trips/month
	Playground	1-4 trips/month

3.4 Trip Rates and Number of Land Uses

This section discusses the methodology for determining the number of units for each of the land uses that were selected from Table 3.1. While frequency of trip making was a parameter used to obtain the type of land uses, trip rates were used to determine the number of each of those chosen land use types. The number of units of the land uses in turn gave the total area and population in the REN.

This section describes the procedure that was followed to determine the area required for a REN. The concept of ‘reverse engineering’ is used in the calculation of area for each land use type.

Trip rates for the 11 major categories used in the NPTS were considered as a starting point. The NPTS also provides data for the total annual vehicle trips per household for all the 11 categories. At the outset, the annual trip making data were converted to vehicle trips made by each household on a daily basis. In converting to daily rates, a five-day week was assumed for work trips, trips to school and church and trips to doctor/dentist. For all other purposes a seven-day week was considered. These daily figures were converted to weekly trip rates, which were then used in conjunction with the trip rates obtained from ITE (Institute of Transportation Engineers) *Trip Generation* Report, 6th Edition, 1997.

The ‘reverse engineering’ procedure used to estimate the area requirement for each of the 11 major categories is explained below.

3.4.1 Step 1: Trip Rates from ITE

Trip rates for the 11 major categories were found in the ITE report. The area calculations were performed based on trip rates defined in terms of 1000 sq. ft. of Gross Floor Area (GFA). In those cases where trip rates in terms of GFA were unavailable, the trip rates in terms of GLA (Gross Leasable Area) were considered.

3.4.2 Step 2: Conversion of Daily to Weekly Trip Rates

Annual vehicle trip rates per household from NPTS (1995) data were converted to weekly trip rates. Weekly rates account for the variation in trip making behavior between weekends and weekdays. This can be illustrated in the example below:

Land use category: shopping center

Trip purpose: shopping

ITE trip rate for weekday = 42.92 trip ends/day/1000 sq. ft. GFA

ITE trip rate for Saturday = 49.97 trip ends/day/1000 sq. ft. GFA

ITE trip rate for Sunday = 25.24 trip ends/day/1000 sq. ft. GFA

The ITE trip rates were converted to trip rates per 1000 sq. ft. GFA *per week* for compatibility with the NPTS trip data. In converting to weekly trips, a weighted average of the weekday and weekend (Saturday and Sunday) trips was carried out in those cases where trip rates for both weekdays and weekends were available.

In the shopping center case, average trip rate per week = (42.92*5 + 49.97 + 25.24) =

289.82 trips/week/1000 sq. ft. GFA

3.4.3 Step 3: Sample Area Calculation

The area requirement for each land use was determined by a simple formulation considering the correspondence between the number of weekly trips per household for each category as obtained from NPTS, and the trip rates per 1000 sq. ft. GFA from ITE. In the sample calculation below, the land use category "shopping center" (code # 820, ITE Report, 1997) is used as one case of the trip purpose "shopping".

Trip rate for shopping center = 289.82 trips/week/1000 sq. ft. GFA

(The weekly trip rate includes rates for weekdays, Saturday, and Sunday, as demonstrated in the previous subsection.)

NPTS trip rate for shopping = 9.63 trips/week/HH

Area required for shopping center = (1000/289.82)* 9.63

= 33.23 sq. ft./HH

Area required for a shopping center to support 100 households:

= 33.23 * 100 = 3323 sq. ft./100 HH

The calculation shown above is repeated for all the NPTS categories of trip making. The calculations are based on the area associated with 100 households. The total area requirement for 100 households has been used as a base unit to come up with the number of households (hence population) required to support the total area required for non-residential uses.

3.4.3.1 Caveat

The above formulation needs to be treated with caution. First "shopping center" should not be treated synonymously with all shopping land uses. For this particular case, shopping center was chosen as a category for the trip purpose 'shopping" because it exists as a defined trip category in ITE for which it is easy to obtain the trip rate. In the NPTS, “shopping” includes various land use categories, like grocery and supermarket. The NPTS defines trips for shopping as:

> “Trips to purchase commodities such as groceries, furniture, clothing, etc. for use or consumption elsewhere”.

In fact, shopping might include many other categories not mentioned specifically in the NPTS definition above. It is very cumbersome to obtain trip rates for each specific shopping purpose. For analysis purposes, “shopping center” has been used as the generalized category, because it represents a variety of “shopping” purposes. If individual trip rates for shopping like groceries, furniture, clothing, etc., were used, they together would yield a much higher area requirement. Also, trip rates for all land use categories that come under “shopping” (listed in Table 3.1) are not available in the ITE Report. So, for our generic purposes of analysis, this simplification seems to be reasonable.

3.4.4 Step 4: Considerations for Different Trip Purposes

Steps 1 through 3 were repeated for all the other trip purpose categories. In many cases, as in “Other social and recreational” and “Other family business”, more than one land use type was chosen (see Table 3.1), and a single weighted ITE trip rate for that trip purpose was arrived at. Here is a sample calculation:

Trip purpose: Other Social and Recreational

Land Use categories included in this purpose and the relevant calculations for average trip rates are shown in Table 3.2.

Table 3.2 Average Trip Rate Calculations

Land Use Category (Other Social and Recreational)	Weekday trip rate (/1000 sq. ft. GFA)	Saturday trip rate (/1000 sq. ft. GFA)	Sunday trip rate (/1000 sq. ft. GFA)	Weekly trip rate (/1000 sq. ft. GFA)
Video Rental	31.54	26.92	-	31.54*5+26.92*2 =211.54 (trip rate for Saturday assumed in absence of Sunday data)
Fast-food with drive thru	496.12	722.03	542.72	496.12*5+722.03+131.84=3745.35
High-turnover sit-down restaurant	130.34	158.37	131.84	130.34*5+158.37+131.84=941.91
Movie theater with matinee	20.32	23.92	10.67	20.32*5+23.92+10.67=136.19
Health Club	4.3	-	-	4.3*7=30.10
Total				5065.09
Average trip rate				(5065.09/6) = 844.18

The average trip rate of 844.18 will be found in Table 3.3 for the “social and recreational” trip purpose.

The land use types chosen for the sub-categories were limited to those for which ITE trip rates were available. The trip purposes of “Other” and “Purpose not reported” (in Table 3.3) were not evaluated.

The trip rate for “school” was determined based on data for elementary, middle/junior and high schools. Because “School and Church” appear together as one category in the NPTS (see Table 3.3), the values were further averaged after considering both the average weekly rates for school and church.

The trip purpose “To and from work” has been considered in this study, but it has not been included in calculating the total area required for the neighborhood. There are a couple of reasons behind this. First, area required for workplaces is difficult to estimate, given the fact that the trips may go out to several adjoining neighborhoods. Second, the space needed for workplaces exerts a huge influence on the total area requirement for the model neighborhood and hence may be overestimated if ITE trip rates are used. Also, the REN is a neighborhood with a high percentage of residences, so large-scale work places and offices would typically not be located there. Only small offices compatible with a residential neighborhood, like banks and law offices, have been included. The workplaces chosen for the REN are listed in Tables 3.4 and 3.5.

3.4.5 Step 5: Choice of Base Unit

The sq. ft. area requirements associated with 100 households (see Table 3.3) in the module were added up to obtain the total floor area requirement. The unit of 100 HH has been chosen a base unit for the initial area calculation for the REN.

Table 3.3 Representation of Area Calculations Based on Major Trip Purposes

Trip Purpose	Trip/year/HH	Trip/day/HH	Trip/week /HH	ITE trip rate/week	Sq. ft./100 HH/week
Earning a Living					
To or From Work	553.00	2.13	10.63	44.00	24175.07
Work related business	80.00	0.31	1.54	-	-
Family and Personal Business					
Shopping	501.00	1.37	9.63	289.82	3324.46
Doctor/Dentist	33.00	0.13	0.63	157.25	403.57
Other family business	626.00	1.72	12.04	831.62	1447.60
School and Church	98.00	0.38	1.88	77.97	2417.26
Vacation	2.00	0.01	0.04	-	
Visiting friends and family	155.00	0.42	2.98	-	
Other social and recreational	269.00	0.74	5.17	844.18	612.79
Miscellaneous					
Other	2.00	-	0.04	-	-
Purpose not reported	0.00	-	-	-	-
Total	2321.00	-			32380.76

From NPTS trip generation data:

Total number of annual vehicle trips (includes automobile trips and transit, but not trucks) per household = 2321

From Table 3.3, for 100 HH, the non-residential floor area required is 32380.76 sq. ft.

Excluding work places, the area requirement for 100 HH, for non-residential purposes, is 32380.76 – 24175.07 = 8205.69 sq. ft.

3.5 Determination of the Number of Land Uses

In Section 3.4, the floor area of non-residential land uses required to support 100 HH units has been calculated. The term “non-residential” for this analysis means commercial and retail land uses, educational institutions (schools), churches, and public service buildings (post office, public library). It also refers to the small-scale workplaces that fit in a neighborhood setting, like offices for attorneys and consultants. These uses have been included in the REN (see Table 3.4, found at the end of Section 3.5). The floor area of workplaces (meaning office buildings, or office parks), although included in the same table, will not be further utilized in determining the total land area of the neighborhood, because such workplaces will not be a part of the neighborhood setting. In this section, the methodology for obtaining the number of units for each land use type will be presented. The area of residences (considering the average lot size) -- single-family dwellings, multi-family dwellings and apartments -- will also be determined. The total land area for residences, combined with the total land area for commercial uses, gives the area of 1 module as part of a REN.

3.5.1 Step 1: Area Required for Each Land Use Type

The types of land use were selected from Table 3.1, based on the 11 major categories as formulated by NPTS. The choice of the sub-categories of land uses was guided by a subjective evaluation of the frequency of trip making to the most commonly visited land uses in a neighborhood, which was explained in Section 3.3. The average value of the ‘X’ variable (as obtained from ITE *Trip Generation* Report) gave the floor area requirement for one unit of each land use. An example would be the land use “day-care center” (code # 565, ITE Report, 1997) used as one case of the trip purpose “school and church”. In this case, the average value of X variable (i.e., floor area of the land use) in the sample = 4000 sq. ft. Thus, from the ITE Report, the floor area requirement for a single day-care center would be 4000 sq. ft.

However, in many cases, the floor areas of the sites surveyed and submitted to the ITE report were substantially larger than would be expected in a neighborhood like the REN, which has compact land uses. For many land use types, there were only a few data points in the ITE report. The ITE figures point to a bias towards larger areas that might be applicable to suburban developments characterized by larger stand-alone land uses. In such cases, the floor areas of non-residential land uses were based on examples drawn from the local community. These locally available areas were thought to be more representative of the area requirements in a compact, mixed-use neighborhood such as the REN. Land uses like copying center, florist, and barber shop, for which floor areas were not available in the ITE report, were also estimated from local examples.

3.5.2 Step 2: Number of Units of Each Land Use Type

In Table 3.3, the floor area for say, shopping that is supported by 100 HH units can be determined. The trip purpose category “shopping” would include several types of land uses, as shown in Table 3.1. Two variables were considered: the number of units of non-residential land uses and the number of HH units. That is, there is inter-dependency between the number of HH units and a particular non-residential land use type. If the number of units of each land use type is held constant, then the number of HH units required to support that land use can be determined. For example:

From Table 3.4 (found at the end of Section 3.5) for 1 module (see Section 3.5.9 for definition of a module):

Number of supermarkets = 2

Number of convenience stores = 1

Considering several other land use categories under “shopping”, total floor area required = 2(12864) + 1675 + 2(1749) + 1155 = 32056 sq. ft.

From Table 3.3:

Total floor area required for “shopping” per 100 HH per week = 3324.46 sq. ft.

# of HH required to support a total shopping floor area requirement of

32056 sq. ft. = (32056/3324.46)*100 = 964 HH units.

The number of units for each category (2 supermarkets, 1 convenience store, etc.) was established based on judgment and examples drawn from the local community. In the above example, the total area requirement for shopping gave the number of HH units that would be required to support the land use category of “shopping”. Having computed the number of HH units makes it possible to estimate the population and the area requirement for residences in the REN.

3.5.3 Step 3: Adjustments for Multi-Story Buildings

Once the number of units for each land use type is determined, the total area of all the non-residential land use types can be obtained. Some of these land uses would be in the form of multi-story buildings, so adjustments must be made to ascertain the footprint area of those buildings. The two cases where such adjustments were made are cited below, from Table 3.4 (found at the end of Section 3.5).

Land use category: community center

Trip purpose: other social and recreational

Total floor area of building = 5000 sq. ft.

# of stories = 2

Therefore, footprint area of building = 2500 sq. ft.

Land use category: fitness center

Trip purpose: other social and recreational

Total floor area of building = 7402 sq. ft.

# of stories = 2

Therefore, footprint area of building = 3701 sq. ft.

The relevant calculations for three examples of mixed-use buildings are given in Table 3.5. An example can be drawn from Table 3.5.

Mixed-use buildings = 3 types

Floors in each mixed-use building = 4

Consider Building Type # 1:

# of stories = 4

Plan area for each floor = 5000 sq. ft.

Representative land uses on 1st Floor: Convenience Store, Beauty Salon

Representative land use on 2nd Floor: Bank

Land Use on 3rd and 4th Floors: Apartments on each floor with plan area of 5000 sq. ft.

The plan area was established based on reasonable estimates and examples drawn from the local community. The plan area of a mixed used building was converted to land area using a Floor Area Ratio (FAR) of 1.0. The land area includes space for parking and open space around the buildings.

3.5.4 Step 4: Number of Housing Units Required

After the area for non-residential land uses (excluding open space, for the time being) is converted to footprint areas in a module, the number of HH units required for that area can be determined. The square footage area required to support 100 HH units (excluding workplaces) has already been calculated (see calculation at the bottom of Table 3.3). So the number of HH units required to support the total footprint area (for non-residential uses, excluding open spaces) of the module can be obtained as shown below:

Total floor area for trips, excluding open space (see Table 3.4) =

32056 + 38649 + 69000 + 44320 + 3036 + 11000*4 (# of mixed-use buildings) = 231061 sq. ft.

Total plan (footprint) area for non-residential uses =

= 32056 + 38649 + 69000 + 44320 – 3701 (for 2nd floor of fitness center) - 2500 (for 2nd floor of community center) + 3036 + 11000 = 191860 sq. ft.

Plan area requirement for non-residential uses for 100 HH units, excluding
workplaces = 8205.69 sq. ft. (See Table 3.3.)

# of HH units required to support a total non-residential floor area of
231061 sq. ft. = (231061/8205.69)* 100 = 2816 HH units.

Therefore, the number of HH units required in 1 module is 2816.

3.5.5 Step 5: Population

The population required to support the non-residential land uses is obtained by assuming an average of 2.5 persons per HH (NPTS, 1995).

Population = 2816 * 2.5 = 7040

3.5.6 Step 6: Area Required for Housing Units

The area requirement for the HH units was obtained considering the guidelines of new urbanist community development as laid down in *A New Urbanist Lexicon* by Richard McLaughlin (1996). The minimum requirement for residential density as given in the Lexicon is 5 units per residential acre. Seven units per acre was chosen as a reasonable figure for residential density for purposes of the REN calculations. That is, the average lot size for a housing unit would be 1/7 acre. The average lot size accounts for single-family dwellings and apartments.

Calculation of Residential Area requirement:

A minimum density of 5 units per residential acre (McLaughlin, 1996).

Using 7 HH units per acre, housing land area required for 2816 HH
= 2816*1/7 = 402.27 acres = 0.6275 sq. mi.

Net residential density = Total # of HH units/Total Area
= 2816 HH units/640 acres = 4.4 units per total acre

This figure is in conformity with the area requirements as prescribed in the Lexicon (McLaughlin, 1996). This figure will be found in Table 3.6 (at the end of Section 3.5).

3.5.7 Step 7: Streets

Twenty percent of the total land area for residential and non-residential purposes was set aside for the street network (Urban Land Institute, 1977).

3.5.8 Step 8: Total Area of 1 Module

Residential area + Non-residential area + Streets = Area of 1 module

Total footprint area for non-residential (except mixed use buildings) = 191860 – 11000 = 180860 sq. ft.

Assuming 50% lot coverage by building (to account for setbacks and green space, if any), land area for non-residential land uses = 180860*2 = 361720 sq. ft.

Consider FAR = 1.0, land area for mixed-use buildings = 11000*4 = 44000 sq. ft.

Total land area for all non-residential land uses = 361720 + 44000
= 405720 sq. ft.

Space for parking:

Consider 1 space/ 300 sq. ft. of GFA, for non-residential uses (Zoning Digest, 2002)

1 space = 18.5 feet x 9 feet (INDOT Standard Drawings 1999, Highway Research Board, *Parking Principles: Special Report* 1971)

Parking area required for all non-residential land uses = (231061/300)*18.5*9
= 128205 sq. ft.

Total land area for non-residential uses + parking space = 405720 + 128205
= 533925 sq. ft. = 0.019 sq. mi.

Total land area for residential and non-residential land uses = 0.6275 + 0.019
= 0.6465 sq. mi.

Adding 20 percent of this area for streets, total land area = 1.2*0.6465 = 0.7758
= 0.88 * 0.88 mile square

The area for 1 module was calculated to be roughly around 0.88 x 0.88 mile square. In order to provide ample open space, the total size of the module was rounded up to 1.0 x 1.0 mile square. As a result, about 20 percent (128 acres) was available for open space, which could be in the form of parks, playgrounds, sports fields, neighborhood commons, etc. This conforms to the *Urban Land Institute* (1977) guideline of 15 acres per 1000 population.

3.5.9 Step 9: Area of REN

The neighborhood prototype actually consists of four similar modules, each 1.0 by 1.0 mile square. Although one square mile is a good size for a neighborhood (Perry 1920, Kunstler 1996), it may not be large enough to allow this analysis to detect the impacts of a particular mixed land use pattern within the 45 sq. mi. UTOWN study area using the standard travel demand model. In addition, a four-module REN permits inclusion within the REN land use types that are visited with moderate frequency by a typical household. Instead of being excluded from a one-module REN, these land use types can be included in one or two of the four REN modules. Moreover, a four-module REN provides the opportunity to explore how the edges (Alexander 1977, Kunstler 1996) of each module can interface with (a) the adjacent modules and (b) the major road that cuts through the REN. Thus, the total size of the REN is 2.0 by 2.0 miles square.

The allocation of non-residential land uses was done in a random manner, and would therefore vary from module to module within the REN. For the land use allocation procedures, see Section 4.7 in Chapter 4 and Table A1 in Appendix.

The spreadsheet in Table 3.4 summarizes the calculation of the area requirement for the different non-residential land use types. Calculations are shown for 1 module, i.e., 1.0 x 1.0 mile square in area.

Table 3.4 Detailed Calculations for Non-Residential Area Requirement

Trip Purpose/ Land Use Type	Unit Area (sq. ft.)	# Units	Footprint area (sq. ft.)
Shopping			
Supermarket	12864	2	25728
Convenience Store	1675	1	1675
Clothing	1749	2	3498
Hardware store	1155	1	1155
Total	17443		32056
Other Family Business			
Post Office	4524	1	4524
Banks	3610	2	7220
Gas station (w/ conv mkt.)	1000	3	3000
Drugstore	925	2	1850
Copying Center/Office Supply	700	1	700
Books and Magazine Center	700	0	0
Florist	754	0	0
Barber Shop	700	1	700
Beauty Salon	800	1	800
Plumbing Repair and Service	500	1	500
Commercial Washers and Dryers	1200	2	2400
Dry Cleaners	1100	2	2200
Total	16413		38649
Schools and Church			
Elementary school	47000	1	47000
Day Care Center	4000	1	4000
Church	18000	1	18000
Total	69000		69000
Other Social and Recreational			
Sit-down restaurant	2500	3	7500
Fast-food restaurant	2500	2	5000
Drive-in restaurant	1500	1	1500
Coffee Shop	800	1	800
Ice-cream and confectionary	500	1	500
Pizza Place	500	1	500
Fitness center	7402	1	7402
Public Libraries	6363	1	6363
Movie theater	7055	1	7055
Video Rental	2700	1	2700
Community Center (2 storied building)	5000	1	2500
Total	41820		44320
Doctor/Clinic (4 storied building)	3036	1	3036

Table 3.4 Continued

Trip Purpose/ Land Use Type	Unit Area (sq. ft.)	# Units	Footprint area (sq. ft.)
Workplaces (not included in this model)			
General Office Building	199000	1	199000
Government Office Building	18000	1	18000
Total	217000		217000
Average sq. ft per floor in gen. office bldg			48000
Average sq. ft per floor in govt. office bldg			4500
Average sq. ft per floor in industrial bldg			32000
Total			84500
Area for mixed-use buildings			11000

Table 3.5 Area for Mixed Use Buildings

Bldg. Type # 1:	Floor Area (sq. ft.)
Ist Floor:	
Convenience store	4000
Beauty Salon	1000
2nd Floor:	
Bank	5000
3rd Floor: Apartments	5000
4th Floor: Apartments	5000
Footprint area of building	5000
Bldg. Type # 2:	**Floor Area (sq. ft.)**
1st Floor:	
Copying Center	846
Barber Shop	700
Florist	754
Books & Magazine	700

Table 3.5 Continued

Bldg. Type # 2:	Floor Area (sq. ft.)
2nd Floor:	
Consultant Office	1500
Accountant Office	1500
3rd Floor: Apartments	3000
4th Floor: Apartments	3000
Footprint area of building	3000

Table 3.5 Continued

Bldg. Type #3:	Floor Area (sq. ft.)
1st Floor:	
Attorneys Office	2200
Insurance Office	800
2nd Floor: Apartments	3000
3rd Floor: Apartments	3000
4th Floor: Apartments	3000
Footprint area of building	3000

Table 3.6 Key Statistics for 1 Module

Total area	:	1.0 * 1.0 mile square (640 acres)
Total (floor area) non-residential uses	:	231061 sq. ft.
Land area for housing	:	402.27 acres
Open spaces, parks	:	128 acres
Residential uses	:	63% of total area
Streets	:	20%
Residential density (net)	:	4.4 units per acre
Population	:	7040

3.6 Conclusions and Discussion

Some key points relating to the methodology adopted for designing the reverse engineered neighborhood prototype are listed below.

1. An attempt has been made to include most of the commonly visited non-residential land uses that would satisfy the trip making needs of the community, except for trips made to employment centers, office parks, etc., that have not been included in the REN.
2. The neighborhood model has been designed based on the principle of accommodating most of the non-work trips within a reasonable distance from home.

3. In calculating the area requirement for the various land uses, based on trip purposes, work trips have been treated separately. Workplaces have not been included in calculating the areas of the modules because it is likely that most work trips would still be made outside the neighborhood. Small-scale offices like consultants, law firms, banks, that fit in the neighborhood scale have been included.
4. Areas for specific land uses have been calculated from the trip making data available from NPTS. In the absence of such data for specific land uses, reasonable estimates of area have been made based on judgment and upon observations drawn from the local community.
5. The procedure adopted for the design of the neighborhood, which incorporates the concept of "reverse engineering", is aimed at creating an 'ideal' and livable community. An attempt was made to come up with the number of HH units that can support a particular non-residential floor area. The non-residential floor area was determined from the list of frequently visited land uses in a neighborhood. The design is structured, yet subjective in many respects. A sensitivity analysis may guide the modification and refinement of the land uses and their orientation within the neighborhood.
6. The initial REN design is not sacrosanct. It is subject to refinement depending on network performance and evaluation of MOEs in subsequent analyses.
7. The REN model does not contain all the non-work trips within the study area, nor should it. There would still be non-work trips made outside the study area. Residents do have the freedom to meet their non-work trip needs by traveling outside the area. The REN merely provides its residents with a reasonable opportunity to satisfy their more common trip making needs within the neighborhood. A particular land use (especially those visited less than once a month) may not have been included in a HH's REN. In addition, a person may prefer to shop at a store other than those located in the person's REN.
8. Most of the key statistics in Table 3.6 adhere to the neighborhood principles as set forth in *The Community Builder's Handbook* (Urban Land Institute, 1977) and

> *New Urbanist Lexicon* (McLaughlin, 1996). Residential uses cover 63% of the area, compared to the guideline of 60% for residential and 40% for ancillary uses. Open spaces and parks form a sizeable portion, which is also in conformity with ULI's guideline of 15 acres per 1000 population. Residential density (net) of 4.4 units per acre matches up with the Lexicon (McLaughlin, 1996).

This concludes the model development task. In the subsequent task, the REN model will be tested for transportation-related performance measures using a four-step travel demand modeling procedure. In preparation for the four-step modeling using standard modeling software, the model is transferred to a geographic information system (GIS) database, with the zone structure and land uses and their locations defined. The task of data preparation for input to the travel demand modeling process is explained in Chapter 4. Finally, the performance measures obtained from the four-step modeling for the REN will be compared to a neighborhood model with separated land uses.

CHAPTER 4. DATA PREPARATION FOR TRAVEL DEMAND MODELING

This chapter presents an outline of the steps involved in preparing the data for the four-step travel demand modeling analysis. The size and area requirements for the land uses (residential and non-residential) in the REN have already been determined in Chapter 3. In this chapter the methodology for determining the zone structure and adjacent street network for the REN, and the allocation of the mixed land uses within the REN are described. These are the potential inputs for the four-step modeling procedure using TransCAD (Caliper Corporation, 2001).

In this study, two scenarios will be analyzed. The Measures of Effectiveness (MOEs) for REN will be compared with those of a Euclidean neighborhood, named EUCLID. The size, zone structure and the corresponding street network for the EUCLID are identical to those of the REN. However the nature of land uses and their allocation may vary. (See Chapter 6 for details.) The purpose is to determine how well these two neighborhoods (of the same scale) perform with varying levels of activity (defined by land uses within the neighborhood).

4.1 Four-Step Travel Demand Forecasting Process

Travel demand forecasting is often referred to as the “four-step” process. The steps are: trip generation, trip distribution, mode choice and traffic assignment. With land use patterns affecting travel patterns, many planning professionals advocate land-use activity to be a ‘Step 0’ in the four-step modeling process. The method for allocating the land uses within the REN (i.e., ‘Step 0’) will be discussed in Section 4.5. The modeling approach incorporated in the current study is to shape land uses so as to fit the trip making characteristics of people. This methodology is the reverse of the current practice, which aim at determining travel patterns for a fixed pre-determined set of land uses.

4.2 Travel Demand Forecasting in the GIS Context: TransCAD

The network performance analysis inherent in the travel demand forecasting process has been accomplished using a geographic information based (GIS) based transportation planning package: TransCAD, Version 4.0 (Caliper Corporation, MA, 2001).

In a GIS, data are typically associated with point, line or area features. Because networks are separate from line layers in TransCAD, many different networks can be associated with the same geography.

The application of transportation models using TransCAD is a data intensive process. Much time needs to be spent on preparation of inputs. The subsequent sections of this chapter, as well as Chapter 5, give an overview of the modeling process adopted in each of the four steps of travel demand forecasting.

4.3 Data Preparation in TransCAD for Four-Step Modeling Procedure

All GIS based files in TransCAD are associated with a point, line or area layer. Hence, the first task in data preparation is to create a geographic layer that represents the map of the study layer. In the present case, an existing geographic map file from the TransCAD Tutorial database was utilized for our purpose. This map (called UTOWN) already had the line layer (street layer), node layer and area layer associated with it. The map file and the associated line and area layers were in editable format; hence UTOWN could be easily modified. The proposed setup of the REN was arrived at based on the considerations described in the subsections that follow.

4.3.1 Block and Zone Sizes in the REN

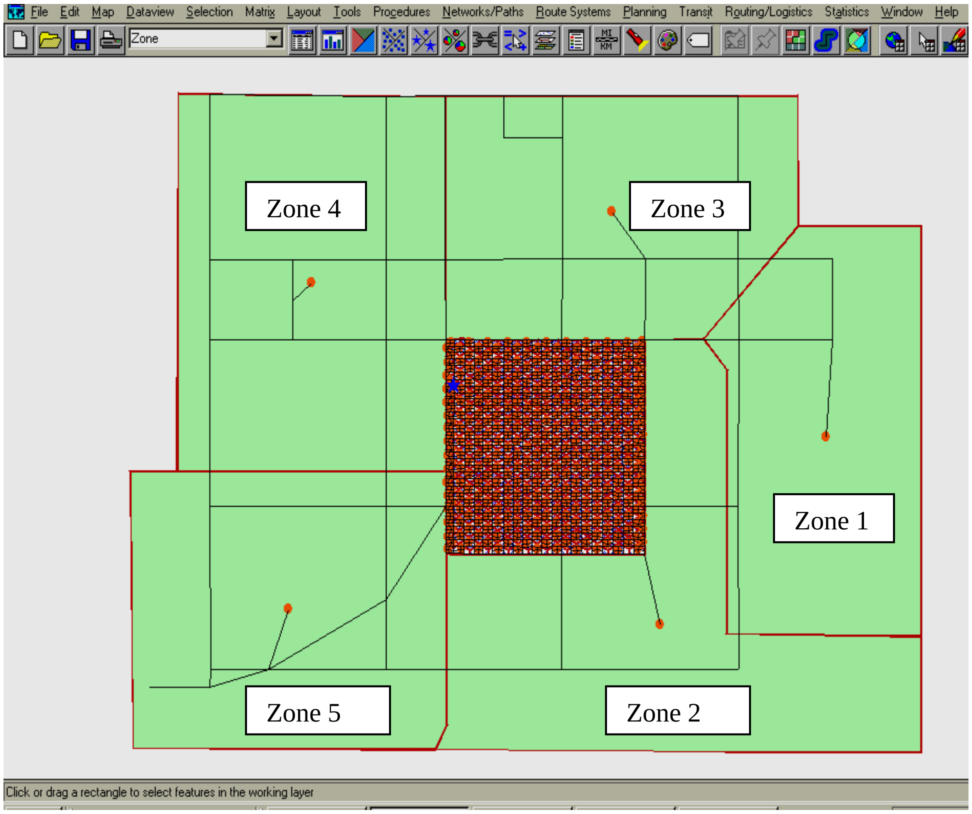
1. The REN is a square with a total size of 2.0 x 2.0 miles square. This includes 4 smaller modules, each with an area of 1.0 x 1.0 mile.

2. The entire area of REN is divided into uniform rectangle-shaped blocks, each of size 500 feet x 315 feet. This size was chosen based on recommendations in “New Community Design to the Rescue” (Hirschhorn, Souza, 2001). In that document, on the important issue of street connectivity, the Envision Utah Model has been cited:

   “By definition, the highly connected street pattern in a walkable community is composed of smaller block sizes to minimize walking distances between destinations. The scale of residential lots and ownership patterns lends itself to smaller blocks than commercial areas. As a rule the maximum block size for residential uses is three acres (220 feet by 600 feet), while the maximum block size for commercial uses is about four acres (500 feet by 600 feet). Note that these block sizes are maximums; smaller block sizes are always possible and are encouraged.”

   For this study, the block sizes for both residential and commercial uses were kept at a uniform 500 feet x 315 feet. This figure was arrived at based on some rough estimates of lot size and frontage requirements for houses, which also satisfy the Utah recommendations cited above. A grid network of streets surrounds each block. There is no functional classification of streets within the REN, that is to say, no street hierarchy exists. All the streets serve as alternate routes for reaching a destination.
3. Based on the calculations for block size, the size of traffic analysis zones within the REN was determined. Having the same number and size for the zones as that for the blocks would have been an ideal case. But it was thought that one zone per block would result in an excessively large number of zones, which would make analysis difficult and cumbersome. As a result, the number of zones was cut in half and their average area doubled. The zones are diamond shaped, enclosing an entire block and a quarter of each of the surrounding four blocks (Fig. 4.2). The total number of zones in the study area is 352.
4. Because the analysis uses the UTOWN geographic database, the REN was inserted within the existing zone layout of UTOWN. The original UTOWN had 5

zones. The REN was inserted in a corner of a zone numbered as “455” in the TransCAD map view (Fig. 4.1). Because the REN has its own local street network, it had to be ensured that major streets from the original UTOWN network do not intersect the REN. So, the street network of UTOWN was modified so that the streets coincided with the edge of a zone. Now, only one existing major street crosses the REN in a north-south direction, bisecting the REN approximately.



Click or drag a rectangle to select features in the working layer

Fig. 4.1 TransCAD Screen Capture of REN and the UTOWN Zones

4.3.2 Centroids and Centroid Connectors

Centroids are special nodes in the network that represent the center of a traffic analysis zone. Typically trips either start or end at centroids. The links that connect centroids to the other links in a network are known as centroid connectors. These centroid connectors are not real physical links, but instead are a simplified representation of the local road network that let individuals access the highway network. In particular, paths between an origin and a destination travel over one centroid connector at the beginning of the trip, and one at the end of a trip, but never use a centroid connector in any other way.

In the REN, there is a centroid corresponding to each of the 352 diamond shaped zones, and there are centroid connectors to each of the four streets in the block. The reason for having four centroid connectors is to give every block face an opportunity to be loaded during traffic assignment.

Fig. 4.2 shows the zone structure adopted for the REN neighborhood. This road and zone structure will remain the same for any neighborhood design to be analyzed. Fig. 4.3 shows all the 352 zones, along with the adjacent zones of UTOWN.

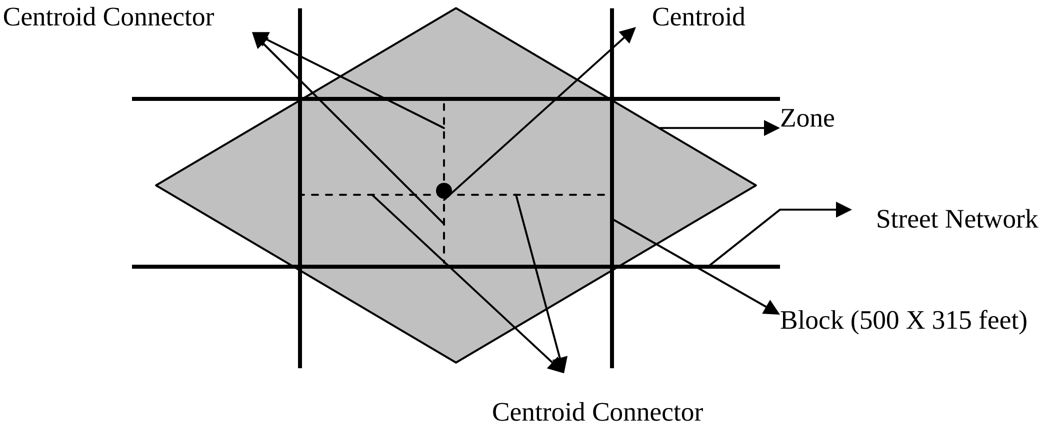
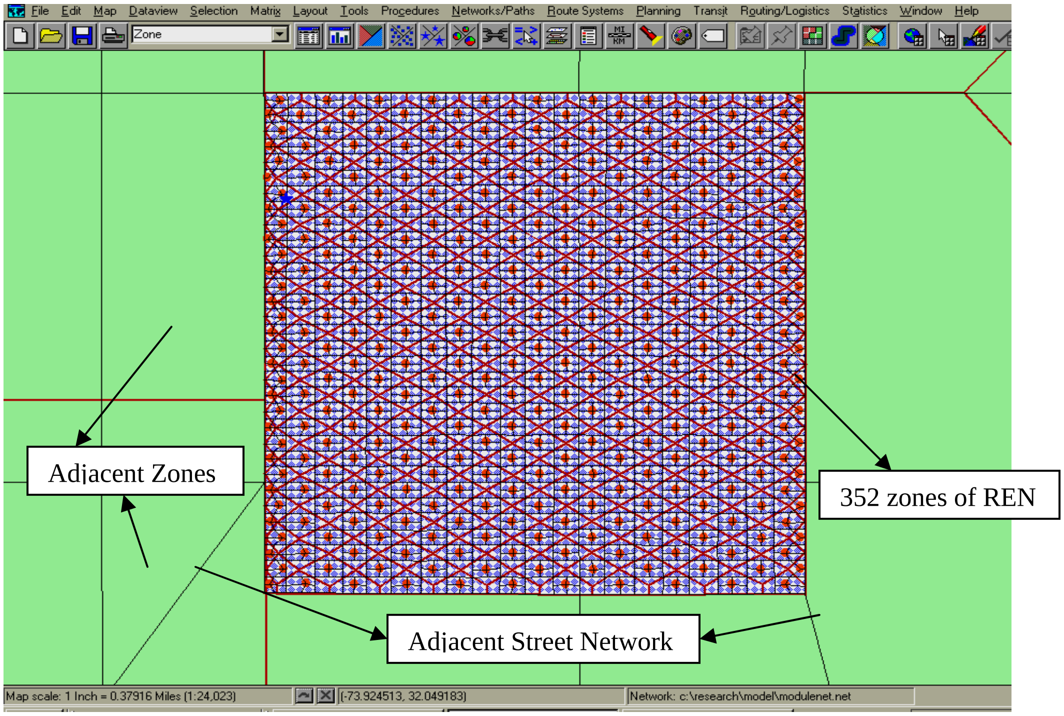


Fig. 4.2 Representation of Zone, Street Network, Block, Centroid and Centroid Connectors



Map scale: 1 Inch = 0.37916 Miles (1:24,023)

(-73.924513, 32.049183)

Network: c:\research\model\modulenet.net

Fig. 4.3 TransCAD Screen Capture with Zones of the REN and the Adjacent Zones

4.4 Analysis

The neighborhood model of the REN is tested for performance measures by carrying out a traditional four-step travel demand forecasting process using the analysis package TransCAD. The two scenarios that will be considered for analysis are:

1. Entire network (regional model) with REN and the five adjacent zones of UTOWN.
2. REN subnetwork, consisting of 352 zones

The regional model and the subnetwork are analyzed for suitable measures of effectiveness (MOEs), like total vehicle distance traveled, total vehicle time traveled, and trip lengths, for home-based work, home-based non-work and non-home based trip purposes.

In the second stage, a Euclidean neighborhood (termed EUCLID, see Chapter 6) is analyzed. EUCLID has the same size and scale as the REN, except that the nature and allocation of land uses in EUCLID (see Chapter 6) are different from those in the REN. EUCLID has the same number of zones and the same zone structure as REN. However, EUCLID is predominantly a residential neighborhood; there are no retail and non-retail establishments in EUCLID. Analysis of EUCLID is done as follows:

1. Entire network (regional model) with EUCLID and the five adjacent zones of UTOWN.
2. EUCLID subnetwork, consisting of 352 zones

Finally, a comparative assessment of the MOEs obtained from the REN and EUCLID neighborhood models is carried out. This comparison entails both the regional and the subarea (subnetwork) models for REN and EUCLID. This type of evaluation may indicate, for example, whether different land use patterns create more congestion in one neighborhood, or if trip lengths in one neighborhood type are generally longer. The comparison will help to assess the benefits of certain types of allocation of land uses.

4.5 Method Outlining the Allocation of Mixed Land Uses for REN

The allocation of land uses in the REN (comprising of a total area of 4 sq. mi.) was done by randomly assigning the land uses to the 352 available zones. The spreadsheet showing the allocations of the mixed used is presented in Appendix Table A1. However, the procedure for the development of the spreadsheet is explained in the following steps:

1. Because the neighborhood consists primarily of residences (about 63%, see Chapter 3, Table 3.5 for details), it was assumed that residences would be a part of all the 352 zones. Each zone has an average of 32 housing units.
2. In assigning residential units to the 352 zones, no distinction was made between type of residences, namely, single-family, multi-family or apartment houses. Allocation was made merely on the housing density, which is approximately 7 residential units per acre (see Section 3.5, Chapter 3).

3. All the land use types are assigned unique identifiers (IDs). For example, in Appendix Table A1, the land use “Day Care Center (3)” in zone ID# 11 has an ID# 116. If there is more than one land use falling under the same category, each of those have unique IDs as well. For example, the land use Day Care Center (4) which is of the land use category Day Care Center, also has a unique ID# 161, and it corresponds to zone ID# 75 in Appendix Table A1. The numbers in parentheses that follow the land use description, for example, Day Care Center (1) or Day Care Center (4), indicate that there might be more than one land use in the same category. The unique number field in the land use description is another way to assign unique land use IDs like 116 and 161, in this example.
4. The ID numbers for the 352 zones are copied to an Excel file from the mapview in TransCAD. The IDs for the zones and the IDs for the land uses along with the description of each of these land uses are tabulated in Excel format.
5. The next task is to randomly assign the land uses to the zones. In this exercise, one or more of the land uses (or none, in some cases) may be assigned to a zone. That means that each of the zones would have a unique ID corresponding to a land use associated with it. Depending on the area of each zone, and the average area requirement of each land use, it was estimated a maximum of four land uses could be assigned to each of the zones, in addition to a fixed (average) number of housing units in each zone.

   The maximum number of (non-residential) land uses in a zone = 4

   Range = 0 - 4

   Probability of selecting 0, 1, 2, 3 or 4 non-residential LU per zone = 1/5 = 0.2
6. Considering an equal probability of 0.2, a random number generation for all the zones was carried out considering a discrete probability distribution. This gave the number of land uses that will be randomly assigned to each zone.

   For example, number of land use types for zone ID# 11 is 1, zone ID# 13 is 0, and zone ID # 17 is 2. These numbers can be found in Appendix Table A1.
7. Next, the land use types need to be selected for each zone. All 180 land use types have an equal probability of selection in the random assignment procedure.

Another set of random numbers is generated, each with a discrete probability of 1/180, considering each zone and its corresponding number of land uses. For zone ID# 21, there are 4 non-residential LU types. So, by this method, it is possible to get 4 randomly generated land use IDs. This procedure is repeated by carrying out a random number generation for each zone separately.

8. Once land uses have been randomly assigned to all the zones, the land uses were checked to see if there was duplication of non-residential land uses in a zone. In case of any duplication, any one of the duplicate land uses was dropped from the zone, based on the analyst's judgment. For example, the random allocation procedure generated the land use "Church (1)" with land use ID# 27 to zone ID# 86. Also "Church (4)" with land use ID# 162 was assigned to both zone ID# 89 and zone ID# 329. This is a case of duplication of a non-residential land use within a module because the same land use has been assigned to two zones. Because zones with IDs 86 and 89 are in close proximity, it was decided to remove the church from zone ID# 89 and retain it in zone ID# 329. Removal of church from zone ID# 89 results in that zone now having two land uses instead of three.
9. Table A1 shows that there are a total of 334 land uses, including 142 open spaces or parks, each with unique identifiers from p1 to p142 (p stands for "park").

   The total of 142 open spaces could be arrived at from the following calculations:

   Open space for each 1 sq. mi. of module = 128 acres (see Table 3.5)

   Total open space for the neighborhood = 128 x 4 = 512 acres

   Considering the size of a block (500 feet x 315 feet) as the size requirement for a green space, the number of such spaces required = 142

   Thus the open spaces have been marked as p1 to p142.
10. The other land use types also have designated unique IDs numbered from 1 to 180. These include IDs for each of the different categories of land uses. For example, if there were a total of 8 supermarkets in the neighborhood, each of those would have a unique ID. As is also evident in the spreadsheet (Appendix

Table A1), each of the supermarkets would have a land use description like Supermarket (1), Supermarket (2), …, Supermarket (8).

Fig. 4.4 shows a portion of the REN neighborhood with random allocation of land uses in the zones (which are depicted as diamond shaped quadrilaterals). The blocks with numerals indicate the zone IDs. The legend key for the land use type is given below.

H – Housing

P – Park

D – Dry Cleaners

I – Ice-cream and Confectionary

G – Gas Station with Convenience Market

PO – Post Office

C – Commercial Washers and Dryers

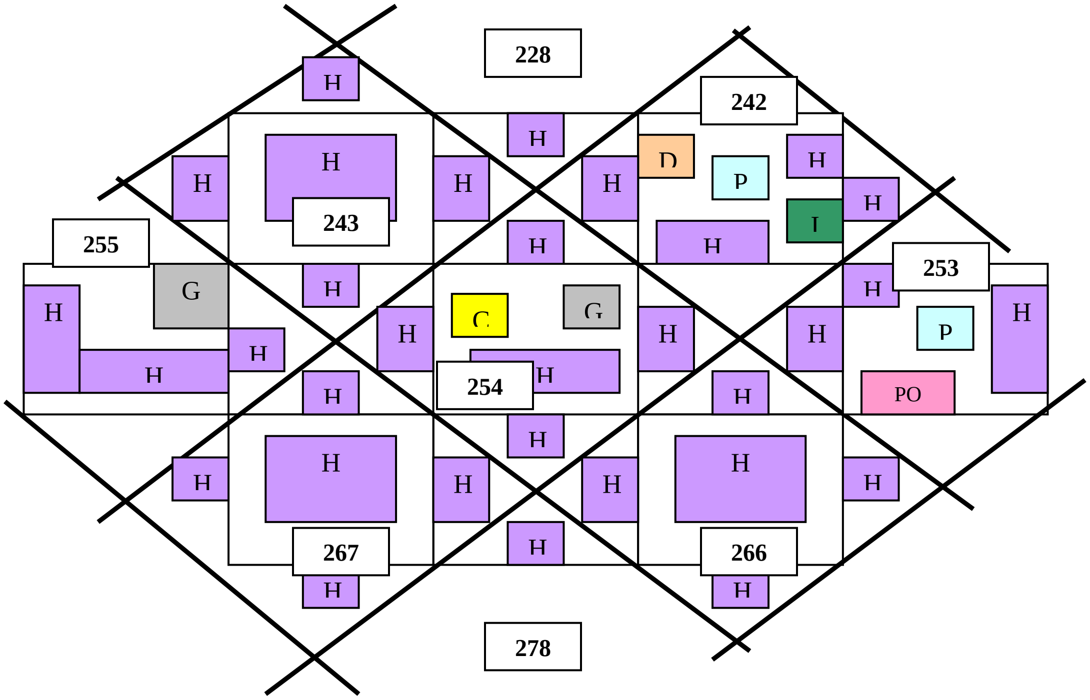


Fig. 4.4 A Portion of the REN with Land Uses Allocated

The land uses shown in Fig. 4.4 do not indicate exact building or lot locations within a zone. They simply represent land uses that are located somewhere in each block. See Table A1 in the Appendix for a complete listing of land uses in each zone.

This concludes the task of data preparation for input to the modeling software for the four-step analysis. In the next chapter, the travel demand forecasting procedure is carried out for the reverse engineered neighborhood (REN). A similar four-step analysis will be carried out (in Chapter 6) for a Euclidean neighborhood (EUCLID) having separated land uses. Finally, a comparative assessment for the performance measures between the two neighborhood types will be made in Chapter 7.

CHAPTER 5. ANALYSIS OF REVERSE ENGINEERED NEIGHBORHOOD

This chapter presents the four-step travel demand modeling process adopted to evaluate the transportation-related performance measures for the reverse engineered neighborhood: REN. The stages in the modeling process have been itemized under separate sections as:

- Trip Generation
- Trip Distribution
- Mode Split and Choice Analysis
- P-A to O-D Transformations and Time-Of-Day Analysis
- Traffic Assignment

The four-step procedure is first conducted for the entire UTOWN study area. In the traffic assignment phase, the 352-zone REN subarea is analyzed using the MOEs -- total vehicle-distance-traveled, total vehicle-time-traveled, trip lengths in terms of distance and time, etc. The evaluation of the traffic characteristics for the REN sub-network is done to capture the effect of trips that have at least one end, or both ends, within the REN. In a post-assignment procedure, trip lengths (in minutes) for each trip purpose using the loaded travel times are calculated for the entire UTOWN study area, and also considering those trips in and out of REN.

An attempt has been made to conduct the four-step procedure using the TransCAD representation of UTOWN with very little or no modifications to the input.

The following sections outline the detailed step-by-step procedure for the travel demand forecasting process.

5.1 Trip Generation

5.1.1 Overview

In trip generation, methods are applied to predict productions and attractions or origins and destinations. The zone that contains the home end of home-based trips or the origin end of the non-home-based trips is considered to have produced the trip. The destination zone where an out-of-home activity will be undertaken is considered to have attracted the trip. Whether one uses origins and destinations (Os & Ds) or productions and attractions (Ps & As) is dictated by the data at hand and the study objectives. The terms P/A and O/D may be used interchangeably in this report, although one should keep in mind the differences. This stage of the transportation planning process is concerned with the number of trips that start and end in each zone, and not with making the connections between origins and destinations of trips.

This section discusses the methodology for trip generation adopted in this study, and relevant data preparation methods for input in the travel demand model.

5.1.2 Units

Trip production in passenger transportation can be thought of in terms of person trips or vehicle trips. It is usually preferable to focus on the individual as the behavioral unit of relevance for several reasons:

- Individuals make trip frequency decisions, not vehicles.
- Trip production for non-motorized modes is important to the analysis at hand.
- Person trips can be converted to vehicle trips, if necessary, at later stages in the analysis.

In the context of the current analysis, the area requirements have been calculated from ITE trip rates (see Chapter 3), which are given in terms of vehicular trips. However, trip generation procedures (using cross-classification) incorporate trip rate tables that employ person trips per household. The four-step process in this analysis uses person trips up to the stage of trip distribution. In mode choice analysis, the trip share for motorized and non-motorized modes is estimated. Person trips are subsequently converted to vehicle trips before being loaded onto the network for assignment.

5.1.3 Trip Purposes

For this model, the classification of trips is based on three broad categories: home-based-work (HBW), home-based-other (HBO) and non-home-based (NHB). The classifications into several sub-categories, like shopping and school in the “module” development stage, are only relevant for estimation of the land use area requirement and for setting the size of the neighborhood. Refer to Chapter 3 for detailed calculations in the development of the REN. In the four-step modeling process, the HBW, HBO (also known as home-based non-work or HBNW) and NHB trip purposes have been used to analyze network performance.

5.1.4 Method: Productions

As discussed in Chapter 4, there are three primary tools that can be used in modeling trip production: cross-classification, regression models, and discrete choice models. In this analysis, a cross-classification procedure has been adopted for calculating trip productions.

Cross-Classification methods of calculating productions separate the population in an urban area into relatively homogenous groups based on certain socio-economic characteristics. For example, one may classify households in an area by both family size (1,2,3,4,5+ persons/HH) and auto ownership (0,1,2+ autos/HH), which results in 15 classifications. Average trip production rates (the estimated number of trips that will be taken by a household or an individual) are empirically derived from either aggregate or disaggregate data sets for each of the classifications. In the example above, 15 average trip rates would be derived.

Once trip rates are known for each classification, these trip rates are usually applied to each zone. The average characteristics of each zone are used to determine the classification to which the zone belongs, which then determines the trip rate to apply to the houses or individuals in the zone. Using this method, one trip rate is applied to all people in the zone (NCHRP 365, 1998).

The trip production model in this analysis is based on households (aggregate model) rather than individuals (disaggregate model), because NCHRP 365 (1998) uses HH trip rates. Moreover, it is very difficult to obtain data on individual rates. In the present case, cross-classification was carried out using persons/HH and autos/HH. To do a cross classification in TransCAD, the inputs required are:

1. Trip rate table that defines the classifications to be used and includes the trip rates for each classification.
2. Average values for the classification parameters (persons/HH and auto ownership in this case) within each zone in the study area.

The trip rate table for cross-classification analysis is shown in Table 5.1. The source of this table is the *Travel Estimation Techniques for Urban Planning* (NCHRP 365, 1998). The trip rate table as available in this report has been modified and in this case, only the relevant trip rates corresponding to an urban area population of 199999 and above (denoted as 199999+ in Table 5.1) have been used. The total population for the entire UTOWN study area (comprising of 357 zones) does not fall in the range of 49000-199999. Hence the next higher range of 199999+ has been used to obtain the trip rates. The trip table was obtained from the built-in UTOWN database in TransCAD.

The columns in Table 5.1 contain trip rates for:

R_ADPT/HH = Average daily person trips per household
R_HBW_PT/HH = Home-based work person trips per household
R_HBO_PT/HH = Home-based other person trips per household
R_NHB_PT/HH = Non-home based person trips per household

Table 5.1 Trip Rate Table for Cross-Classification

Population	Auto/ HH	HH size (persons)	R_ADPT/ HH	R_HBW_PT/ HH	R_HBO_ PT/HH	R_NHB_PT /HH
199999+	0	1	1.4000	0.2800	0.7560	0.3640
	0	2	6.3000	1.3860	3.4020	1.5120
	0	3	9.2000	1.7480	5.1520	2.3000
	0	4	9.2000	1.7480	5.3360	2.1160
	0	100	9.2000	1.5640	5.7040	1.9320
	1	1	4.4000	0.8800	2.3760	1.1440
	1	2	6.5000	1.4300	3.5100	1.5600
	1	3	9.3000	1.7670	5.2080	2.3250
	1	4	10.6000	2.0140	6.1480	2.4380
	1	100	11.6000	1.9720	7.1920	2.4360
199999+	2	1	4.4000	0.8800	2.3760	1.1440
	2	2	8.0000	1.7600	4.3200	1.9200
	2	3	10.5000	1.9950	5.8800	2.6250
	2	4	14.0000	2.6600	8.1200	3.2200
	2	100	17.1000	2.9070	10.6020	3.5910
	100	1	4.4000	0.8800	2.3760	1.1440
	100	2	8.0000	1.7600	4.3200	1.9200
	100	3	11.7000	2.2230	6.5520	2.9250
	100	4	14.8000	2.8120	8.5840	3.4040
	100	100	19.0000	3.2300	11.7800	3.9900

Average values of cross-class parameters:

a) Average number of persons/HH across all the 352 zones (REN) and 5 original UTOWN zones = 2.5

b) Average number of autos/HH across all the 352 zones (REN) and 5 original UTOWN zones = 2.0

The results of cross-classification are the productions for the three categories of trip purposes: HBW, HBO and NHB.

Table 5.2 displays a portion of the tabular results as obtained after cross-classification.

Table 5.2 Productions after Cross-Classification

CrosClas.ID	ADPT/HH	HBW_PT/HH	HBO_PT/HH	NHB_PT/HH
1	52153.50	9909.17	29205.96	13038.38
3	170940.00	32478.60	95726.40	42735.00
4	84210.00	15999.90	47157.60	21052.50
7	378.00	71.82	211.68	94.50
9	378.00	71.82	211.68	94.50
11	378.00	71.82	211.68	94.50

Table 5.2 represents a portion of the actual bin file “crosclass.bin” created by cross-classification to estimate the productions. Note that the values for zones 7, 9 and 11 are identical. This is because all the zones have the same average values for persons/HH and autos/HH. The zones numbered 1, 3, and 4 in Table 5.2 represent the zones of UTOWN, and hence have different values. The productions for UTOWN have been extracted from the UTOWN database, and are dependant on the socio-economic characteristics of the zones; hence the productions would differ significantly from the zones of the REN.

5.1.4.1 Technical Notes on Trip Generation: Production

Building sound trip generation models entails the use of appropriate statistical and econometric methods. This includes relevant theory to specify the model relationships, explanatory variables and classification schemes. Cross-classification can be based on statistical estimation. Indeed, a cross-classification in this context is simply a regression on dummy variables. Cross-classification is applicable in those cases where extensive data are not available; hence the use of the cross-class tables from nationwide data in this analysis can be reasonably justified.

5.1.5 Method: Attractions

In many ways, estimating trip attractions is similar to estimating trip productions, because the problem is the same: to predict the number of trips attracted by relating the number or frequency of trips to the characteristics of individuals, the zone and the transportation network. Network characteristics like street connectivity and the nature of the network itself (grid pattern, cul-de-sac, etc.) also has an effect on the trips and the mode choices made by individuals to different destinations.

5.1.5.1 Regression Equations Based on National Averages

In this analysis, regression equations based on national averages (NCHRP 365, 1998) and the Quick Response Method (QRM) Tables (NCHRP 187, 1978) have been used. QRM uses a regression equation that estimates the number of person trips attracted to a zone based on the retail and non-retail levels of employment in the zone and the number of dwelling units (households) in the zone. Equations 5.1, 5.2 and 5.3 are:

HBW Attractions = 1.7 (Retail Employment) + 1.7 (Non-Retail Employment)…(5.1)

HBNW Attractions = 10.0 (Retail Employment) + 0.5 (Non-Retail Employment) + 1.0 (Dwelling Units)…………………………………………… (5.2)

NHB Attractions = 2.0 (Retail Employment) + 2.5 (Non-Retail Employment) + 0.5 (Dwelling Units)…………………………………………….(5.3)

To use the QRM Trip attractions procedure, the data inputs required in the zone layer are:

- Retail employment in the zone
- Non-retail employment in the zone
- Dwelling units in the zone

TransCAD provides default QRM trip attraction tables in its database, which specifies the three QRM regression equations shown above. The zone-wise data input requirements as mentioned above are input in the dataview of TransCAD for the model. Data fields for Total HH, Retail Employment and Non-Retail Employment for each zone are included in the dataview.

The output of the QRM attraction model is the attractions for the trip purposes. Table 5.3 displays a portion of the tabular results obtained after applying the QRM trip attraction procedure.

Table 5.3 Attractions after QRM Procedure

QRM_ATTR.ID1	QRM_ATTR.HBW_A	QRM_ATTR.HBNW_A	QRM_ATTR.NHB_A
1	67983.00	62867.00	100463.50
3	26885.50	60430.00	45770.00
4	8491.50	19970.00	16000.00
7	0.00	36.00	18.00
9	0.00	36.00	18.00
11	18.70	41.50	45.50

5.1.5.2 Technical Notes on Trip Generation: Attraction

The most appropriate trip attraction model is one that is based on the specific planning or forecasting objectives and on the availability of data.

For long range planning, there will typically be at least two trip attraction equations, one for work trips, and the other for non-work trips. If zonal employment is known, it will typically be the best measure of person work trips attracted to the zone. Special trip attraction models may be recommended for special generators within a region, such as airports and other facilities that attract significant traffic.

The QRM tables incorporate the trip attraction regression equations in NCHRP 187 (1978). These equations have been employed in the current analysis, instead of the NCHRP 365 (1998) equations, because the TransCAD trip attraction procedures use the 1978 equations. However, it may be better to use the updated regression equations of NHCRP 365 (1998) if they use available input data and lead to more reasonable results.

5.1.6 Trip Balancing

In trip generation, separate models are used to predict productions and attractions. This invariably leads to a discrepancy between the number of trips produced in an area and the number of trips attracted to an area. To conserve trips, balancing methods are used so that the number of attractions equals the number of productions. Productions are held constant and attractions are adjusted so that their sum equals the sum of the productions.

The method adopted for balancing is carried out by holding the productions constant. In practice, the productions are considered to be more accurate estimators of the trips made, so productions are held constant, and the attractions are adjusted. During balancing, specific zones called special generators may be chosen, for which production values may not be changed. Similarly, some special zones called special attractors may be specified for which the attraction values may not be changed. In the current analysis, no special generators were used.

Table 5.4 displays a portion of the tabular results obtained after the balancing procedure.

Table 5.4 Output after Trip Balancing

BALANCE.ID1	HBW_PT/HH	QRM_ATTR.HBW_A	HBO_PT/HH	QRM_ATTR.HBNW_A	NHB_PT/HH	QRM_ATTR.NHB_A
1	9909.17	71892.16	29205.96	102382.57	13038.38	83293.82
3	32478.60	28431.47	95726.40	98413.78	42735.00	37947.69
4	15999.90	8979.78	47157.60	32522.31	21052.50	13265.53
7	71.82	0.00	211.68	58.63	94.50	14.92
9	71.82	0.00	211.68	58.63	94.50	14.92
11	71.82	19.78	211.68	67.59	94.50	37.72

As can be observed from Table 5.4, the values for the productions for the three trip purposes of HBW, HBO and NHB remain the same as in Table 5.2. This is because the productions were held constant during balancing and the attractions were adjusted.

5.2 Trip Distribution

5.2.1 Overview

Trip distribution models are used to predict the spatial pattern of trips or other flows between origins and destinations. These models predict the destination choices of trip makers. Usually, in trip distribution, a new O-D matrix is forecasted based on estimates of future productions and attractions and measurements of current flows or measurements of the generalized cost of each trip. Aggregate trip distribution models are used to predict flows between origin and destination zones. Trip distribution models connect the origins and destinations of the trips estimated by the trip generation models. Different trip distribution models can be developed for each of the trip purposes for which trip generation has been estimated.

5.2.2 Issues with Growth Factor and IOM

Growth factor methods do not take into account any information about the transportation network, and thus cannot reflect the impact of changes in the network. These methods are generally used when there is no information available concerning the network interzonal distances, travel times or generalized costs. This may be reasonable for short-term forecasts in which the network has not changed, but it is not appropriate to forecast scenarios that include changes in the network.

Other trip distribution models include "opportunity" models and logit models, both of which estimate the probability that travelers will accept various destination options available. The probability of selecting a particular destination zone is based on the number of trip attractions estimated for that destination zone relative to the total attractions in all possible destination zones. The probability is applied to trip productions estimated for the origin zone, making it conceptually similar to the gravity model. In the Intervening Opportunities Model (IOM) (Whitaker et al., 1981), trip-making behavior is not explicitly related to the distance but to the relative accessibility of the intervening opportunities between an origin and a destination. The basic hypothesis is that the number of trips from an origin zone to a destination zone is directly proportional to the number of opportunities at the destination zone and inversely proportional to the number of intervening opportunities. That is, the number of opportunities starting from an origin i are ranked according to distance to a destination j. If there are m opportunities from i to j, then IOM relates to the probability that the trip maker will satisfy his objective of trip making at any k^{th} intervening opportunity between i and j.

The IOM does not use the absolute distances but the ranked distances. Another point that needs to be considered here is that attractiveness of one zone with respect to another is also taken into consideration. In this context, the number of opportunities posed by each zone is also a factor of the relative attractiveness of one zone with respect to another. So the combination of the number of opportunities in a zone and the relative rank of the opportunities has to be jointly taken into consideration.

In view of the limitations of the applicability of IOM and especially the model's transferability into standard modeling software, IOM could not be further considered in the analysis stage. Growth factor methods too, have their own limitations in terms of their applicability in transportation planning involving transportation networks.

The gravity model has been used in the analysis, and is discussed in detail in the following sections.

5.2.3 Gravity Models

As implemented for planning models, the hypothesis is that the number of trips between zones i and j is a function of the trips originating in zone i and the relative attractiveness and/or accessibility of zone j with respect to all zones. The measure of separation between zones most commonly used for trip distribution is roadway travel time. In this analysis, the free flow travel time has been used as a measure of separation.

5.2.3.1 Impedance Function and Calibration

There are several potential impedance functions to use to derive the relative attractiveness of each zone from the impedance. Popular choices are the exponential, inverse power functions and the gamma function, typically used in most planning models.

The values derived from the impedance function are called the friction factors. The form of these functions (Caliper, 2001) are shown below:

Exponential $f\,(t_{ij}) = e^{-c\,(t_{ij})}$ $c>0$

Inverse power $f\,(t_{ij}) = t_{ij}^{\;-b}$ $b>0$

Gamma $f\,(t_{ij}) = a * t_{ij}^{\;-b} * e^{-c\,(t_{ij})}$ $a>0,\ c\geq 0$

In each of these functions, t_{ij} represents the impedance in terms of travel time. The impedance functions require the specification of parameters to be used in the model. The aim is to select an impedance function and its corresponding parameters such that the gravity model reproduces the trip length distribution (TLD) of the study area. There are several ways to arrive at the parameters. The preferred method is to calibrate the chosen impedance function to match the travel patterns of the study area, or to use parameters that have been previously calibrated for the study area. Alternatively, parameters suggested by national studies or parameters estimated for other study areas can also be used.

In this research, the inverse power function has been chosen as the impedance function for gravity model evaluation. This is because this form of the impedance function has been employed in the UTOWN tutorial database. In the absence of additional information, it seems reasonable to adopt the parameter “b” values used for UTOWN in the TransCAD tutorial. These values are given in Table 5.5.

Table 5.5 Inverse Power Function Parameters

Trip purpose	b
HBW	1.4
HBNW	3.3
NHB	3.3

Developing a suitable gravity model is a trial-and-error process (ITE, 1992) that requires considerable care. This process, often called calibration, identifies the appropriate decay function or "friction factor" that represents the “reluctance” or “impedance” of persons to make trips of various durations or distances. Calibrating the gravity model consists of evaluating the parameters of the impedance function so that the gravity model replicates, as closely as possible, the base year trip length distribution.

An important consideration in developing trip distribution models is "balancing" productions and attractions. Balancing assures that the total productions equal the total attractions in the study area for each trip purpose. Deciding whether the productions or attractions should be the control total depends on whether there is greater confidence in the production (usually population) growth estimate or the attraction (usually employment) growth estimate. It is also possible to average the two (production and attraction) trip estimates. The productions and/or attractions for all zones must then be factored so that their sum matches the control total.

At each iteration of the gravity model, the total trips attracted to each zone is adjusted so that the next iteration of the gravity model will send more or fewer trips to that attraction zone, depending on whether the immediately previous total trips attracted to that zone was lower or higher, respectively, than the trip attractions estimated by the trip generation model (ITE, 1992). Any unacceptable difference between the generation and distribution model estimates after five iterations of the gravity model usually indicates an inconsistency in the assumptions or functions of the trip distribution model and the growth allocation model (Caliper, 2001).

Gravity models can be singly constrained to either productions or attractions or, doubly constrained to both productions and attractions. In a singly constrained model, the flow between zones is calculated from one of the following equations, depending on whether the balancing is constrained to productions or attractions.

$$T_{ij} = P_i * \frac{A_j * f(d_{ij})}{\Sigma A_z * f(d_{iz})} \qquad \text{(constrained to productions)}$$

$$T_{ij} = A_j * \frac{P_i * f(d_{ij})}{\Sigma P_z * f(d_{zj})} \qquad \text{(constrained to attractions)}$$

where: T_{ij} = the forecast flow produced by zone i and attracted to zone j

P_i = the forecast number of trips produced by zone i

A_j = the forecast number of trips attracted to zone j

d_{ij} = the impedance between zones i and j

$f(d_{ij})$ = the friction factor between zones i and j

The present gravity model evaluation was doubly constrained to both productions and attractions.

The inputs for a Gravity Model are:

- Friction factors (usually in the form of a matrix or table) for the zone pairs in the study area
- Estimates of productions and attractions for each zone

The result is a zone-to-zone trip interchange matrix.

5.2.3.2 Creating an Impedance Matrix

The impedance matrix is the first step towards the generation of the friction factor matrix, which is a necessary input to a gravity model. An impedance matrix is first created using shortest paths between all the zone centroids that represent possible origins and destinations. Refer to Fig. 5.1 for a graphic of the shortest path between origins and destinations. The measure of impedance considered for the analysis was travel time, in minutes. In this analysis, all the links in the REN were assigned a free-flow speed of 20 mph. All the other links in the existing UTOWN street network were assigned their corresponding free flow speeds. The length of each link being known, the link travel times (free flow) could be easily computed.

Table 5.6 shows a portion of the impedance matrix. Note that the labels 2085, 2086, etc., in the matrix represent the IDs of the centroids for the corresponding zones in the UTOWN study area.

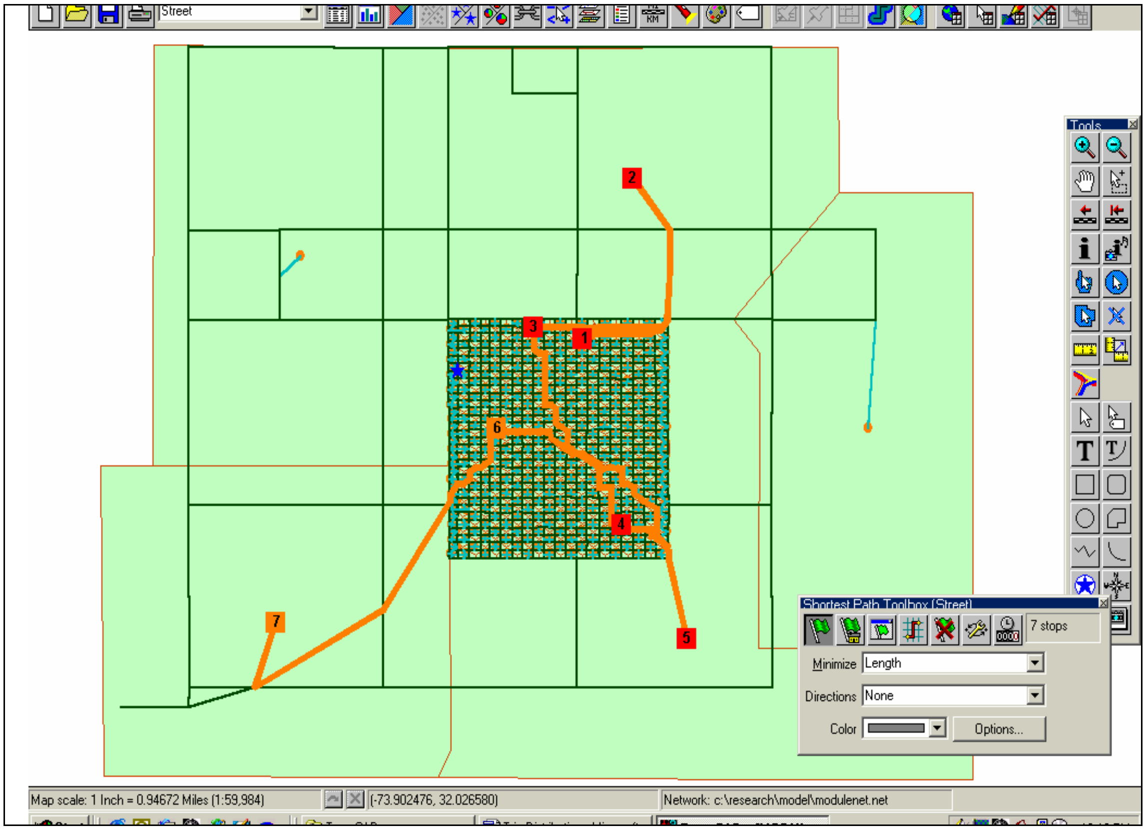
Table 5.6 A Portion of the Impedance Matrix

	2085	2086	2087	2088	2089	2090
2085	0	2.86	1.33	1.05	4.05	3.48
2086	2.86	0	4.01	3.92	1.34	0.77
2087	1.33	4.01	0	0.46	5.20	4.62
2088	1.05	3.92	0.46	0	5.11	4.54
2089	4.05	1.34	5.20	5.11	0	0.74
2090	3.48	0.77	4.62	4.54	0.74	0

In Table 5.6 note that the diagonals of the matrix are all 0. When the impedance matrix was generated, all the diagonal elements of the impedance matrix were computed with zero travel times, the origin and destination being the same along a diagonal. In reality, however, these intrazonal travel times are greater than zero and represent local travel beginning and ending in the same zone. Trip distribution procedures such as the gravity model require a good estimate of these travel times for the outputs to be accurate. Therefore, the impedance matrix was modified to incorporate the intrazonal travel times (see the diagonal elements in Table 5.7). These can be automatically calculated by averaging the travel times between the origin zone and its closest neighbor zones. The only required input is a matrix created by the shortest path matrix procedure. The number of neighbor zones to be included in the averaging calculation was specified to be three.

Table 5.7 A Portion of the Impedance Matrix with Intrazonal Travel Times

	2085	2086	2087	2088	2089	2090
2085	0.47	2.86	1.33	1.05	4.05	3.48
2086	2.86	0.48	4.01	3.92	1.34	0.77
2087	1.33	4.01	0.44	0.46	5.20	4.62
2088	1.05	3.92	0.46	0.45	5.11	4.54
2089	4.05	1.34	5.20	5.11	0.32	0.74
2090	3.48	0.77	4.62	4.54	0.74	0.48



7 stops

Minimize Length

Directions None

Map scale: 1 Inch = 0.94672 Miles (1:59,984)

(-73.902476, 32.026580)

Network: c:\research\model\modulenet.net

Fig. 5.1 Shortest Paths between Origins and Destinations

5.2.3.3 Creating a Friction Factor Matrix

The friction factor matrix can be generated from an Impedance matrix. Once the impedance matrix is ready, the friction factor matrix can be simply generated for the three categories of trip purposes: HBW, HBO and NHB trips. A friction factor matrix is a zone-to-zone matrix that contains the friction factors associated with each pair of zones. The friction factor matrix takes as input the values of the parameters for the inverse power function (available in UTOWN database), which has been chosen as the impedance function. The values of the parameter b considered for the three trip purposes have been shown in Table 5.5. Three different friction factor matrices are created within the same matrix file.

Tables 5.8, 5.9 and 5.10 show a portion of the friction factor matrices for HBW, HBNW and NHB trips, respectively. Note that the labels 1, 3, 4, 7, 9, 11, etc., for the matrices refer to the zone IDs, which correspond to the centroid IDs that were used for the generation of the impedance matrix. This transformation from the centroid IDs to the zone IDs was necessitated as a gravity model evaluation produces a zone-to-zone O-D matrix.

Table 5.8 A Portion of the Friction Factor Matrix for HBW Trips

	1	3	4	7	9	11
1	0.05	0.03	0.01	0.02	0.02	0.02
3	0.03	0.07	0.03	0.05	0.06	0.06
4	0.01	0.03	0.07	0.07	0.07	0.08
7	0.02	0.05	0.07	3.73	4.10	3.46
9	0.02	0.06	0.07	4.10	5.94	8.52
11	0.02	0.06	0.08	3.46	8.52	3.89

Table 5.9 A Portion of the Friction Factor Matrix for HBNW Trips

	1	3	4	7	9	11
1	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	22.21	27.85	18.65
9	0.00	0.00	0.00	27.85	66.55	155.86
11	0.00	0.00	0.00	18.65	155.86	24.54

Table 5.10 A Portion of the Friction Factor Matrix for NHB Trips

	1	3	4	7	9	11
1	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	22.21	27.85	18.65
9	0.00	0.00	0.00	27.85	66.55	155.86
11	0.00	0.00	0.00	18.65	155.86	24.54

5.2.3.4 Gravity Model Evaluation

The inputs to a gravity model are:

1. Production and attraction values for all the zones for HBW, HBNW and NHB trips
2. Friction factor matrix for HBW, HBNW and NHB trips

The result of the gravity model is the generation of a zone-to-zone origin-destination matrix. The procedure for gravity evaluation used in this analysis utilized a doubly constrained model, i.e., one that is constrained to both productions and attractions. The doubly constrained model can be written mathematically as:

$$T_{ij} = a_i * P_i * b_j * A_j * f(d_{ij})$$

subject to: $\sum_j T_{ij} = P_i$

$$\sum_i T_{ij} = A_j$$

where :

T_{ij} = the forecast flow produced by zone i and attracted to zone j

P_i = the forecast number of trips produced by zone i

A_j = the forecast number of trips attracted to zone j

a_i = the balancing factor for row i

b_j = the balancing factor for column j

The doubly constrained model has no simple mathematically derived solution; the solution can be converged upon by iteratively applying equations to balance rows (productions) and columns (attractions). The iterative process continues until a specified value of convergence is achieved, or until a maximum number of iterations are reached. The maximum number of iterations specified for convergence in this model was 20.

Tables 5.11, 5.12 and 5.13 show portions of the output matrix after applying a gravity model. As seen with Friction Factor matrices earlier, the labels 1, 3, 4, 7, 9, 11, etc., for the output matrices refer to the zone IDs that correspond to the centroid IDs of the zones.

Table 5.11 A Portion of the Output Matrix for HBW Trips

	1	3	4	7	9	11
1	8096.94	1207.02	188.41	0.00	0.00	0.33
3	18438.04	10581.58	1329.09	0.00	0.00	2.74
4	7787.02	3595.99	2987.25	0.00	0.00	3.21
7	34.18	17.31	7.37	0.00	0.00	0.39
9	32.44	18.07	7.81	0.00	0.00	0.93
11	33.77	18.56	8.04	0.00	0.00	0.43

Table 5.12 A Portion of the Output Matrix for HBNW Trips

	1	3	4	7	9	11
1	26575.72	2308.04	88.22	0.02	0.01	0.02
3	29703.56	61878.21	1416.98	0.41	0.17	0.38
4	9520.80	11882.67	23370.05	1.41	0.61	1.37
7	19.11	29.64	12.06	10.23	4.64	6.70
9	12.51	24.29	10.24	9.06	7.83	39.53
11	22.16	41.67	17.69	10.11	30.52	10.36

Table 5.13 A Portion of the Output Matrix for NHB Trips

	1	3	4	7	9	11
1	12510.90	496.72	19.41	0.00	0.00	0.00
3	21574.14	20545.97	481.04	0.04	0.02	0.09
4	7666.60	4374.29	8795.98	0.15	0.08	0.37
7	33.82	23.97	9.97	2.46	1.26	4.00
9	20.07	17.81	7.67	1.97	1.93	21.43
11	32.29	27.76	12.05	2.00	6.85	5.10

5.2.3.5 Trip Length Distribution

In transportation analysis, it is sometimes useful to view an existing or forecasted trip length distribution. For example, the calibration of the gravity model is accomplished by reproducing, within a tolerance value, a known trip length distribution. In the scale of this analysis, standard parameters available in the existing UTOWN database have been used for gravity model evaluation. Nevertheless, a trip length distribution (TLD) and the corresponding TLD chart is helpful in getting an idea about the trip frequency distribution for HBW, HBNW and NHB trips. It can also assist in validating the current analysis procedure.

The trip length distribution can be generated from a flow matrix, i.e., the output matrix after trip distribution, and an impedance matrix (e.g., travel time or travel distance). The number of rows in the two input matrices should be the same; so should the matrix labels. The trip length distribution procedure distributes all the trips in their respective travel time intervals (10 in this case). Ten such travel time “bins” were specified for this analysis. The output of this procedure is a matrix, for each of the three trip purposes. Each row of the matrix corresponds to a range of trip lengths, and there is a column each for count, percent, cumulative count, and cumulative percent.

Tables 5.14, 5.15 and 5.16 give the trip length distribution matrices for HBW, HBNW and NHB trips.

Table 5.14 Trip Length Distribution Matrix for HBW Trips

Travel Time Bins (mins)	Count	Percent	Cumulative Count	Cumulative Percent
0.00 – 2.47	2372.91	1.70	2372.91	1.70
2.47 – 4.74	16122.34	11.56	18495.25	13.27
4.74 –7.00	15649.34	11.22	34144.59	24.49
7.00 –9.26	12326.77	8.84	46471.36	33.33
9.26 –11.52	5732.10	4.11	52203.46	37.44
11.52 – 13.78	35831.51	25.70	88034.97	63.14
13.78 – 16.05	8010.26	5.75	96045.23	68.89
16.05 – 18.31	18546.23	13.30	114591.47	82.19
18.31 – 20.57	9712.61	6.97	124304.08	89.15
20.57 -	15122.48	10.85	139426.56	100.00

Table 5.15 Trip Length Distribution Matrix for HBNW Trips

Travel Time Bins (mins)	Count	Percent	Cumulative Count	Cumulative Percent
0.00 – 2.47	60747.34	14.78	60747.34	14.78
2.47 – 4.74	100350.23	24.42	161097.57	39.20
4.74 –7.00	89817.16	21.86	250914.73	61.06
7.00 –9.26	32487.77	7.91	283402.50	68.96
9.26 –11.52	5423.36	1.32	288825.86	70.28
11.52 – 13.78	57511.39	14.00	346337.25	84.28
13.78 – 16.05	7156.04	1.74	353493.29	86.02
16.05 – 18.31	27777.25	6.76	381270.54	92.78
18.31 – 20.57	10540.40	2.56	391810.94	95.34
20.57 -	19130.50	4.66	410941.44	100.00

Table 5.16 Trip Length Distribution Matrix for NHB Trips

Travel Time Bins (mins)	Count	Percent	Cumulative Count	Cumulative Percent
0.00 – 2.47	11215.73	6.11	11215.73	6.11
2.47 – 4.74	35459.79	19.33	46675.52	25.44
4.74 –7.00	30357.42	16.55	77032.94	41.99
7.00 –9.26	15170.98	8.27	92203.92	50.26
9.26 –11.52	4445.00	2.42	96648.92	52.68
11.52 – 13.78	35602.01	19.41	132250.93	72.09
13.78 – 16.05	6548.35	3.57	138799.28	75.66
16.05 – 18.31	18486.09	10.08	157285.37	85.73
18.31 – 20.57	8591.37	4.68	165876.74	90.42
20.57 -	17579.26	9.58	183456.00	100.00

The trip lengths in the above Tables 5.14, 5.15 and 5.16 are based on travel times used as impedance. The trip length distributions for the three different trip purposes have been plotted in the Fig. 5.2. The travel time impedance (in minutes) is plotted against the percent of trips made.

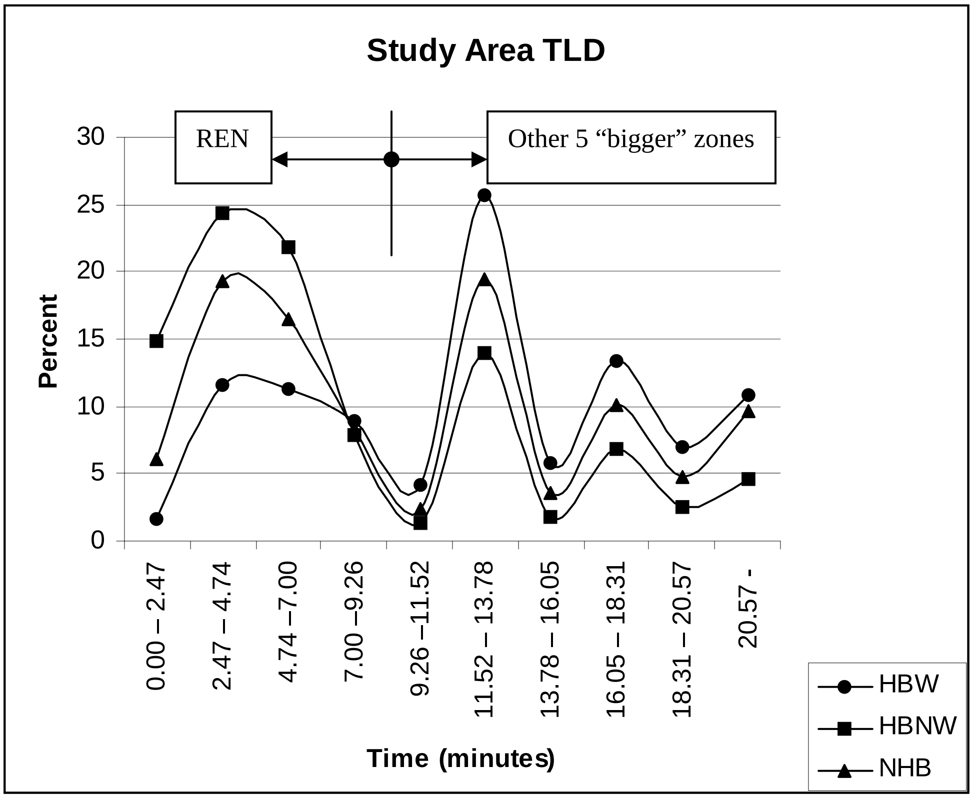


Fig. 5.2 Trip Length Distributions for HBW, HBNW and NHB Trip Purposes

The following can be inferred from the TLD plot:

1. All the three line diagrams exhibit a definite pattern with 2 well-defined crests; the first one in the range of 2.47-4.74 min and the second in the range of 11.52-13.78 min.
2. The first mound around 2.47-4.74 min reflects the trip making behavior within the REN. Because the REN consists of 352 zones that are much smaller in size than the remaining bigger zones, trip lengths within the zones in REN are much shorter.
3. The second peak around a travel time of 11.52-13.78 min can be explained by the considering the trips that are made between the remaining 5 bigger zones

that are not a part of the REN. Because these zones are much larger than the zones of the REN, the trip lengths between these zones are longer.

4. The low “trough” zone between the two peaks would probably represent the fairly short trips between the few zones near the edge of REN and the adjacent bigger zones.
5. HBW trips are the longest of the three trips as expected, indicating that people travel longer distances to commute to work.
6. HBNW and HBO trips exhibit similar shapes although they are shorter than HBW trips. NHB trips fall in line with the HBW trips, as they probably relate to trips made to or from work.

The trip length distribution in the current analysis, represented in Fig. 5.2 demonstrates a shape that is plausible. This trip length distribution is not intended to validate data from ground counts. It simply gives an idea of how the travel times between multiple origin-destination pairs vary depending on the trip purpose.

5.3 Mode Choice

5.3.1 Overview

Mode choice models are used to analyze and predict the choices made by individuals or groups among available modes of transportation. Typically, the goal is to predict the share of trips made by each mode.

Mode choice model estimation may be done either at a disaggregate or aggregate zonal level. Aggregate models seek to predict the zonal shares of trips by mode. Aggregate models are typically estimated using the mode shares by origin-destination pair and average zonal demographics. Disaggregate models are based on individual-level data obtained from surveys (Caliper, 2001). At the individual level, choice is discrete: a person picks one mode from a set of alternatives. Logit models are frequently estimated on individual level data, and then forecasts are made based upon aggregate, explanatory variables.

The data for mode choice models usually include:

1. Socio-economic characteristics of travelers (e.g., income and auto ownership)
2. Service characteristics of the alternative modes (e.g., travel time and cost).

Discrete choice models, which predict the choices made by decision units from a set of discrete alternatives, are often used for mode choice analysis. Discrete choice models are formulated as stochastic models, in which the probability that a particular response is observed is a function of a set of explanatory variables. There are a variety of functional forms that can be proposed for the explanation of discrete choice. One that has proven advantageous, and has been used in the current analysis is the Multinomial Logit (MNL) model.

As the third component of the traditional four-step travel demand forecasting chain, the mode choice model estimates trips using modes of travel applicable to the region under study. Although most regions consider the motorized mode of travel as the universe of choices within the model, recent trends in advanced practice have been toward the inclusion of the non-motorized modes, i.e., walk and bicycle trips. In the setting of the neighborhood model and for the purposes of this analysis, both motorized and non-motorized modes were considered. The motorized mode includes auto and the non-motorized mode includes walk and bike trips. Transit may be a possible motorized mode choice but has not been included in this modeling. A multinomial logit formulation, commonly used in basic mode choice modeling, was used to model the auto, bike and walk trips.

5.3.2 Mode Choice Using Multinomial Logit (MNL) Model

The basic types of data for MNL model estimation and evaluation are:

- A specification of the MNL model, which includes information on the alternatives available, the parameters of the model, and the explanatory variables necessary for the model.

- A dataset on which the MNL model is to be estimated. This is typically a dataset of decision makers or of zones on which there is some information, e.g., income and auto ownership, which may be the explanatory variables for the choice decision that is being studied.
- O-D pair based explanatory variables that are stored in matrix form. These are especially applicable for those mode choice studies in which the characteristics of the alternatives are often based on the origin and destination of the trip.

The MNL model relates the probability that a decision unit (e.g., individual, household) chooses a given alternative from a set of alternatives to the utility of these alternatives, according to the following formula:

$$P_n(i) = \text{prob}(Y_n = i) = \frac{e^{V_{ni}}}{\sum_{j \in C_n} e^{V_{nj}}}$$

where:

$P_n(i)$ = the probability with which person n will choose alternative i

Y_n = the value of the response variable for the individual n

C_n = the set of alternatives in person n’s choice set

V_{ni} = the measurable component of the utility of the alternative i for individual n

MNL models are specified by defining the relative utility for each alternative. This means defining the explanatory variables that enter each relative utility and the relationship of the parameters among the relative utilities. Explanatory variables that enter the utility functions may be of several types. The variables may be characteristics of the decision maker or attributes of the alternative.

The utility functions for auto, walk and bicycle modes are shown in equations 5.4, 5.5 and 5.6.

Utility function for auto (U_{auto})……………………………………………(5.4)

U_{auto} = θ_{auto} + a* TT + b* Avg.Inc + c*ParkCost_d +d*Auto/HH

θ_{auto} = alternative specific constant for auto

TT = travel time variable, using the impedance travel times between each O-D pair
Avg.Inc = average income of HH in each zone
ParkCost_d = parking cost applied to destination zone
Auto/HH = auto ownership per zone
a,b,c,d = parameters for each of the explanatory variables

Utility function for walk (U_{walk})……………………………………………(5.5)

U_{walk} = $\theta_{walk} + a^* TT + b^* LU$
θ_{walk} = alternative specific constant for walk
TT = travel time variable, usually the maximum acceptable time for walk
LU = land use variable
a,b = parameters for each of the explanatory variables

Utility function for bike (U_{bike})……………………………………………….(5.6)

U_{bike} = $\theta_{bike} + a^*TT + b^*LU$
θ_{bike} = alternative specific constant for bike
TT = travel time variable, usually the maximum acceptable time for bike
LU = land use variable
a,b = parameters for each of the explanatory variables

The utility function (equation 5.4) for auto mode has been directly adopted from the UTOWN model (Caliper, 2001). UTOWN did not have walk and bike as alternative modes, and in the absence of actual survey data, it was considered necessary to adopt bike and walk mode share models from other studies and surveys conducted in other areas. Hence, the utility functions for walk (equation 5.5) and bike (equation 5.6) modes were adopted from the activity survey: *Regional Mode Split by Trip Purpose* (Portland Metropolitan Planning, 1994). The explanatory variables for the walk and bike utility functions (namely alternate specific function, travel time and land use variable) were as specified in the models from the Portland study.

A back-calculation was done out to determine the value of unknown explanatory variables when the coefficients and corresponding mode shares for all three modes were known. For the auto model, the values of the parameters a, b, c and d for the auto model were taken directly from the mode choice model for UTOWN. The values of the explanatory variables for this procedure came from the actual socio economic input data for REN. For the walk and the bike mode choice models, the parameters θ (mode-specific constant), a and b were those specified by the Portland study (1994). The actual mode shares for walk and bike were taken from the same study. The input for the variable for travel time (see var1, Table 5.17) was obtained from calculations for maximum acceptable time for walk and bike for an individual. Assuming 2.5 mph for walk, and 10 mph for bike represent conservative assumptions for speeds, the acceptable distance that a pedestrian would be able to travel would be approximately 0.25 to 0.5 mile for walk and 1.5 to 2.5 miles for bike (Center for Housing Innovation, 2001).

Considering the maximum distance to walk as 0.5 mile at a speed of 2.5 mph, the maximum acceptable travel time for walk = (1/2.5)*1/2*60 mins = 12 mins (see var1, Table 5.17).

Considering the maximum distance to bike as 2.5 miles at a speed of 10 mph, the maximum acceptable travel time for walk = (1/10)*2.5*60 mins = 15 mins (see var1, Table 5.17).

The values for the LU variable (var2 for walk and bike modes only, Table 5.17) could be obtained after all the parameters and variable values were fixed and mode shares for walk and bike were known. The LU variable does incorporate several factors that may be considered as conducive to walk and bike trips, like density of housing units, availability of sidewalks, and street connectivity, slower traffic speeds and slower traffic volumes. It is beyond the scope of this research to estimate the weights of each of these factors and their specific values.

Table 5.17 gives the weights and values for the various parameters in auto, walk and bike shares. These values represent the final outcomes of the back-calculation procedure that was carried out to estimate the values of the explanatory variables that satisfy the coefficients and known mode shares. The variables have been generically referred to as var1, var2, var3 and var4, in order of their appearance in each of the model equations 5.4, 5.5 and 5.6 respectively. The weights have also been generically referred to as a, b, c and d, corresponding to each of the explanatory variables. The mode specific constants have been generically termed as $\theta_{\text{mode.}}$

Table 5.17 Multinomial Model

Mode	θ_{mode}	a	var1	b	var2	c	var3	D	var4
Walk	5.523	-0.0788	12	-0.266	55	-	-	-	-
Auto	-0.05	-1.015	6.625	0.005	38.94	-0.105	4.5	0.346	2
Bike	-1.054	-0.102	15	-0.18	44	-	-	-	-

By plugging in the values of the variables and coefficients, in the above equations, the values of the utilities for walk, auto and bike modes can be calculated.

U (walk) = -10.0526

U (auto) = -6.36018

U (bike) = -10.504

p (m) = percentage for each mode

$$P\,(\text{walk}) = \frac{\exp(U(\text{walk}))}{\exp(U(\text{auto}))+\exp(U(\text{walk}))+\exp(U(\text{bike}))} = 2.39\%$$

$$P\,(\text{auto}) = \frac{\exp(U(\text{auto}))}{\exp(U(\text{auto}))+\exp(U(\text{walk}))+\exp(U(\text{bike}))} = 96.08\%$$

$$P\,(\text{bike}) = \frac{\exp(U(\text{bike}))}{\exp(U(\text{auto}))+\exp(U(\text{walk}))+\exp(U(\text{bike}))} = 1.52\%$$

The MNL model is input in the TransCAD database, with information about all the alternatives and their relative weights. For the MNL model to be applied in

TransCAD, the travel time impedance matrix for the shortest path was used. The variables for average income and park cost were incorporated from the socio economic input data for REN.

Tables 5.18, 5.19 and 5.20 show a portion of the zone-to-zone mode share matrices for walk, auto and bike trips obtained after application of a Multinomial Mode Choice evaluation procedure. Each element in these tables shows the zone-to-zone mode share. The sum of each corresponding element in the three tables adds up to 1.0. For example, consider element 9-1 in each table:

Mode share for Walk (Table 5.18) = 0.97

Mode share for Walk (Table 5.19) = 0.01

Mode share for Walk (Table 5.20) = 0.02

Table 5.18 A Portion of Mode Share Matrix for Walk Trips

Zones	1	3	4	7	9	11
1	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
7	0.97	0.80	0.41	0.00	0.00	0.00
9	0.98	0.83	0.36	0.00	0.00	0.00
11	0.97	0.80	0.35	0.00	0.00	0.00

Table 5.19 A Portion of Mode Share Matrix for Auto Trips

Zones	1	3	4	7	9	11
1	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	1.00	1.00	1.00
7	0.01	0.19	0.58	1.00	1.00	1.00
9	0.01	0.16	0.64	1.00	1.00	1.00
11	0.01	0.18	0.65	1.00	1.00	1.00

Table 5.20 A Portion of Mode Share Matrix for Bike Trips

Zones	1	3	4	7	9	11
1	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
7	0.02	0.01	0.01	0.00	0.00	0.00
9	0.02	0.01	0.01	0.00	0.00	0.00
11	0.02	0.01	0.01	0.00	0.00	0.00

5.3.3 Technical Notes on Mode Choice

It is best to estimate the coefficients of a mode choice model using the characteristics of the study area’s transportation network, and the characteristics of the travelers and their travel behavior obtained from household and on-board transit surveys. This method best reflects local travel patterns, because the model is estimated on local data. The model can then be expected to perform more accurately in the forecast mode, all else being equal. Another common approach to mode choice calibration is to transfer or “borrow” coefficients from mode choice models in other urban areas. The equations’ constants are then adjusted to come up with an acceptable range of the observed data.

In this study, model coefficients for the walk and bike modes have been borrowed from studies conducted in the Portland area (Portland Metropolitan Planning, 1994). A back-calculation was performed to estimate the values of unknown explanatory variables from known coefficients and mode shares, in the utility functions. Obviously, transferring mode choice coefficients from a different urban region has its own limitations regarding the applicability of the data in a different study area. Another limitation in the modeling approach for the walk and a bike mode was the specification of the land use variable. The land use variable may be a function of several different attributes like street network, connectivity and facility type, which may be specific to an urban region. It was not within the scope of this research to explore the weights of these specific attributes. It would be ideal to obtain travel survey data from model neighborhoods and networks that are not hypothetical (like REN) but actually exist. However, this was not within the scope of this study.

5.4 P-A to O-D Transformations and Time-of-Day Analysis

5.4.1 Overview

The output from trip distribution is expressed in terms of the productions and attractions. Because the trip assignment algorithms require origins and destinations as inputs, the productions and attractions must be converted.

Another type of data transformation done frequently is the decomposition of a 24-hour trip table matrix (P-A or O-D) to hourly flow matrices. This transformation is based on information about the percentage of flow that occurs in each hour throughout the day. The Time-of-Day procedure takes a 24-hour matrix, with information about the percent of flow per hour and produces hourly matrices. Peak hour factors can then be applied to the resulting matrices.

Both the P-A to O-D and the Time-of-Day procedures also provide means to convert person trips to vehicle trips. This conversion can be based on either an average vehicle occupancy factor, or hourly vehicle occupancy factors, specific to each hour in the day.

5.4.2 Performing P-A to O-D Transformations

In the current analysis the P-A to O-D transformations were carried out using an “Hourly” Look Up table. This look up table provides information on travel that occurs throughout the day, for each hour. Ideally, the source of information for travel occurring in each hour will be the locally initiated surveys. However, due to the absence of locally available data, the default hourly look up table as provided in the TransCAD database has been used. The values in the default table contain inputs for hourly data for the time of day and vehicle occupancy adjustments, and have been obtained from NCHRP 365 (1998). Hourly data are provided for three trip purposes: HBW, HBNW and NHB. These values are based on national averages derived from census data.

In this analysis, the P-A matrix obtained after the mode choice analysis is the input for the transformations to O-D. It may be noted that the matrix obtained after multiplying the total trips by the mode share for auto trips only, is used as input to the transformations. The P-A to O-D transformations and the corresponding Time-of-Day analysis have been done by reporting each hour separately, and using the Hourly Look Up table and also converting the person trips to vehicle trips after using an average vehicle occupancy factor of 1.5.

Tables 5.21, 5.22 and 5.23 show portions of the O-D matrix for HBW, HBNW and NHB trip purposes for the 24-hour period.

Table 5.21 A Portion of the 24-hour O-D Matrix for HBW Trips

	1	3	4	7	9	11
1	5397.96	6548.35	2658.48	0.11	0.08	0.21
3	6548.35	7054.39	1641.69	1.09	0.94	2.04
4	2658.48	1641.69	1991.50	1.42	1.66	2.81
7	0.11	1.09	1.42	0.00	0.00	0.13
9	0.08	0.94	1.66	0.00	0.00	0.31
11	0.21	2.04	2.81	0.13	0.31	0.29

Table 5.22 A Portion of the 24-hour O-D Matrix for HBNW Trips

	1	3	4	7	9	11
1	17717.15	10670.53	3203.00	0.07	0.03	0.07
3	10670.53	41252.14	4433.21	2.00	1.32	2.66
4	3203.00	4433.21	15580.03	2.79	2.38	4.28
7	0.07	2.00	2.79	6.79	4.55	5.57
9	0.03	1.32	2.38	4.55	5.20	23.25
11	0.07	2.66	4.28	5.57	23.25	6.87

Table 5.23 A Portion of the 24-hour O-D Matrix for NHB Trips

	1	3	4	7	9	11
1	8340.60	7356.95	2562.00	0.11	0.05	0.10
3	7356.95	13697.31	1618.44	1.52	0.94	1.72
4	2562.00	1618.44	5863.98	1.97	1.65	2.73
7	0.11	1.52	1.97	1.63	1.07	1.99
9	0.05	0.94	1.65	1.07	1.28	9.39
11	0.10	1.72	2.73	1.99	9.39	3.39

The Time-of-Day procedure allows decomposing of the 24-hour O-D matrix into individual hourly flow O-D matrices. To perform Time-of-Day Analysis, the percent of flow that occurs in each hour is applied to the trips. In this analysis, a Time-of-Day procedure was applied to the morning peak (AM peak) period between 8-9 hours and evening peak (PM peak) between 17-18 hours, to obtain the percent flow of trips, congestion during these specific time periods. A traffic assignment was applied to these peak periods. (See Section 5.5.)

Tables 5.24, 5.25 and 5.26 show portions of the O-D matrix for HBW, HBNW and NHB trips for the morning peak between 8 and 9 AM.

Table 5.24 A Portion of the O-D Matrix for HBW Trips (8-9 AM)

	1	3	4	7	9	11
1	496.61	74.03	11.56	0.00	0.00	0.02
3	1130.87	649.00	81.52	0.00	0.00	0.17
4	477.60	220.55	183.22	0.00	0.00	0.20
7	0.02	0.20	0.26	0.00	0.00	0.02
9	0.01	0.17	0.30	0.00	0.00	0.06
11	0.02	0.21	0.32	0.00	0.00	0.03

Table 5.25 A Portion of the O-D Matrix for HBNW Trips (8-9 AM)

	1	3	4	7	9	11
1	602.38	362.80	108.90	0.00	0.00	0.00
3	362.80	1402.57	150.73	0.07	0.05	0.09
4	108.90	150.73	529.72	0.09	0.08	0.15
7	0.00	0.07	0.09	0.23	0.15	0.19
9	0.00	0.05	0.08	0.15	0.18	0.79
11	0.00	0.09	0.15	0.19	0.79	0.23

Table 5.26 A Portion of the O-D Matrix for NHB Trips (8-9 AM)

	1	3	4	7	9	11
1	333.62	294.28	102.48	0.00	0.00	0.00
3	294.28	547.89	64.74	0.06	0.04	0.07
4	102.48	64.74	234.56	0.08	0.07	0.11
7	0.00	0.06	0.08	0.07	0.04	0.08
9	0.00	0.04	0.07	0.04	0.05	0.38
11	0.01	0.07	0.11	0.08	0.38	0.14

Tables 5.27, 5.28 and 5.29 show portions of the O-D matrix for HBW, HBNW and NHB trips for the evening peak between 5 and 6 PM.

Table 5.27 A Portion of the O-D Matrix for HBW Trips (5-6 PM)

	1	3	4	7	9	11
1	669.35	1455.29	613.33	0.03	0.02	0.03
3	168.70	874.74	288.20	0.26	0.22	0.28
4	45.97	118.94	246.95	0.34	0.39	0.42
7	0.00	0.01	0.02	0.00	0.00	0.00
9	0.00	0.01	0.02	0.00	0.00	0.00
11	0.03	0.23	0.27	0.03	0.07	0.04

Table 5.28 A Portion of the O-D Matrix for HBNW Trips (5-6 PM)

	1	3	4	7	9	11
1	1417.37	853.64	256.24	0.01	0.00	0.01
3	853.64	3300.17	354.66	0.16	0.11	0.21
4	256.24	354.66	1246.40	0.22	0.19	0.34
7	0.01	0.16	0.22	0.54	0.36	0.45
9	0.00	0.11	0.19	0.36	0.42	1.86
11	0.01	0.21	0.34	0.45	1.86	0.55

Table 5.29 A Portion of the O-D Matrix for NHB Trips (5-6 PM)

	1	3	4	7	9	11
1	517.12	456.13	158.84	0.01	0.00	0.01
3	456.13	849.23	100.34	0.09	0.06	0.11
4	158.84	100.34	363.57	0.12	0.10	0.17
7	0.01	0.09	0.12	0.10	0.07	0.12
9	0.00	0.06	0.10	0.07	0.08	0.58
11	0.01	0.11	0.17	0.12	0.58	0.21

5.5 Traffic Assignment

5.5.1 Overview

Traffic assignment models are used to estimate the flow of traffic on a network. These models take as input a matrix of flows that indicate the amount of traffic between origin and destination (O-D) pairs. The flows for each O-D pair are loaded onto the network, based on travel time or impedance of the alternative paths that could carry this traffic.

In the present analysis, the User Equilibrium method has been used for traffic assignment. This method uses an iterative process to achieve a convergent solution, in which no travelers can improve their travel times by shifting routes. In each iteration the network link flows are computed which incorporate the capacity restraint effects and flow dependant travel times. This method updates travel time iteratively based on link performance functions. The BPR (Bureau of Public Roads) formulation has been used as the volume-delay function.

5.5.2 Required Network Attributes and Model Settings

The required network attributes and settings for traffic assignment using user equilibrium are shown in Table 5.30.

Table 5.30 Required Link Attributes for UE

Attributes	Contents	Required Settings
Time	Free-flow travel time	Iterations
Capacity	Maximum flow that a link can carry	Convergence
		Alpha (α)
		Beta (β)

The number of iterations specified was 20 and the convergence was set at 0.01 for the assignment procedure. Standard default values of α (0.15) and β (4.0) were used.

5.5.3 Standard Results of Traffic Assignment

The purpose of traffic assignment is to forecast the traffic conditions for the given network and demand volumes. The assigned link volumes are the primary output of the assignment model. Table 5.31 gives the link outputs as a result of the assignment procedure using User Equilibrium.

Table 5.31 Link Outputs for UE

Link Output Fields	Contents
AB_Flow, BA_Flow	Volume on link from A to B/from B to A (A and B are end nodes of a link)
Total_Flow	Total volume on links in both directions
AB_Time, BA_Time	Travel time (or cost) for link from A to B/from B to A
Max_Time	Maximum travel time (or cost) for links in both directions
AB_voc, BA_voc	Volume to capacity (V/C) ratio for link from A to B/from B to A
Max_voc	Maximum V/C ratio for links in both directions
AB_speed, BA_speed	Speed on link from A to B/from B to A at last iteration of assignment

System-wide results, shown in Table 5.32, are also reported.

Table 5.32 System-wide Outputs

System-wide outputs	Contents
Total VHT	Total vehicle hours from assignment
Total VMT	Total vehicle miles from the assignment

5.5.4 Performing Traffic Assignment using UE

A traffic assignment procedure using user equilibrium was applied to the street network in REN and the adjacent five zones. The following cases were considered for assignment:

1. Hourly O-D pairs for morning peak hour (8-9 AM)
2. Hourly O-D pairs for evening peak hour (5-6 PM)

The system-wide outputs for HBW, HBNW and NHB trips for each of the above three cases are presented in Table 5.33.

Table 5.33 System-wide Outputs for AM and PM Peak Hours for REN Regional Model

	AM peak (8-9)	PM peak (5-6)
HBW trips		
Total V-time-T (mins)	13787	19084
Total V-dist-T (miles)	5468	7380
HBNW trips		
Total V-time-T (mins)	11261	28448
Total V-dist-T (miles)	4427	10529
NHB trips		
Total V-time-T (mins)	4371	6833
Total V-dist-T (miles)	1793	2798

5.5.5 Subarea Analysis for REN

When forecasting transportation demand for a region, there may be need to perform a more detailed investigation of traffic patterns within a subarea. In the present analysis, it is important to understand the nature of trip making within the REN subarea (consisting of 352 zones) in addition to the system-wide outputs for trip assignment. It is especially useful to try to capture the effects of the mixed land uses on the traffic characteristics within the subarea. The results of a subarea analysis performed for the REN subarea can be compared with a similar analysis of the Euclidean neighborhood. (The EUCLID subarea analysis will be done in Chapter 6.) For this reason, a traffic assignment was carried out for the REN subarea, and its Measures of Effectiveness (MOEs) were evaluated.

In a subarea analysis, an O-D trip table for the subarea is created. The reduced O-D matrix is used as the demand table for performing a traffic assignment on a subarea network, which maybe more detailed than the regional network.

5.5.5.1 Defining the Subarea

The subarea can be defined by a “cordon line” that circumscribes the area or by selecting one or more areas in an area layer and use the outer boundary of the area set as a cordon. In this analysis, all 352 zones of the REN made up the subarea.

The subarea O-D matrix is defined by “cross-links” and “internal centroids”. Cross-links are links that cross the cordon line, and internal centroids are centroid nodes that are inside the cordon. An end node of a cross-link, whether it is a centroid or a regular node, is called an external station, if it is located outside the cordon. A subarea O-D matrix is a square matrix, which means that within the matrix there is a row and column for each of the internal centroids and the external stations.

A trip is assigned to the subarea O-D matrix if any part of the trip is inside the subarea. There are four ways that a trip can be at least partially inside the subarea:

1. The trip originates or passes through an external station, passes through the subarea, and ends at or passes through an external station.
2. The trip originates at or passes through an external station, enters the subarea, and ends at an internal centroid.
3. The trip originates at an internal centroid, exits the subarea, and ends at or passes through an external station.
4. The trip originates at an internal centroid and ends at another internal centroid.

The results of the subarea analysis are presented in Table 5.34. The outputs are in terms of Vehicle-distance-Traveled (V-dist-T, in miles) and Vehicle-time-Traveled (V-time-T, in mins). Traffic assignment for the subarea was carried out for the following cases:

1. Hourly O-D pairs for morning peak hour (8-9 AM)
2. Hourly O-D pairs for evening peak hour (5-6 PM)

Table 5.34 System-wide Outputs for AM and PM Peak Hours for REN Subarea

Trip Purpose	AM peak (8-9)	PM peak (5-6)
HBW		
Total V-time-T (mins)	14008	19365
Total V-dist-T (miles)	5543	7474
HBNW		
Total V-time-T (mins)	11600	28931
Total V-dist-T (miles)	4542	10687
NHB		
Total V-time-T (mins)	4531	7028
Total V-dist-T (miles)	1848	2865

Comparing Tables 5.33 and 5.34, it can be observed that the values for V-time-T and V-dist-T are within one percent of each other. This is because Table 5.34 still gives the system-wide statistics for the entire UTOWN study area, as in Table 5.33. The only difference is that, in Table 5.34, the subarea is defined within the UTOWN study area.

Table 5.35 gives the outputs for Vehicle-minutes-Traveled and Vehicle-miles-traveled considering the subnetwork only. The assignment procedure considers only the subarea consisting of the 352 zones in the REN. The external stations and the cross links are generated by the software. Thus the outputs relate specifically to that subset of the trips that are loaded onto the subnetwork.

Table 5.35 Outputs for AM and PM Peak Hours for REN Subnetwork

	AM peak (8-9)	PM peak (5-6)
HBW		
Total V-time-T (mins)	1784	2426
Total V-dist-T (miles)	594	808
HBNW		
Total V-time-T (mins)	3125	7645
Total V-dist-T (miles)	1041	2548
NHB		
Total V-time-T (mins)	540	879
Total V-dist-T (miles)	180	293

5.5.5.2 Technical Notes on Subarea Analysis

Subarea analysis is useful especially when dealing with extremely large regions. One of the important uses of subarea analysis is for generating reports that are based on the traffic assignment from a statewide or large regional model. The results of a subarea analysis should be treated with caution. While it can be beneficial to reduce the dimensions of the traffic assignment problem significantly, the model results do differ even if the subnetwork is a straight subset of the original network.

5.5.6 Estimation of Trip Lengths

As a post-assignment procedure, trip lengths by trip purpose were estimated based on the congested travel times obtained after the network is loaded for traffic assignment. The trip lengths were generated from a trip length distribution (TLD), obtained from the flows after traffic assignment. These trip lengths are based on the loaded travel times after the AM and PM peak hour analyses. However, it was observed that over 90% of the links were not congested (v/c < 1.0). So, a TLD using the free flow travel times would have yielded the same results; therefore it is not presented.

Table 5.36 gives the average, minimum and maximum trip lengths by travel time (in minutes), and also their standard deviation, for the entire UTOWN study area. Table 5.37 gives the trip lengths (in minutes) for all those trips that either originate or terminate within the REN subarea.

Table 5.36 Trip Lengths (with Loaded Travel Times) for the UTOWN Study Area with REN

	Trip Length (mins) for REN + 5 adjacent zones			
Trip Type	Avg.	Min.	Max.	S.D.
HBW	12.403	0.212	22.832	6.297
HBNW	7.818	0.212	22.832	6.008
NHB	10.179	0.212	22.832	6.764

Table 5.37 Trip Lengths (with Loaded Travel Times) for Trips In and Out of REN

	Trip Length (mins) for trips in and out of REN			
Trip Type	Avg.	Min.	Max.	S.D.
HBW	6.322	0.212	19.791	3.809
HBNW	2.401	0.212	19.791	3.228
NHB	2.273	0.212	19.791	3.200

By comparing Tables 5.36 and 5.37, it can be observed that trip lengths are substantially longer when the entire UTOWN study area (consisting of REN + adjacent 5 zones) is considered, than when trips in and out of REN are considered. The minimum trip length (0.212 minute) however, remains the same in both the cases, because the shortest trip would probably be the one that has both ends inside the REN.

The TLD in terms of loaded travel times (in minutes) by trip purpose have been plotted in Figures 5.3 and 5.4. Fig. 5.3 gives the TLD plot for all trips in the UTOWN study area. Fig. 5.4 gives the TLD plot for only those trips that have at least one end inside the REN.

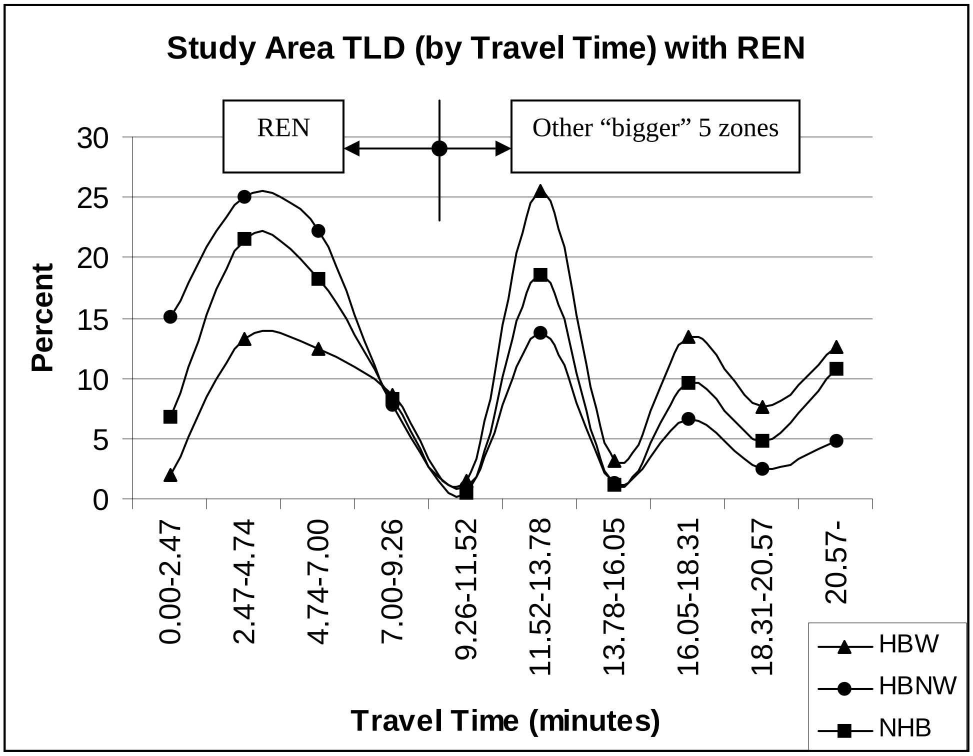


Fig. 5.3 UTOWN Study Area TLD with REN Using Loaded Travel Times

All three line diagrams in Fig. 5.3 represent all the trips that occur in the study area.

The following can be inferred from the TLD plot in Fig. 5.3:

- All three lines exhibit a definite pattern with 2 well-defined crests; the first one in the range of 2.47-4.74 min and the second in the range of 11.52-13.78 min.
- The first peak around 2.47-4.74 min reflects the trip making behavior within the REN. Because the REN consists of 352 zones that are much smaller in size than the remaining bigger zones, trip lengths within the zones in REN are much shorter.
- The second peak around a travel time of 11.52-13.78 min can be explained by the considering the trips that are made between the remaining 5 bigger zones that are not a part of the REN. Because these zones are much larger than the zones of the REN, the trip lengths between these zones are longer.

- The low "trough" between the two peaks probably represents the intermediate length trips between the few zones near the edge of REN and the adjacent bigger zones.
- HBW trips are the longest of the three trips as expected (see also Table 5.36), indicating that people travel longer distances to commute to work. HBNW and HBO trips exhibit similar shapes although they are shorter than HBW trips. NHB trips fall in line with the HBW trips, because they probably relate to trips made to or from work.

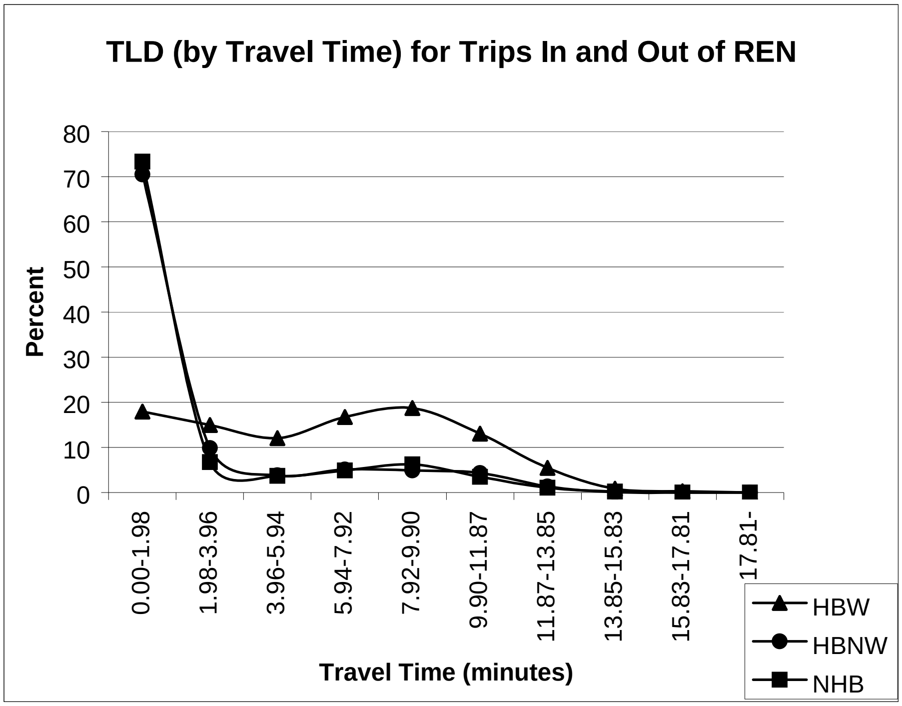


Fig. 5.4 TLD for Trips In and Out of REN Using Loaded Travel Times

All three line diagrams in Fig. 5.4 represent only those trips that either begin or end inside the REN. The plot includes trips that occur between REN and the adjacent 5 bigger zones, but does not include the trips that occur between the bigger zones.

The following can be inferred from the TLD plot in Fig. 5.4:

- There are very large percentages of short trips (0-4 minutes, approximately) for HBNW and NHB trips. This can be explained by the location of most non-residential land uses inside the REN, thus shortening the trip making distances (hence times).
- The percentage of short trips (0-4 minutes) is substantially lower for HBW trips, because only a few work-related trips would be made at such short distances from the REN. This is because only a few work places are located in the REN.
- The trip lengths (by travel time) for HBW, HBNW and NHB trips are lower for trips in and out of REN than for all the trips that occur within the UTOWN study area. (See Fig. 5.3 and Table 5.36.) The reason is implicit, because in Fig. 5.4, the long trips that occur between the bigger zones are not considered. Trips in and out of REN are much shorter, because most HBNW and NHB trip making (except HBW trips) are satisfied at shorter distances from home.
- HBW trips are the longest (see Table 5.37) of the three trip purposes, as expected, indicating that people commute longer distances to work. Also, only a few work places have been included in the REN. Consequently, most of the work trips would still go outside the REN and still remain fairly long trips, when compared to HBNW and NHB trips. HBNW and HBO trips exhibit similar shapes although they are shorter than HBW trips. NHB trips fall in line with the HBW trips, because they probably relate to trips made to or from work.

This concludes the four-step travel demand modeling process for the UTOWN study area with the REN. In the following chapter, a similar analysis procedure will be adopted for the UTOWN study area with a Euclidean neighborhood (EUCLID). A comparative assessment of the transportation-related performance measures obtained from the two scenarios will be made in Chapter 7.

CHAPTER 6. ANALYSIS OF EUCLIDEAN NEIGHBORHOOD

6.1 Overview

In this chapter, a hypothetical “Euclidean” neighborhood model will be evaluated using travel demand modeling software. The “Euclidean” neighborhood is similar to a conventional suburban development, with residential and non-residential uses separated, and development being rather sparse, not dense and compact. The Euclidean neighborhood has a street network characterized by a dendritic pattern. Residential areas often have cul-de-sacs (New Urban News, 2000).

In this study, a hypothetical Euclidean neighborhood (named EUCLID) is represented in a standard software tool (TransCAD), as was done with the reverse engineered neighborhood: REN. The EUCLID neighborhood has the same dimensions as the REN. The purpose is to evaluate and compare the transportation-related performances of the two neighborhoods. This analysis is restricted to an examination of how well the two neighborhoods perform because of different land use patterns. All other variables like design characteristics of street network, lane width, will be held constant; only the type and number of the land uses in these two neighborhood settings will differ.

6.2 Considerations for Development of EUCLID Model

The EUCLID neighborhood has the same dimensions as that of the REN. The total population in the UTOWN study area is the same, in order to make a fair comparative assessment between the two design concepts. The EUCLID neighborhood is extracted from the UTOWN database, as was REN. It has 352 smaller zones and five adjacent bigger zones, each of which has the same size as that of the REN. The zone structure and the street network remains the same in the two scenarios. The zone structure and determination of block sizes have already been explained in Sections 4.3 and 4.5. Except for the type and number of land uses within the 352 zones, all other modeling variables are held constant for the purposes of this analysis.

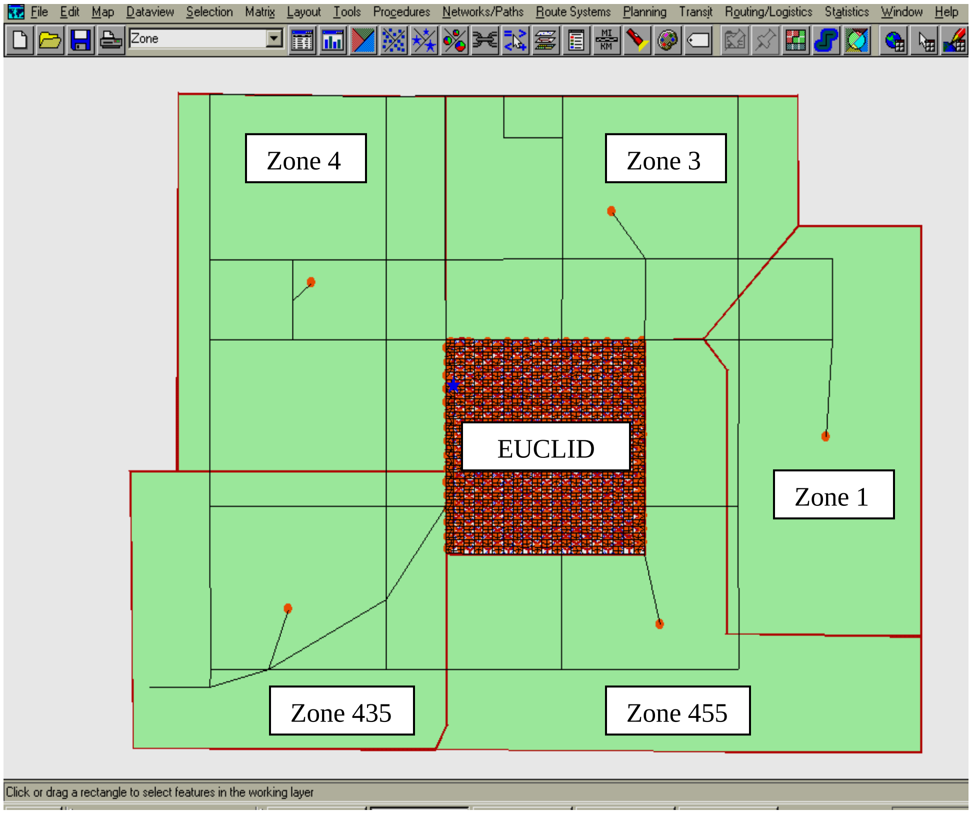
6.2.1 Land Uses and Population in EUCLID

The land use in the 352 smaller zones (in EUCLID) is predominantly residential. A residential section of the UTOWN network, used for many years to demonstrate the travel demand modeling process and related software, was chosen as the site for REN and EUCLID (UTPS Training Session, 1982). A UTOWN database exists in the Tutorial sub-directory of TransCAD (Caliper, 2000). The database confirms that most of the land occupied by the 352 smaller zones was occupied for residential purposes. Thus it was decided to have residential uses in the 352 smaller zones.

The population for the entire UTOWN study area with EUCLID (comprising of 357 zones) equals the population of the UTOWN study area with REN. This means that additional population located in the REN would be distributed over the entire UTOWN study area with EUCLID. The population for the UTOWN study areas with the two scenarios (REN and EUCLID) was kept the same so that the total trips in the UTOWN study area remain the same. This would enable a fair comparison of the two cases, in terms of the MOEs (Measures of Effectiveness). The procedure is explained below.

Table 6.1 shows the population calculations for the UTOWN study area. The percentage increase in the population for the study area with the REN with respect to the original population of the UTOWN is first computed. This percentage (9.9%, from Table 6.1) is added uniformly to all the zones in the UTOWN study area with EUCLID. In Table 6.1, the population for REN/EUCLID is given for all the 352 zones taken together. The population calculations for zone # 455, is shown proportional to its area of 9 sq. mi. The population for EUCLID is also proportional to its area (4 sq. mi., see Section 3.5.9). The population for REN is 7040 (see Section 3.5.5) x 4 modules = 28160.

Fig. 6.1 shows the UTOWN study area with the EUCLID neighborhood. Fig. 6.2 shows a graphic for zone ID# 455, which is the parent zone of EUCLID and REN.



Click or drag a rectangle to select features in the working layer

Fig. 6.1 TransCAD Screen Capture Showing EUCLID and the Adjacent UTOWN Zones

Table 6.1 Population Calculations for UTOWN Study Area with EUCLID

Zone	Population (UTOWN)	Population (REN+5 zones)	Population (EUCLID+5 zones)
REN/EUCLID (352 zones)	(4/13)*41583 = 12795	7040*4 = 28160	12795*1.099 = 14056
455	(9/13)*41583 = 28788	28788	28788*1.099 = 31625
1	12418	12418	12418*1.099 = 13642
3	41175	41175	41175*1.099 = 45232
4	20050	20050	20050*1.099 = 22026
435	40700	40700	40700*1.099 = 44710
Total	155926	171291	171291
% Increase in population for study area with REN w.r.t. UTOWN study area = (171291-155926)/155926 *100 = 9.9			

The zone IDs in Table 6.1 and Fig. 6.1 are as found in TransCAD mapview.

The population for zone IDs 1, 3, 4 and 435 are as found in TransCAD Tutorial database for UTOWN.

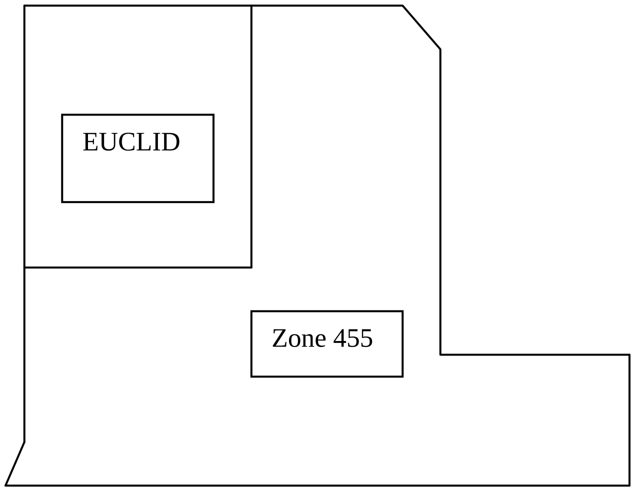


Fig. 6.2 Zone # 455 –the “Parent” Zone of EUCLID (and REN)

Average population in a single zone of REN = 28160/352 = 80

Average population in a single zone of EUCLID = 14056/352 = 40

These average population values were used as the population for each zone, as the socio-economic input data in the analysis.

Change in population and the number of housing units are the only changes made for comparison between the REN and EUCLID neighborhoods. Because there are no non-residential uses in EUCLID, there is no retail and non-retail employment in the EUCLID. All retail and non-retail employment that existed in the parent zone of EUCLID (from the UTOWN study area) would now be found in zone # 455.

6.3 Analysis of EUCLID

This section presents the analysis of the EUCLID neighborhood using the four-step travel demand modeling procedure. The first subsection relates to analysis of the regional model considering the entire UTOWN study area. The second subsection deals with analysis of the EUCLID subarea. Finally, in the third subsection the results of the trip length distributions for the regional model and the subarea are presented.

6.3.1 Analysis of Regional Model

First, analysis of EUCLID and the five adjacent zones in UTOWN is done using the standard transportation four-step modeling procedures in TransCAD. The modeling steps are the same as those used for REN, and do not need to be repeated, in this section. The only changes are in the socio-economic characteristics--number of housing units and population—within the EUCLID neighborhood (consisting of the 352 zones, as in REN). The street network and the zone structure remains the same as for REN.

Trip generation is carried out using cross-classification (NCHRP 365, 1998) to obtain the productions and Quick Response Tables (NCHRP 187, 1978) were used to get the attractions. Trip balancing was done by holding the productions constant. For the trip distribution procedure, the inverse power function (see Table 5.5) and its parameters were used to define the impedance function. A gravity evaluation was used to obtain the O-D matrix for all trips. Mode choice analysis was carried out using a multinomial logit (MNL) model. The model parameters and coefficients used were as in Table 5.17. Time-of-Day procedures with peak hourly factors were applied to morning (8-9 AM) and evening peak (5-6 PM) hours, and a vehicle occupancy rate of 1.5 was applied to convert the person trips to vehicle trips. The resulting auto trips (the result of applying a mode choice model) were loaded onto the network to run a traffic assignment procedure, using the user equilibrium (UE) method. Table 6.2 gives the system-wide outputs for HBW, HBNW and NHB trips for AM and PM peak hours.

Table 6.2 System-wide Outputs for AM and PM Peak Hours for EUCLID Regional Model

	AM peak (8-9)	PM peak (5-6)
HBW trips		
Total V-time-T (mins)	14215	19976
Total V-dist-T (miles)	5602	7552
HBNW trips		
Total V-time-T (mins)	9318	25107
Total V-dist-T (miles)	3848	9116
NHB trips		
Total V-time-T (mins)	4135	6441
Total V-dist-T (miles)	1733	2694

6.3.2 Subarea Analysis of EUCLID

A subarea analysis with the 352 zones of the EUCLID neighborhood as the subarea was carried out for AM (8-9) and PM (5-6) peak hours. Table 6.3 gives the system-wide outputs in terms of Vehicle-distance-Traveled (V-dist-T, in miles) and Vehicle-time-Traveled (V-time-T, in mins), for the EUCLID subarea. Table 6.4 gives the corresponding outputs for the EUCLID subnetwork only.

Table 6.3 System-wide Outputs for AM and PM Peak Hours for EUCLID Subarea

	AM peak (8-9)	PM peak (5-6)
HBW trips		
Total V-time-T (mins)	14225	20002
Total V-dist-T (miles)	5607	7562
HBNW trips		
Total V-time-T (mins)	9468	25298
Total V-dist-T (miles)	3900	9180
NHB trips		
Total V-time-T (mins)	4215	6540
Total V-dist-T (miles)	1761	2729

Comparing Tables 6.2 and 6.3, it can be observed that the values for the V-time-T and V-dist-T are within one percent of each other. This is because Table 6.3 still gives the system-wide statistics for the entire UTOWN study area, as in Table 6.2. The only difference is that, in Table 6.3, the subarea is defined within the UTOWN study area. However the output still relates to the study area-wide results with the EUCLID subarea defined specifically.

Table 6.4 Outputs for AM and PM Peak Hours for EUCLID Subnetwork

	AM peak (8-9)	PM peak (5-6)
HBW trips		
Total V-time-T (mins)	1300	1749
Total V-dist-T (miles)	433	582
HBNW trips		
Total V-time-T (mins)	698	1780
Total V-dist-T (miles)	232	593
NHB trips		
Total V-time-T (mins)	234	377
Total V-dist-T (miles)	78	125

Table 6.4 gives the outputs for Vehicle-minutes-Traveled and Vehicle-miles-traveled considering the subnetwork only. Traffic assignment in the subarea analysis considers only the subarea consisting of the 352 zones in the EUCLID. The external stations and the cross links (see Chapter 5) are generated by the software. Thus the outputs relate specifically to those trips that are loaded onto the subnetwork.

6.3.3 Estimation of Trip Lengths

Trip lengths by trip purpose for the UTOWN study area with EUCLID are estimated as a post-assignment procedure. The loaded travel times obtained from traffic assignment are used to generate the trip length distribution (TLD). As in the case of the

UTOWN study area with REN, most of the links were not congested (v/c < 1.0). A TLD using the free flow travel times would have yielded much the same results, so they are not tabulated here. TLDs for trips having at least one end within the EUCLID neighborhood are also generated to capture the trip making patterns for trips in and out of EUCLID only.

Table 6.5 gives the average, minimum and maximum trip lengths by travel time (in minutes), and also their standard deviation, for the entire UTOWN study area. Table 6.6 gives the trip lengths (in minutes) for all those trips that either originate or terminate within the EUCLID subarea.

Table 6.5 Trip Lengths (with Loaded Travel Times) for the UTOWN Study Area with EUCLID

	Trip Length (mins) for EUCLID + 5 adjacent zones			
Trip Type	Avg.	Min.	Max.	S.D.
HBW	12.677	2.352	22.832	6.311
HBNW	8.573	0.212	22.832	5.812
NHB	10.567	0.212	22.832	6.672

Table 6.6 Trip Lengths (with Loaded Travel Times) for Trips In and Out of EUCLID

	Trip Length (mins) for trips in and out of EUCLID			
Trip Type	Avg.	Min.	Max.	S.D.
HBW	7.455	2.352	19.791	2.553
HBNW	3.047	0.212	19.791	3.530
NHB	3.862	0.212	19.791	3.874

By comparing Tables 6.5 and 6.6, it can be observed that trip lengths are substantially longer when the entire UTOWN study area (comprising of EUCLID + adjacent 5 zones) are considered, than when only trips into and out of EUCLID are considered. The minimum trip length increases from 0.212 to 2.352 minutes for HBW trips in both Tables 6.5 and 6.6. This is because EUCLID is purely residential, and all work trips would have to go outside the EUCLID subarea, making trip lengths considerably longer. However, there might be trips for HBNW and NHB purposes within the EUCLID, hence the minimum trip length for these purposes will still be as low as 0.212 minutes.

The TLDs in terms of loaded travel times (in minutes) by trip purpose has been plotted in Figures 6.3 and 6.4. Fig. 6.3 gives the TLD plot for all trips in the UTOWN study area. Fig. 6.4 gives the TLD plot for only those trips that have at least one end inside the EUCLID.

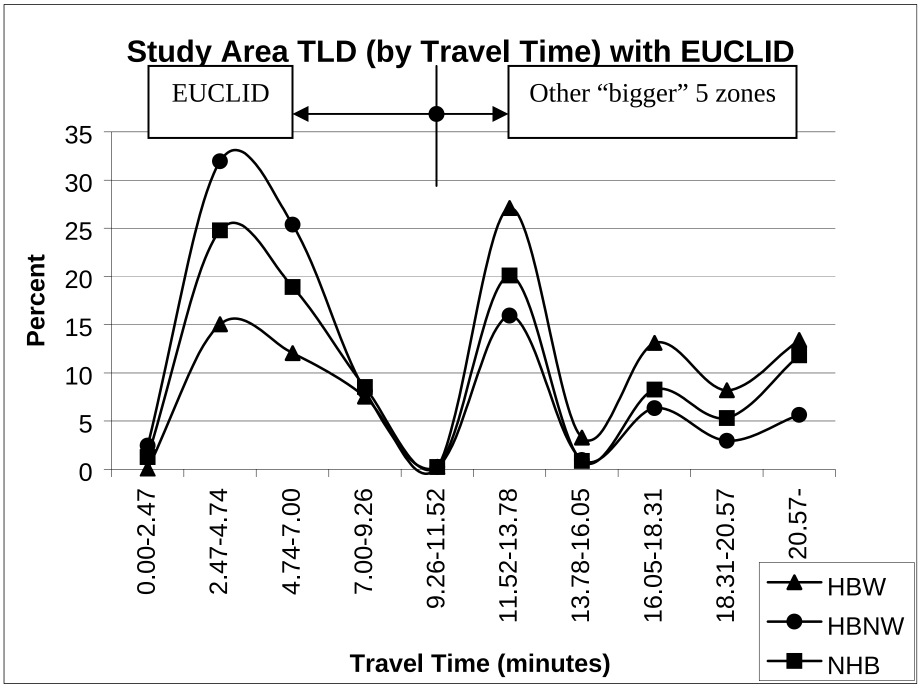


Fig. 6.3 UTOWN Study Area TLD with EUCLID Using Loaded Travel Times

By comparing Fig. 6.3 with Fig. 5.3, it can be observed that this plot is almost identical in shape. There are 2 well-defined crests in the region of 2.47-4.74 mins and 11.52-13.78 mins. The first crest represents the trip making behavior within the EUCLID neighborhood, and the other crest depicts the trips that are made between the other 5 adjacent zones. HBW trips are the longest of the three purposes, as can be normally expected.

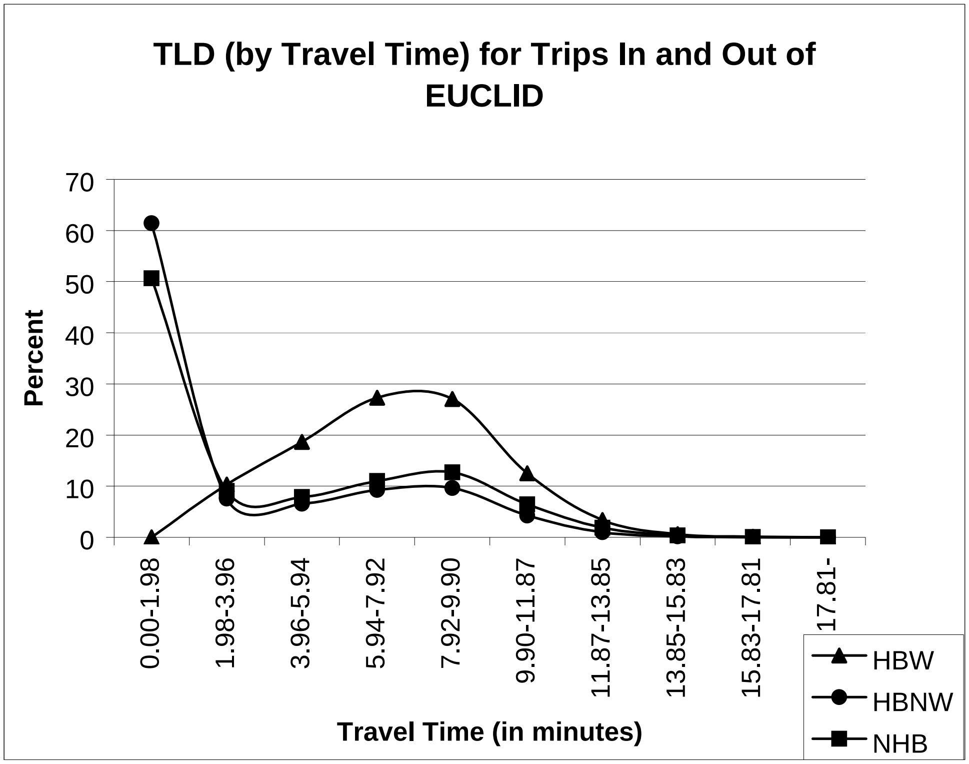


Fig. 6.4 TLD for Trips In and Out of EUCLID Using Loaded Travel Times

Fig. 6.4 shows a TLD plot that has a pattern similar to Fig. 5.4. There are a very large number of short trips (0-4 minutes, approximately) for HBNW and NHB trips. The percentage of trips for the HBW case, in the range of 0-1.98 minutes is 0, indicating that there are no work trips within EUCLID, because it is purely residential.

The following can be inferred from the TLD plot in Fig. 6.4:

- All three lines represent only those trips that either begin or end inside the EUCLID. The plot includes trips that occur between EUCLID and the adjacent 5 bigger zones, but does not include the trips that occur between the bigger zones.
- There are substantial percentages of short trips (0-4 minutes, approximately) for HBNW and NHB trips. However, the percentage of short trips (0-2 minutes, approximately) for HBW trips is 0, indicating that there are no work trips within the EUCLID, because it is purely residential.
- The trip lengths (by travel time) for HBW, HBNW and NHB trips are lower for trips in and out of EUCLID than when compared to all the trips that occur within the study area. (See Fig. 6.3 and Table 6.5.) The reason is implicit, because in this plot, the long trips that occur between the bigger zones are not considered.
- HBW trips are the longest (see Table 6.6) of the three trip purposes, as expected, indicating that people are willing to travel longer distances to work. Also, because no workplaces have been included in the EUCLID neighborhood, the minimum travel time to work (2.352 minutes) is greater than the minimum trip lengths for HBNW and NHB trips. This is because EUCLID has no workplaces and all work trips have to go outside EUCLID. HBNW and HBO trips exhibit similar shapes although they are shorter than HBW trips. NHB trips fall in line with the HBW trips, because they probably relate to trips made to or from work.

In the next chapter, the results of the analysis for the EUCLID neighborhood will be compared with those of the REN. This comparison will enable a better understanding of the transportation related performances of these two neighborhoods under varying land use patterns.

CHAPTER 7. ANALYSIS RESULTS AND CONCLUSIONS

This chapter presents a comparative assessment of the analysis results for the two scenarios: the REN and EUCLID neighborhoods in the UTOWN study area. The transportation-related performance measures evaluated for the two neighborhoods, as obtained from the travel demand modeling procedure, are compared. Conclusions are drawn regarding how well these two neighborhoods perform with respect to their different land use patterns.

7.1 Comparing REN vs. EUCLID

In this section, a comparison of the results of the travel demand forecasting process is presented. The two scenarios that were evaluated were: REN and EUCLID. The REN is a compact development with a mix of residential and non-residential land uses in a 4 sq. mi. area. The EUCLID neighborhood has the same area, street network and zone structure as the REN, but is purely residential. Each of these scenarios was analyzed for system-wide outputs for vehicle miles traveled and total time spent in minutes. Also, the REN and EUCLID neighborhoods were analyzed for the characteristics of their respective subareas, which consist of the 352 smaller zones. The following section presents a comparison of the performance measures for the regional model as well as the subarea analyses.

7.1.1 Measures of Effectiveness (MOEs)

A variety of statistics can be generated for post-assignment evaluation. Common measures of effectiveness (MOEs) for tripmaking on networks are:

1. Vehicle-distance-Traveled (V-d-T in miles)
2. Vehicle-time-Traveled (V-t-T in minutes)
3. Average trip length by trip purpose

For the present analysis, a comparative assessment of the average trip lengths by trip purpose is the most useful. The first two MOEs (V-d-T and V-t-T above) involve network totals. They would not permit an easy comparison between the REN and EUCLID. Although the UTOWN study area population remains the same for the two cases, the type and number of land uses vary within the REN and the EUCLID neighborhoods. This has a bearing on the trips produced and hence on the vehicle times and distances. It is more useful to make a comparison between the average trip lengths for the REN and the EUCLID regional models as well as for the REN and EUCLID subareas, to detect any changes in the trip characteristics.

Table 7.1 gives a comparison of the average trip lengths (in minutes) for REN and EUCLID, considering all 357 zones in the UTOWN study area. The values indicate the vehicle trip lengths, in terms of loaded travel times, obtained from traffic assignment. The maximum and minimum trip lengths and standard deviations can be found in Table 5.36 (UTOWN study area with REN) and Table 6.5 (UTOWN study area with EUCLID).

Table 7.1 Comparison of Average Trip Lengths for the UTOWN Study Area with REN/EUCLID

Average trip length (mins)	REN + 5 zones	EUCLID + 5 zones	% Change w.r.t. EUCLID
HBW	12.403	12.677	- 2.2
HBNW	7.818	8.573	- 8.8
NHB	10.179	10.567	- 3.7

Table 7.1 shows the percent decrease in the trip lengths for the UTOWN study area with REN when compared to UTOWN study area with EUCLID. The decrease is minimal in case of the HBW trips, because most work trips would go outside the REN. The EUCLID has no HBW attractions, because it has no workplaces. On the other hand, REN has very few workplaces. The decrease in trip lengths for the UTOWN study area with REN is greatest in the case of HBNW trips. This is because many frequently-visited non-residential land uses are located within the REN, while the EUCLID neighborhood has few non-residential land uses.

Because most of the trips in UTOWN do not have either end in the REN/EUCLID subarea, the impacts of the subarea neighborhood design are muted in Table 7.1. To focus on the changes in tripmaking by REN/EUCLID residents, a subarea analysis was performed.

Table 7.2 gives a comparison of the trip lengths (in minutes) for trips having at least one end within the REN or EUCLID. For figures indicating the maximum and minimum trip lengths and their standard deviations, refer to Table 5.37 (UTOWN study area with REN) and Table 6.6 (UTOWN study area with EUCLID).

Table 7.2 Comparison of Average Trip Lengths for Trips In and Out of REN/EUCLID

Average trip length (mins)	Trips in and out of REN	Trips in and out of EUCLID	% Change w.r.t. EUCLID
HBW	6.322	7.455	-15.2
HBNW	2.401	3.047	-21.2
NHB	2.273	3.862	-41.1

Table 7.2 shows the percent decrease in the trip lengths for the REN subarea when compared to the EUCLID subarea. The decrease is minimal in the case of HBW trips, because most work trips would go outside the REN. Comparing Tables 7.1 and 7.2, it can be observed that the percentage reductions in the average trip lengths are much greater when only the trips that originate or terminate within the REN or EUCLID are

considered, than when all the trips in the UTOWN study area are considered. This is because the subarea analysis relates to tripmaking only within the REN or EUCLID. That means, it considers all trips that either begin or end in the subarea. These trips may have their destination ends either within or outside the subarea. Alternatively, trips from anywhere in the UTOWN study area can also have their destination end within the subarea. The subarea MOEs include the entire trip made into or from the REN, not just the portion of a trip made within the REN. Hence the results of the subarea analysis are more pronounced.

The following figures show the TLDs in terms of distance (in miles) for HBW, HBNW and NHB trip purposes. Fig. 7.1 gives the TLD plot for the UTOWN study area with REN. Fig. 7.2 gives the TLD plot for the UTOWN study area with EUCLID.

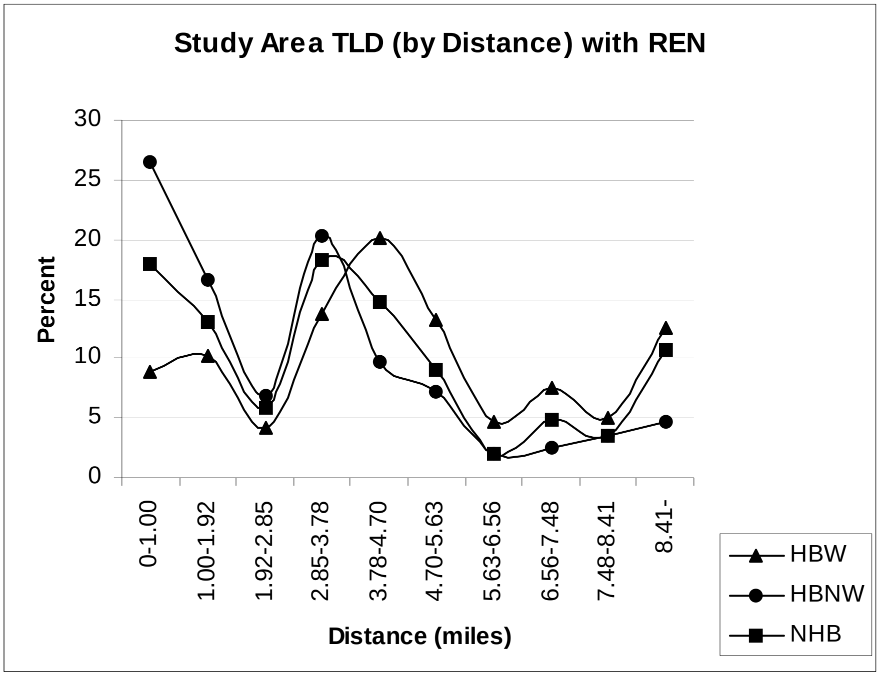


Fig. 7.1 UTOWN Study Area TLD (by Distance) with REN

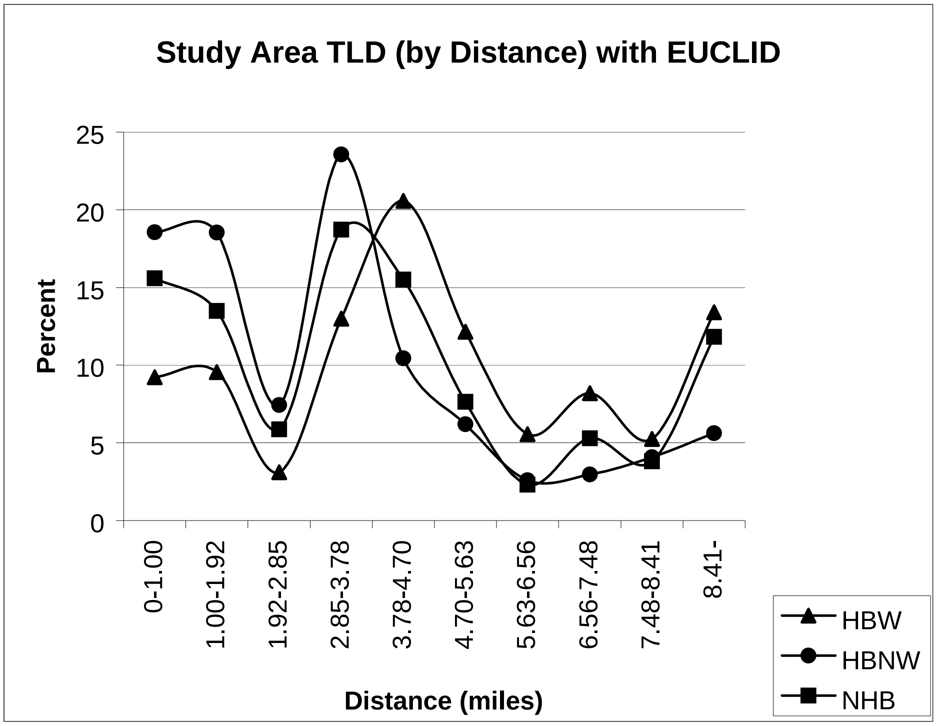


Fig. 7.2 UTOWN Study Area TLD (by Distance) with EUCLID

From Figs. 7.1 and 7.2, it can be observed that more than 25 percent trips are within a mile long for HBNW trips for the REN case, compared to around 18 percent (for HBNW trips) for the EUCLID. The TLDs also show that highest percent of trips for the HBNW trip purpose is found in the range 0-1 mile for the REN (Fig. 7.1) compared to 3-4 miles for EUCLID (Fig. 7.2). The two figures indicate that most of the work trips are generally longer trips than for other purposes in both REN and EUCLID. Table 7.3 gives a comparison between the average trip lengths (in miles) for the UTOWN study area with EUCLID and REN. Trip lengths are substantially shorter for HBNW trips for the UTOWN study area with REN. There are also modest reductions for HBW and NHB trips for the REN case.

Table 7.3 Comparison of Average Trip Lengths by Distance for UTOWN Study Area

Average trip length (miles)	REN + 5 zones	EUCLID + 5 zones	% Change w.r.t. EUCLID
HBW	4.601	4.712	-2.4
HBNW	2.933	3.233	-9.3
NHB	3.790	3.949	-4.0

Fig. 7.3 gives the TLD plot for trips that have at least one end inside the REN. Fig. 7.4 gives the TLD plot for trips having at least one end inside EUCLID.

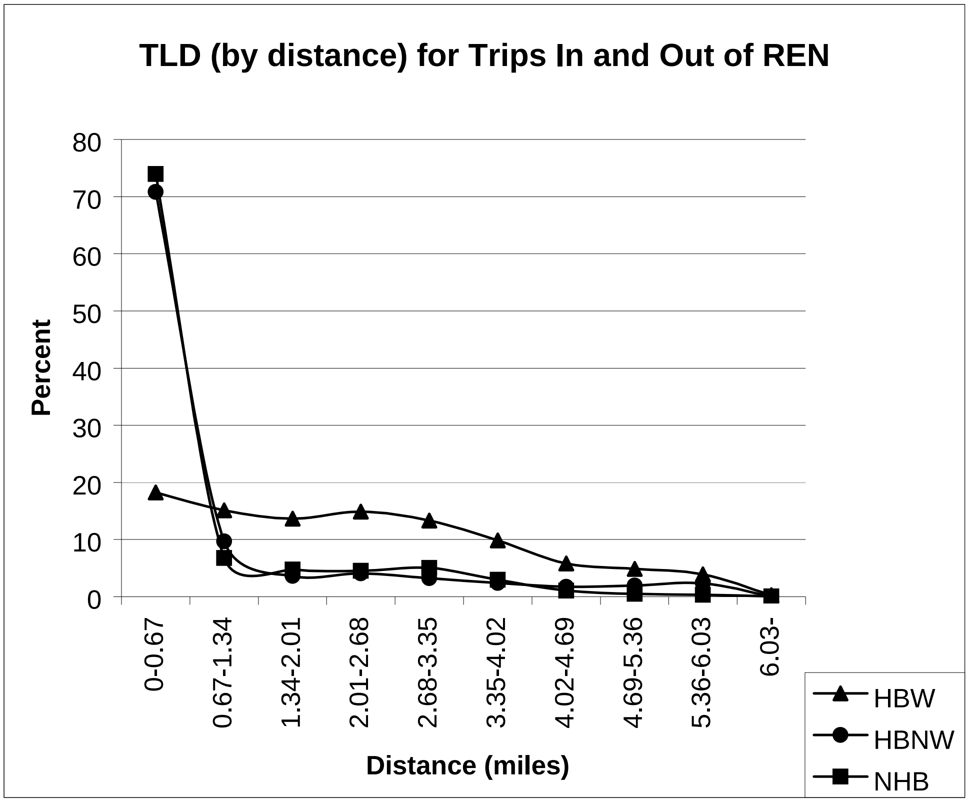


Fig. 7.3 TLD (by Distance) for Trips In and Out of REN

In Fig. 7.3 it can be observed that a very high percentage of trips (more than 70%) for HBNW and NHB purposes are made within two-thirds of a mile. The percent of

HBW trips in the same range is substantially lower. Because the trips in this analysis include only auto trips, it can be inferred that there is potential for a possible mode shift to non-motorized modes (like walking or biking) for these very short trips.

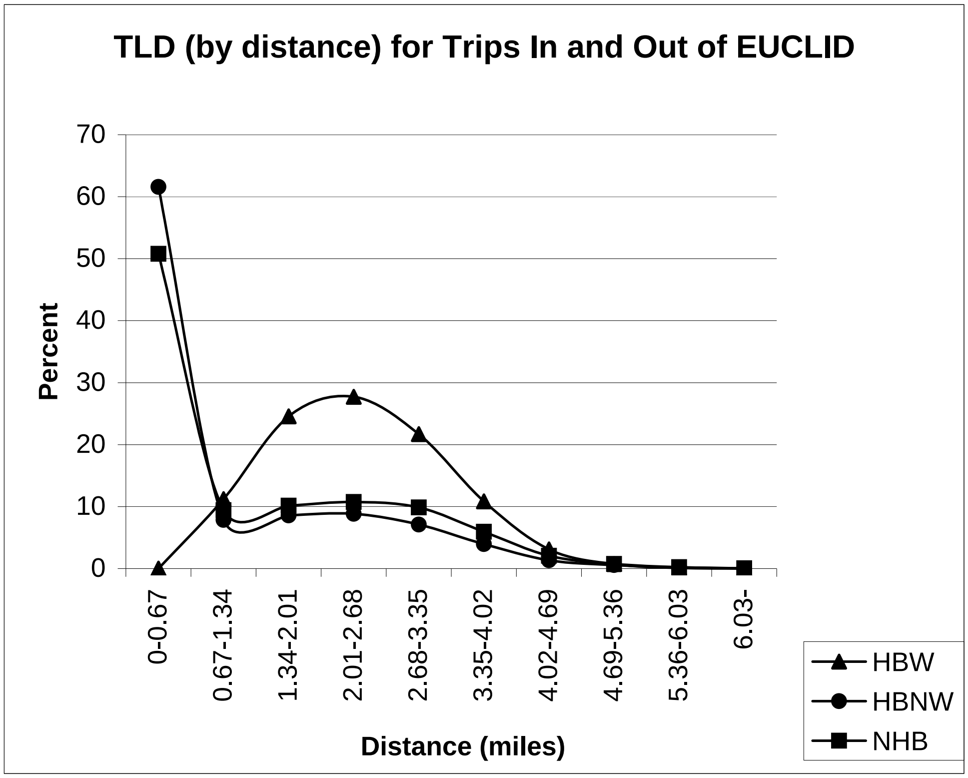


Fig. 7.4 TLD (by distance) for Trips In and Out of EUCLID

In the case of trips in and out of EUCLID (see Fig. 7.4), it is again true that a substantial percentage of HBNW and NHB trips (approximately 50-60%) are less than two-thirds of a mile long. This is because trip making for non-work purposes use the NCHRP 187 equations in which the attractions for HBNW and NHB trips are functions of housing units besides employment. However, there are no trips less than two-thirds of a mile for the HBW trip purpose. This plot also suggests, as in Fig. 7.3, a possible mode shift from auto to bike and walk modes for these shorter trips.

Table 7.4 gives a comparison between the average trip lengths (in miles) for the trips that either originate or terminate within EUCLID and the REN. Trip lengths are substantially shorter for HBNW and NHB trips for the REN subarea. There are also modest reductions for HBW trips in the REN case. When compared to the corresponding changes in trip lengths in Table 7.3, the changes are much more pronounced in this case. The absolute values of the trip lengths for all purposes are also much lower in this case, than those in Table 7.3, where all the trips in the UTOWN study area are considered. This is because these trip lengths (Table 7.4) consider only those trips that go into or out of the REN and EUCLID. It does not consider the potentially longer trips that occur between the remaining five bigger zones of the UTOWN study area.

Table 7.4 Comparison of Average Trip Lengths by Distance
for Trips In and Out of REN/EUCLID

Average trip length (miles)	Trips in and out of REN	Trips in and out of EUCLID	% Change w.r.t. EUCLID
HBW	2.292	2.407	-4.8
HBNW	0.909	1.012	-10.2
NHB	0.763	1.278	-40.3

7.2 Results Summary

The performance measures obtained in the comparative study between the REN and the EUCLID neighborhoods indicate that, in terms of some transportation performance measures, the REN operates more effectively. The results of the exercise that compared the average trip lengths (per trip) given by distance (miles) and time (minutes) point to the fact that less travel is required for all three trip purposes in the REN network. This suggests that allocation of land uses and their type have a definite bearing on the trip lengths and hence on the congestion in a network. Residents of the REN are able to choose from a wide range of easily accessible non-residential land uses that are within the neighborhood, thereby reducing their trip lengths both in terms of distance and time.

In this preliminary study, the characteristic of primary concern is the land use in the REN and EUCLID. Possible differences in the street design characteristics, like lane widths, parking and characteristics that relate to the network have not been incorporated in the travel demand model. It is not within the scope of this preliminary study to compare a large number of networks from which generalized conclusions can be drawn. Rather an attempt has been made to provide a reasonable basis for drawing general conclusions about the impacts of land uses that reflect the REN and EUCLID neighborhood concepts.

The increased efficiency of the REN is the result of having more trip destination choices available to residents at acceptable distances. The results of this analysis, therefore, only indicate whether different land use patterns within a neighborhood lead to different trip lengths. Higher tripmaking due to availability of a greater variety of land uses within the REN results in a sizeable reduction in non-work trip lengths. The work trip lengths are not affected as much, because large-scale offices and other employment centers were not included in the REN.

A reduction in trip lengths was noted when the REN and the EUCLID subareas were compared, rather than when the regional models (the entire UTOWN study area with REN or EUCLID) were compared. This is apparent because the subareas entail a much more detailed and microscopic region.

The results of this study show that there is a large percentage of short trips (above 75% for REN and 50-60% for EUCLID) in the range of 0-0.67 miles. These findings can be utilized to investigate if there is a possibility of converting these fairly short auto trips to non-motorized modes like walk and bike.

7.3 Future Research

The results of the present research are informative regarding mixed land uses and their benefits on a transportation network. This preliminary analysis is limited to an examination of how well two neighborhoods perform with different land use patterns. All other variables modeled were held constant, except for the type and number of the land uses in these two neighborhood settings. Other elements of a neighborhood, like the street network details, have not been varied. The effect of the street network design characteristics such as street patterns and lane width, which might be different for a Euclidean development (characterized by cul-de-sacs and dendritic street patterns), compared to the grid pattern of streets in a REN. Street network differences should be considered in addition to land use differences. In addition to street design characteristics, it may also be useful to have longer blocks for the EUCLID neighborhood than the REN. Street parking (on one side or both sides) that may affect vehicular speeds and lane capacities may also need to be considered. Introducing these additional constraints on to the network would provide a more comprehensive basis for understanding the benefits of mixed use, compact developments.

Another interesting issue is whether it is necessary to have 352 zones to adequately model the subarea being analyzed. The number of zones may be reduced substantially from the current figure of 352, to detect possible changes in the results. This approach will validate whether it is necessary to have such a dense zone structure.

It is risky to use nationwide data and model coefficients in evaluating the transportation-related performances, for such specific scenarios. Wherever possible, data from existing neighborhoods should be used for the modeling procedure. This is especially useful to calibrate the parameters of the impedance function and link performance function that replicate the travel patterns of a study area. In this study, the mode choice modeling was largely based on coefficients borrowed from other regional models and from an existing UTOWN database. This approach has its own limitations regarding transferability of data and its applicability in a different scenario. For a mode choice analysis, data from similar existing developments need to be collected to determine the parameters of the multinomial mode choice model to estimated mode share for auto, walk and bike modes. These results would be extremely useful to detect any possible shift between motorized and non-motorized modes. Introduction of transit systems would allow a more accurate description of travel patterns in different neighborhood scenarios.

It would be meaningful to model a new urbanist and a transit oriented development to see how they compare with the REN. Several more case studies of different forms of developments, with varying limitations as regards land uses and network characteristics, need to be conducted before conclusions of the advantage of the performance of one network over another can be made.

It would also be helpful to analyze a scenario where it would be possible to retrofit an existing development, e.g., consider how a EUCLID type of development could evolve into a REN, in order to capture the possibility of existing land use patterns being modified for a better match with personal travel preferences.

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APPENDIX

Table A1 Spreadsheet Showing Allocation of Mixed Land Uses for REN

Zone #	# of LU	Land Use ID# and Description			
	1	116			
		Day Care Center (3)			
13	0				
17	2	317	245		
		p137	p65		
21	4	280	128	174	82
		p100	Public Libraries (3)	Movie theater (4)	Fitness center (2)
25	4	299	288	192	75
		p119	p108	p12	Sit-down restaurant (6)
29	3	92	52	200	
		Supermarket (6)	Shopping Center (2)	p20	
33	0				
37	2	312	105		
		p132	Drugstore (5)		
41	3		106	178	264
			Drugstore (6)	Mixed use 10	p84
45	0				
49	1	118			
		Sit-down restaurant (7)			
9	0				
7	0				
15	0				
19	1	321			
		p141			
23	0				
27	0				
31	1	149			
		Gas station w/ conv mkt. (12)			
35	2	115	62		
		Elementary school (3)	Copying Center/Office Supply (2)		
39	0				
43	1	223			
		p43			
47	1	326			
		p146			
51	4	95	41	20	23
		Clothing (6)	Community Center (1)	Plumbing Repair and Service (1)	Dry Cleaners (1)
53	2	301	271		
		p121	p91		
55	1		16		
			Drugstore(2)		

Zone #	# of LU	Land Use ID# and Description			
57	0				
59	2		148	134	
			Gas station (w/ conv mkt.)(11)	Mixed use 8	
61	4	135	263	196	311
		Mixed use 9	p83	p16	p131
64	3	33	7	187	
		Drive-in restaurant (1)	Shopping Center (1)	p7	
63	1	154			
		Beauty Salon (4)			
67	3		1	4	274
			Supermarket (1)	Clothing (1)	p94
66	0				
69	1			230	
				p50	
71	3	13	181		229
		Gas station (w/ conv mkt.)(2)	p1		p49
75	3	309	127	161	
		p129	Fitness center (3)	Day Care Center (4)	
74	1		226		
			p46		
73	1	91			
		Supermarket (5)			
78	2	169		3	
		Coffee Shop (4)		Convenience Store (1)	
77	0				
81	2		220	2	
			p40	Supermarket (2)	
80	0				
84	0				
83	0				
86	1	27			
		Church (1)			
90	1	48			
		Convenience Store (2)			
89	2	270	28		
		p90	Sit-down restaurant (1)		
88	1	259			
		p79			
93	2	260			88
		p80			Mixed use 4
92	0				
100	1	61			
		Drugstore (4)			

Zone #	# of LU	Land Use ID# and Description			
99	0				
98	4	68	124	171	90
		Dry Cleaners (3)	Coffee Shop (3)	Pizza Place (4)	Mixed use 6
97	0				
96	1	285			
		p105			
95	2	122		55	
		Fast-food restaurant (6)		Banks (3)	
102	1	15			
		Drugstore (1)			
105	2	239			238
		p59			p58
104	3	182	194	213	
		p2	p14	p33	
108	0				
107	0				
111	1			325	
				p145	
110	3	249	137	98	
		p69	Supermarket (8)	Specialty retail center (3)	
114	0				
113	2	275	102		
		p95	Gas station (w/ conv mkt.)(7)		
117	2	246	278		
		p66	p98		
116	3	248	199	320	
		p68	p19	p140	
122	2	202	211		
		p22	p31		
121	0				
120	3		232	184	73
			p52	p4	Sit-down restaurant (4)
119	1	207			
		p27			
129	2	310	150		
		p130	Drugstore (7)		
128	3	262	266	256	
		p82	p86	p76	
127	1	38			
		Public Libraries (1)			
126	1	139			
		Clothing (7)			
125	0				

Zone #	# of LU	Land Use ID# and Description			
124	4	203	34	70	76
		p23	Coffee Shop (1)	Elementary school (2)	Fast-food restaurant (3)
131	0				
133	0				
135	1		5		
			Clothing (2)		
134	2	327	297		
		p147	p117		
140	3		191	18	290
			p11	Barber Shop (1)	p110
139	3	235	227	272	
		p55	p47	p92	
138	2	283	186		
		p103	p6		
137	2	168	279		
		Drive-in restaurant (4)	p99		
143	2	67	332		
		Commercial Washers and Dryers (4)	p152		
142	1	140			
		Clothing (8)			
146	1	222			
		p42			
145	0				
157	0				
156	2	228		318	
		p48		p138	
155	2	109	47		
		Beauty Salon (3)	Supermarket (4)		
154	1		6		
			Hardware store (1)		
153	0				
152	0				
151	0				
150	1	291			
		p111			
149	1	247			
		p67			
148	0				
159	1	117			
		Church (3)			
161	1	155			
		Plumbing Repair and Service (4)			
171	1	242			

Zone #	# of LU	Land Use ID# and Description			
		p62			
170	2	32			44
		Fast-food restaurant (2)			Mixed use 2
169	1		121		
			Fast-food restaurant (5)		
168	1	31			
		Fast-food restaurant (1)			
167	3		84	111	334
			Movie theater (2)	Commercial Washers and Dryers (5)	p154
166	0				
165	2		219	328	
			p39	p148	
164	1	69			
		Dry Cleaners (4)			
163	1		42		
			Doctor/Clinic (1)		
162	0				
183	0				
182	1			114	
				Dry Cleaners (6)	
181	2		251	141	
			p71	Hardware store (4)	
180	2		198	252	
			p18	p72	
179	3	104	30	215	
		Gas station (w/ conv mkt.)(9)	Sit-down restaurant (3)	p35	
178	1	308			
		p128			
177	1			120	
				Sit-down restaurant (9)	
176	1			136	
				Supermarket (7)	
175	2			153	151
				Barber Shop (4)	Drugstore (8)
174	0				
173	3		72	54	243
			Church (2)	Post Office (2)	p63
185	1		94		
			Clothing (5)		
196	1				179
					Mixed use 11

Zone #	# of LU	Land Use ID# and Description			
195	0				
194	0				
193	1		87		
			Doctor/Clinic (2)		
192	0				
191	1			206	
				p26	
190	2	96	316		
		Hardware store (3)	p136		
189	0				
188	0				
187	0				
208	2	156			205
		Commercial Washers and Dryers (7)			p25
207	0				
206	1	177			
		Doctor/Clinic (4)			
205	2	265	281		
		p85	p101		
204	2	146		193	
		Banks (8)		p13	
203	1				176
					Community Center (4)
202	1		119		
			Sit-down restaurant (8)		
201	1	236			
		p56			
200	0				
199	1		8		
			Specialty retail center (1)		
198	0				
210	0				
220	0				
219	0				
218	0				
217	0				
216	2	78	71		
		Drive-in restaurant (2)	Day Care Center (2)		
215	0				
214	2	304	59		
		p124	Gas station (w/ conv mkt.)(6)		
213	1	65			

Zone #	# of LU	Land Use ID# and Description			
		Plumbing Repair and Service (2)			
212	0				
211	1		204		
			p24		
231	0				
230	0				
229	0				
228	1				49
					Clothing (3)
227	0				
226	1		103		
			Gas station (w/ conv mkt.)(8)		
225	2	276	303		
		p96	p123		
224	3	234	180	93	
		p54	Mixed use 12	Convenience Store (3)	
223	2	100	253		
		Banks (5)	p73		
222	1		29		
			Sit-down restaurant (2)		
233	1				269
					p89
235	1	83			
		Public Libraries (2)			
245	0				
244	2	269			88
		p109			Mixed use 4
243	0				
242	3	296		113	125
		p116		Dry Cleaners (5)	Ice-cream and confectionary (3)
241	2		163	17	
			Sit-down restaurant (10)	Copying Center/Office Supply (1)	
240	1			14	
				Gas station (w/ conv mkt.)(3)	
239	2	142	129		
		Shopping Center (4)	Movie theater (3)		
238	1	225			
		p45			
237	1	231			
		p51			
236	0				

Zone #	# of LU	Land Use ID# and Description			
257	0				
256	1	175			
		Video Rental (4)			
255	1		147		
			Gas station (w/ conv mkt.)(10)		
254	2	57	22		
		Gas station (w/ conv mkt.)(4)	Commercial Washers and Dryers (2)		
253	2		300	99	
			p120	Post Office (3)	
252	2	58	86		
		Gas station (w/ conv mkt.)(5)	Community Center (2)		
251	0				
250	0				
249	0				
248	1		293		
			p113		
247	2	159			85
		Dry Cleaners (8)			Video Rental (2)
259	1	190			
		p10			
269	0				
268	1	108			
		Barber Shop (3)			
267	0				
266	0				
265	0				
264	1	133			
		Mixed use 7			
263	1	89			
		Mixed use (5)			
262	1			37	
				Fitness center (1)	
261	1	170			
		Ice-cream and confectionary (4)			
260	2	9		51	
		Post Office (1)		Hardware store (2)	
281	2	157	197		
		Commercial Washers and Dryers (8)	p17		
280	1		123		
			Drive-in restaurant (3)		
279	1	254			

Zone #	# of LU	Land Use ID# and Description			
		p74			
278	1	292			
		p112			
277	1		80		
			Ice-cream and confectionary (2)		
276	1	258			
		p78			
275	0				
274	0				
273	0				
272	0				
271	1			10	
				Banks (1)	
283	1		122		
			Pizza Place (2)		
293	0				
292	1	107			
		Copying Center/Office Supply (3)			
291	0				
290	1	210			
		p30			
289	0				
288	3	77	212	11	
		Fast-food restaurant (4)	p32	Banks (2)	
287	1	284			
		p104			
286	1	241			
		p61			
285	1	214			
		p34			
284	0				
304	1		331		
			p151		
303	0				
302	1		233		
			p53		
301	0				
300	1		195		
			p15		
299	0				
298	1	257			
		p77			
297	2	66	302		

Zone #	# of LU	Land Use ID# and Description			
		Commercial Washers and Dryers (3)	p122		
296	1	240			
		p60			
295	0				
306	1	313			
		p133			
308	2			305	138
				p125	Convenience Store (4)
318	0				
317	1		152		
			Copying Center/Office Supply (4)		
316	1		185		
			p5		
315	2		101	45	
			Banks (6)	Mixed use 3	
314	0				
313	1		216		
			p36		
312	0				
311	1				160
					Elementary school (4)
310	1	282			
		p102			
309	0				
330	2	130		189	
		Video Rental (3)		p9	
329	1				162
					Church (4)
328	0				
327	2		218	244	
			p38	p64	
326	0				
325	1	237			
		p57			
324	1	250			
		p70			
323	0				
322	1	208			
		p28			
321	2	64		307	

Zone #	# of LU	Land Use ID# and Description			
		Beauty Salon (2)		p127	
320	0				
334	0				
345	1	144			
		Post Office (4)			
344	0				
343	0				
342	1	273			
		p93			
341	1				298
					p118
340	1	56			
		Banks (4)			
339	1	261			
		p81			
338	0				
337	2	323	24		
		p143	Dry Cleaners (2)		
336	2	188	46		
		p8	Supermarket (3)		
357	0				
356	0				
355	1	277			
		p97			
354	0				
353	0				
352	0				
351	1	329			
		p149			
350	0				
349	0				
348	2			306	166
				p126	Fast-food restaurant (7)
347	0				
361	2		217	201	
			p37	p21	
363	1	145			
		Banks (7)			
373	0				
372	0				
371	2		221	172	
			p41	Fitness center (4)	
370	0				

Zone #	# of LU	Land Use ID# and Description			
369	1			322	
				p142	
368	1	287			
		p107			
367	0				
366	1	295			
		p115			
365	1		286		
			p106		
385	1	112			
		Commercial Washers and Dryers(6)			
384	3	21	165	63	
		Commercial Washers and Dryers (1)	Sit-down restaurant (12)	Barber Shop (2)	
383	1				74
					Sit-down restaurant (5)
382	0				
381	1	40			
		Video Rental (1)			
380	0				
379	0				
378	1			268	
				p88	
377	0				
376	0				
375	1	294			
		p114			
387	0				
397	1		183		
			p3		
396	0				
395	1	132			
		Doctor/Clinic (3)			
394	2		39		110
			Movie theater (1)		Plumbing Repair and Service (3)
393	0				
392	1		173		
			Public Libraries (4)		
391	0				
390	2	79	53		
		Coffee Shop (2)	Specialty retail center (2)		

Zone #	# of LU	Land Use ID# and Description			
389	0				
388	0				
409	1	324			
		p144			
408	0				
407	1	330			
		p150			
406	0				
405	0				
404	0				
403	2	224	12		
		p44	Gas station (w/ conv mkt.)(1)		
402	1	319			
		p139			
401	0				
400	0				
399	1	126			
		Pizza Place (3)			
411	0				
421	0				
420	0				
419	1		314		
			p134		
418	0				
417	1	167			
		Fast-food restaurant (8)			
416	1	255			
		p75			
415	0				
414	1				36
					Pizza Place (1)
413	0				
412	2			19	25
				Beauty Salon (1)	Elementary school (1)
433	0				
432	0				
431	0				
443	0				
429	1	143			
		Specialty retail center (4)			
428	0				

Zone #	# of LU	Land Use ID# and Description			
426	1	333			
		p153			
425	0				
424	1	60			
		Drugstore (3)			
423	2	97	164		
		Shopping Center (3)	Sit-down restaurant (11)		
437	1			35	
				Ice-cream and confectionary (1)	
439	0				
445	1		267		
			p87		
444	0				
447	0				
449	1		158		
			Dry Cleaners (7)		
454	0				
453	0				
452	1	315			
		p135			
451	2			131	43
				Community Center (3)	Mixed use 1
456	2	50	26		
		Clothing (4)	Day Care Center (1)		
Total	**334**				