CHAPTER 3

LITERATURE REVIEW

3.1 GENERAL

The literature review is categorized into three sections. The first section highlights the land use transport interactions and the second deals with the transport impact on land use whereas the third section discuss the studies conducted to analyze the travel characteristics and land use changes in major cities.

3.2 LAND USE TRANSPORT INTERACTION

The urban land use and transport are closely interlinked. The development of CBD and urban area, the land use development and transport take place simultaneously. The densification of land use development and the pressure on the basic infrastructure in the city center of urban areas have resulted in movement of the people into the outer urban peripheral areas in the form of settlements or inhabitants. The relationship between land use and transport in these areas is not simultaneous, but the land use may be developed earlier and then there arises the necessity of providing a good transport facility and vice-versa, i.e., owing to the development of a rail or bus corridor, the surrounding land may attract settlement of people due to the accessibility criteria.
Various studies and theories to emphasize the land use transport interaction have been done. Some studies have explained the two-way interaction of land use and transport in three basic theories, i.e., technical theories (urban mobility), economic theory (cities as markets) and social theories (society and urban space).

Hansen (1959) demonstrated for Washington DC that locations with good accessibility had a higher chance of being developed and at higher density than remote locations. The pattern of land use development along the rail corridors especially around transit stations is dominated by the transport related activities of the people in the settlements.

Successful policies to achieve sustainable urban transport are policies that reduce car travel and make the remaining travel more sustainable. Based on the results of both theoretical considerations and empirical studies, the following policy conclusions are made. Land use and transport policies are successful, only if they make car travel less attractive, Residential and employment density as well as large agglomeration size and good public transport accessibility of a location should be positively correlated with the modal share of public transport. Neighborhood design and a mixture of work places and residences with shorter trips are likely to have a positive impact on the share of cycling and walking.

Higher accessibility increases the attractiveness of a location for all types of land uses and should, therefore, influence the direction of urban development and urban density. Higher residential density and mixed land use is positively correlated with public transport. However, efficient public transport requires a minimum ridership. Locations with better accessibility are developed more rapidly and with higher density than remote areas. Transport policies to improve the attractiveness of public transport have in general not
led to a major reduction of car travel. They have attracted only little
development at public transport stations, but contributed to further
suburbanisation and population.

Some interesting policy innovations have originated in North
America. TOD combines light rail transit with bus feeder networks and the
concentration of jobs, services and residences at transit stops. Smart growth
comprises urban growth boundaries, and New Urbanism: the new movement,
often promotes regional co-operation, polycentric articulated settlements,
rural-urban linkages, infill development, new towns and villages, e.g.,
Portland, Oregon. It grows in more compact form than other cities and urban
development is slow process, the first signs of success. Public transport use
has increased by sixty percent. Traffic congestion occurs less frequently than
in other cities. STELLA models, were applied in North American and
European cities, to address issues of sustainable urban transport (Wegener,
accessed on 2003).

A method of refinement was made in “Understanding the Link
between Urban Form and Travel Behavior” (Handy 1995) by using the
concept of “accessibility”. The author proposed that land use structure could
be thought of as a means of defining transit accessibility at the regional level.
Density, land use mix and design can be thought of as attributes of local
accessibility for transit.

Density increases accessibility by shortening average trip lengths for
all travel modes. Land use mix increases accessibility by increasing the
number of nearby destinations available for a given trip purpose or activity.
Design increases accessibility by enhancing the directness, safety or
attractiveness of travel. Land use structure increases attractiveness and the
feasibility of transit services if there are a relatively small number of large
compact, mixed-use employment centres. Figure 3.1 shows the symbiotic and ongoing relationship between transit usage and land use form.

\[\text{Figure 3.1 Relationship between Transit Use and Land Use Form}\]

The main findings of Land Use Form, residential density Influences Transit Use (TCRP Report 16, 1996) are the following:

- Residential densities have significant influence on rail transit station boardings.
- Residential densities have more influence on light rail ridership and costs.
- The availability of feeder bus service and park-and-ride lots, also influence ridership.
- Residents in higher-density residential areas are more likely to walk to transit.
- Use of feeder bus service depends mainly on the level of service and parking available, not on the built environment
• Catchment areas are larger in more suburban areas and where transit station parking is ample
• The types and mix of land uses influence the demand for transit as well as the use of non-motorized modes.

Arrington and Brinckerhoff (2004) presented an overview of elements of a successful integrated LRT and TOD strategy. Designing development - oriented transit and achieving supportive public policy were examined. They even said that “built it and they will come” is a theory i.e. “Building transit first, in the hope development will follow”. A successful TOD reinforces both the community and the transit system. At an individual station, TOD can increase ridership by 20 percent to 40 percent and up to 5 percent overall at the regional level.

Finally, an integrated LRT and TOD strategy had offered five lessons and ten steps to success in planning for LRT and TOD. A few parameters are plan for a mix of uses, increase density, station area planning, and link TOD to community livability and so on. The study emphasized that TOD is not enough for development to be adjacent to light rail (TAD). The development must be shaped by transit.

Cervero and Duncan (2002) examined rail commuting in the San Francisco Bay Area, focusing on the self-selection. A conceptual three-tiered model of residential location, vehicle ownership and mode choice. The research focuses on location and mode choices solely with respect to intercity rail systems as opposed to bus lines or other forms of mass transit.

Simple statistics suggests that living near rail stops strongly influenced commuting. Among those residing within ½ mile of a station,
19.6 percent got to work by rail transit, among those living beyond the ½ mile radius, the share was 8.6 percent. The nested structure, accounting for the interdependence between residential location and mode choice, suggests a ½ mile radius most strongly associated with ridership.

Newman and Kenworthy (1991) attempted to study 32 major world cities. They showed that there were very clear relationships between transport and urban form. It is possible to suggest that the following aims are considered to be desirable outcomes from improving transport and urban form, namely reducing the level of dependence on the private car and improving the balance between public and private transport, thus reducing the public transport deficit.

The main parameter describing the form of a city is its density, which has significant effects on travel distances and modal split. The Asian cities are even more extreme with densities some ten times those of the United States and Australian cities. Hong Kong is by far the highest density city in the sample and probably in the world. It revealed that higher residential densities mixed with the employment activity were essential if there is to be much less dependence on the automobile. Residential density in the central city does correlate strongly with all the transport patterns, including the amount of walking and bicycling. The linkage to density would appear to be very strong.

There is strong correlation between petrol consumption and provision for the automobile in terms of road supply and parking. Petrol use and urban density by city region in the New York Tri State Metropolitan Area, 1980 found that less urban density in persons per hectare used more petrol and vice versa. In particular, the assumption will be how to shift the
automobile dependent cities of the US and Australia into something more like the transport balance found in European cities and Asian cities.

Each of the transport infrastructure policies outlined would have an influence on urban form and should not be seen as separate. The primary urban form policy theme is Reurbanization, to increase the intensity of urban activity overall so that population densities of around 30 per ha to 40 per ha and job densities of around 20 per ha are obtained. This means an immediate policy of restricting or at least slowing urban development at the urban fringe on concentrating on redevelopment, generally has the added benefit of capital savings due to better use of present urban infrastructure.

3.2.1 Land Use Parameters

Various land use factors or Urban form factors affect travel patterns, including density, land use mixes, and roadway connectivity and design (TDM Encyclopedia, accessed on 2003), encouraging public transit use through land use planning. This is normally done by increasing development densities or the location and mix of land use types. Public transport modes, including rail stations, serve as a catalyst for more accessible land use by creating higher density and mixed uses. The general principle in which land use planning can encourage the use of public transport both bus and rail are to locate trip origins and destinations arranged in nodal patterns near public transport routes and ensure sufficiently intense trip densities to establish an efficient service. Such systems are viable and efficient (Taxonomy, accessed on 2004).

Land Use Structure: Land Use Structure is the way in which land use is organized in spatial terms, focusing on large geographic areas of analysis. It includes such attributes as location of uses and distinctness of
transportation corridors. Land use structure affects transit patronage in two ways, namely the location of employment centers, which affects the probability people will choose transit, and the distinctness of a transit corridor, which is influenced by the distance people are willing to walk, bike or drive within an area to access transit.

**Location of Land Uses:** A number of metropolitan areas, including Boston, Baltimore, Washington, D.C., Dallas, Denver, San Francisco, Portland, and Seattle have conducted simulations using regional travel demand forecasting models to identify the types of urban form that best support transit use. These studies concluded that at least one, if not more of the following land use, attributes supports higher transit patronage:

- Compact land use form,
- Employment and residential uses in corridors served by high capacity transit,
- A greater mix of land uses in transit corridors, and pedestrian and bicycle enhancements.

The guidebook contains information on the following subjects,

- The basic relationships between urban form and public transportation,
- The role of transit in regional planning,
- The role of transit in corridor planning, and
- Station area planning and development.

Public transportation services like rapid transit, commuter rail, light rail, and bus provide extensive mobility and access, given land use patterns
that ensure sufficient ridership to make the service cost-effective. Although transit accounted for less than 2 percent of all trips in urban areas nationwide, it accounted for 5.2 percent of all trips in large urban areas with rail transit service. The following section discusses transportation-related attributes of urban form: land use density or compactness, CBD size, land use mix, and urban design.

### 3.2.2 Land Use Density or Compactness

Density or compactness of employment and population is the single most important factor associated with transit use. Residential density is measured in terms of dwelling units or persons per acre or square mile. As density increases, automobile ownership decreases, and automobile travel as measured by gasoline consumption or per capita Vehicle Miles of Travel (VMT) also decreases. Similarly, transit use increases with density. Residential densities influence commuter mode choices, transit trips per person, proportion of personal trips by transit, and rapid rail station boardings. Such densities are particularly important in determining light rail ridership. The density of nearby housing strongly influenced commuter mode choices.

In general, land use mix shortens trips and encourages walking and transit use. In neighborhoods, land use mix induces transit use for commuter trips, although it is less influential than density. In fact, density accounts for 10 to 20 times more transit use for commuting trips than land use mix.

Urban design can promote transit-oriented land use served by a mix of automobile and transit services. Overall, effective urban design makes higher densities acceptable to consumers as shown in Table 3.1. It indicates that land use mix and urban design features at work sites increase the number of work-related trips made using transit by 3 to 4 percentage points. For
instance, the first line of the table shows that transit is used on average for 2.9 percent of commuting trips at work sites without a mix of land uses. However, transit use increases to 6.4 percent when land uses are mixed. Thus, land use mix boosts transit ridership to work sites by 120 percent. In Portland, Oregon, researchers found that the combination of land use mix and urban design can reduce automobile trips by 7 percent.

Table 3.1  Transit Shares at Work Sites with Alternative Land Use Characteristics and TDM Programs

<table>
<thead>
<tr>
<th>Land Use Characteristics</th>
<th>Transit with Land Use Characteristics Missing in Percent</th>
<th>Transit with Land Use Characteristics Present in Percent</th>
<th>Absolute Change in Percent</th>
<th>Increase in Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix of land use</td>
<td>2.9</td>
<td>6.4</td>
<td>+3.5</td>
<td>120</td>
</tr>
<tr>
<td>Accessibility to transit</td>
<td>3.4</td>
<td>6.3</td>
<td>+3.3</td>
<td>85</td>
</tr>
<tr>
<td>Availability of convenience services</td>
<td>3.4</td>
<td>7.1</td>
<td>+3.7</td>
<td>108</td>
</tr>
<tr>
<td>Perception of safety</td>
<td>3.6</td>
<td>5.4</td>
<td>+1.8</td>
<td>50</td>
</tr>
<tr>
<td>Aesthetic urban setting</td>
<td>4.2</td>
<td>8.3</td>
<td>+4.1</td>
<td>102</td>
</tr>
</tbody>
</table>


Regions can succeed in integrating transit into their land use planning. Key to this success is adoption of a strong regional vision of the desired settlement pattern. Land use regulations must also be developed to implement this vision. Transit can then be used for focusing growth. Regions that have succeeded in maximizing the influence of transit on urban form have integrated transit service into their land use and development plans.

Density seems to matter the most in influencing transit use. The two most significant variables for determining transit demand are overall housing
density and overall employment per acre. Newman and Kenworthy (1989) recommended densities above 12 to 16 persons per acre for public transit-oriented urban lifestyles. Frank and Pivo (1994) concluded, based upon a study in the Seattle metropolitan area, that beyond the threshold of 50 to 75 employees per acre, and 9 to 13 persons per gross acre, transit work trips showed a significant increase in modal share. Additionally, the threshold for transit shopping trips existed at 75 employees per acre and over 18 persons per gross acre.

The Nationwide Personal Transportation Survey (NPTS) also found that 10.3 percent of those living within 1/4 mile of public transit used it to get to work, while only 3.8 percent of those living within 1/4 and 2 miles used it, and less than 1 percent of those living farther away used it. Bernick (1990) found that 30 to 40 percent of apartment residents living within 1/2 mile of Walnut Creek and Pleasant Hill Bay Area Rapid Transit (BART) stations took BART to work and another 25 percent used other public transit, compared to 13 percent using transit region wide, 1990. Table 3.2 identifies Pushkarev and Zupan’s findings regarding the relationship of residential densities and different types of transit services.

**Table 3.2 Recommended Residential Densities for Transit Service**

<table>
<thead>
<tr>
<th>Service Levels</th>
<th>Residential Density Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Rail: 5 minute peak headways</td>
<td>9 dwelling units / acre (25-100 sq.mile corridor)</td>
</tr>
<tr>
<td>Rapid Rail: 5 minute peak headways</td>
<td>12 dwelling units / acre (100-150 sq.mile corridor)</td>
</tr>
<tr>
<td>Commuter Rail: 20 trains / day</td>
<td>1-2 dwelling units / acre (existing track)</td>
</tr>
</tbody>
</table>

Factors, which influence transit service types, are household income, household size, or the complimentary influences of land use mix, pedestrian amenities and trip purpose. Transit Cooperative Research Program (TCRP) found that residential densities have more influence on light rail ridership and cost than on commuter rail. Several analysts have identified densities necessary to support transit systems. These studies provide an indication of patronage changes with density.

3.2.3 Land Use Mix

Mixed land uses are such as locating appropriate businesses and public services in or adjacent to residential areas. Mixed land uses can yield a number of transportation benefits. More the complementary land uses are mixed, i.e., offices, shops, restaurants, banks, etc. more likely people are to walk and less likely to drive and trips are potentially more spread out throughout the day and week, instead of clumped during the morning and evening peak periods.

In an analysis of suburban activity centres around the United States, (Cervero 1989) found that suburban activity centres with some on-site housing averaged between three to five percent more commute trips by walking, cycling and transit than centres without on-site housing. Additionally, introducing a retail component to the activity centre increased transit use and carpooling by about three percent for every ten percent increase in retail and commercial floor space.
3.2.4 Urban Design

In another study (1000 Friends of Oregon 1995) examined the effects of various land use variables in influencing household Vehicle Mile Travel (VMT) and vehicle trip generation using multiple regression.

Measures that reduce per household by VMT 10 percent (Portland, OR)

- Increase household density from 2 to 10 or 3 to 15 households per acre, or
- Increase the number of jobs accessible by transit in 30 minutes by 100,000 or
- Increase the number of jobs accessible by automobile in 30 minutes by 105,000.

Transit must be competitive with the automobile at the origin, along the line haul, and at the destination, must attract riders, and must be cost-effective. Therefore, competitive transit is service that connects origins and destinations in an effective and cost-efficient manner so that it is a feasible alternative to the automobile. During the research, project personnel learned that the following factors contribute to the ability of transit to be effective, to be efficient, or both. The origin, destination, and line-haul related factors namely residential density, proximity to station, parking availability, feeder bus availability, employment density, proximity to station, Length of line and balance of origins and destinations along the corridor are discussed.
3.2.5 Origin Related Factors

3.2.5.1 Residential density

Pushkarev and Zupan (1977) study recommended minimum densities for various types of transit services, as follows:

- Light rail: 5 min peak headways, 9 dwelling units / residential acre, 25 to 100 square-mi corridor
- Rapid transit: 5 min peak headways, 12 dwelling units / residential acre, 100 to 150 square-mi corridor

Recent research indicates that a 10 percent change in density (persons per acre) is associated with roughly a 6 percent change in light rail ridership at a given station, and a 2.5 percent change in commuter rail ridership at a given station. Other researches find that in far denser settings, such as Chicago, a much higher elasticity exists, namely 1 percent change in residential density is associated with a slightly more than 1 percent increase in both bus and rail riders.

3.2.5.2 Proximity to rail station

Proximity of residents to rail stations affects transit use significantly. On the basis of recent analyses, the rail mode share drops approximately 1 percent for each 100 feet from the station, up to a distance of about 1.5 mile Figure 3.2 summarizes research on the correlation of ridership and proximity to transit stations. All else being equal, rail ridership potential is affected by station proximity. In light of these and other findings, communities seeking to maximize transit use should encourage new development to cluster within 0.25 mile of rail stations. Residents here are 5 to 7 times more likely to use rail than other area residents.
3.2.5.3 Parking and feeder bus availability

Park-and-ride facilities and feeder bus services to transit stations expand transit catchment areas, thereby increasing patronage. For commuter rail, the situation is reversed. Parking produces a 200 percent increase in ridership over stations without parking, while feeder buses contribute only about 50 percent more riders than stations without such services. Providing these access modes, among commuter rail lines ranging in length from a few mile to nearly 80 mile, is beneficial.

3.2.6 Line-Haul Related Factors

3.2.6.1 Length of line

Research indicates that the longer a rail line, the greater the patronage; however, the law of diminishing returns seems to apply. For
example, for light rail, a hypothetical increase in length from 6 to 10 mile (a 67 percent increase) only increases ridership by about 10 percent. For commuter rail, increasing line length from 20 to 30 mile (a 50 percent increase) increases ridership by nearly 90 percent, but from 30 to 40 mile (a 33 percent increase); however, ridership increases only 20 percent. Table 3.3 shows the summary of findings.

Table 3.3   Summary of Findings on Cost Efficiency and Effectiveness for Hypothetical Rail Corridors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Cost Efficiency</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light Rail</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential density gradient</td>
<td>Highly positive</td>
<td>Highly positive</td>
</tr>
<tr>
<td>CBD employment density</td>
<td>Moderately negative (at high CBD job levels may not be possible)</td>
<td>Highly positive</td>
</tr>
<tr>
<td>CBD employment density</td>
<td>Slightly positive</td>
<td>Moderately positive Greater impact for larger CBDs</td>
</tr>
<tr>
<td>Feeder bus</td>
<td>Unclear</td>
<td>Highly positive</td>
</tr>
<tr>
<td>Parking availability</td>
<td>Unclear (site specific)</td>
<td>Moderately positive</td>
</tr>
<tr>
<td>Line length</td>
<td>Slightly positive</td>
<td>Slightly positive</td>
</tr>
<tr>
<td><strong>Commuter Rail</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential density gradient</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
<tr>
<td>CBD employment</td>
<td>Slightly negative</td>
<td>Highly positive</td>
</tr>
<tr>
<td>CBD employment density</td>
<td>Highly positive</td>
<td>Highly positive</td>
</tr>
<tr>
<td>Feeder bus</td>
<td>Unclear</td>
<td>Moderately positive</td>
</tr>
<tr>
<td>Parking availability</td>
<td>Unclear (site specific)</td>
<td>Highly positive</td>
</tr>
<tr>
<td>Line length</td>
<td>Strongly positive, insufficient riders for shorter lengths</td>
<td>Varies, best at 50 mile length</td>
</tr>
</tbody>
</table>

3.2.7 Station Area Planning and Development Principles

3.2.7.1 Employment and residential density close to the stations

Employment and residential density are the most important factors associated with transit ridership at either end of the trip. Ideally, density should be highest closest to the stations, although any housing close to a station will boost ridership. Curitiba and Toronto have encouraged such a development pattern through their station area zoning.

The more buildings within walking distance of a transit station, the more people will use transit. Walking distances tend to be shorter on the home end of the trip 0.5 mile to 0.75 mile in urban areas. In downtowns, commuters will walk further to a commuter rail station than a bus or light rail station, and further from any rail station than a bus stop. In suburban areas, walking catchments areas are 8 to 10 times larger than those of downtown station areas and 3 to 4 times larger than those of urbanized areas. In dense, mixed use urban areas, walking is common. Between 0.5 and 1.5 mile, the proportion of transit riders who walk to or from transit steadily decreases. Rail's mode share drops about 1 percent for every 100 ft. increase in distance between the residence and the rail station for a range of up to 1.5 mile. At the work end destination, the elasticity is about 1.5 percent per 100 ft for a range of up to 1 mile.

For the densest and for most mixed-use settings, most access and egress trips are less than 1.5 mile. As densities decrease, average access and egress distances increase. For the urban district stations, average access and egress distances are approximately 2 mile. For the low-density station areas, the average is approximately 3.2 mile, for suburban center stations, the
average is approximately 4.2 mile. For Down Town and dense urban stations, transit is the usual choice for trips beyond 1 mile. For suburban stations, park-and-ride is the usual choice for trips beyond 1,700 ft. For egress trips beyond 0.5 mile, transit is the preferred choice.

3.2.7.2 Zoning

Floor Space Index (FSI) refers to permissible built-up area to plot area. FSI in sampled city centers in India was only 1.60, compared to indices ranging from 5 to 15 in Asian City centers (Pucher and Koratyswaroopan 2004, Bertaud 2004). The normal range of FSI permitted in major Indian cities is 1.00 to 3.00. In Mumbai, maximum permitted FSI is 4.5 in Nariman point and Cuffe Parade in South (CMDA 2004). In Cities such as Manhattan, HongKong and Singapore, it is permitted to go higher. Even in Dharavi redevelopment project, FSI is 4 for slum houses and 3.1 for municipal Government. The State Government has to grant an FSI of 4 at the metro stations for residential units (TCRP Report16 1996). Hence, the study is limited to use approximately uniform FSI of 4 along the corridor.

Floor Area Ratio (FAR) represents the ratio of the total building area to the plot area. FAR 6 was initially permitted along the structural axes; this was reduced to 5 for office towers and 4 for residential units. Higher densities are permitted for office use because offices generate more transit ridership per square feet than residences.

TCRP concluded that transit can influence urban form, and the design of the urban environment can encourage transit use and reduce dependence on the automobile. Public policies can support more compact urban form, land use mix, and transit-friendly design. Communities seeking to
increase transit use and transit-oriented development may want to adopt policies and practices that reflect the following premises,

- Density or compactness of employment and population is the most important factor associated with transit use. Channeling suburban development into higher density clusters of development will support transit rather than low-density sprawling patterns that require automobile access.
- Within areas served by transit, land use mix and urban design can encourage transit use, balance directional flows along transit lines, and reduce automobile use.

### 3.3 TRANSPORT IMPACT ON LAND USE

Transport impact on land use is broadly defined as any alteration to the pattern of urban, social or economic development caused by transport policy. The central indicators of distributional change can thus be either economic (such as property rents, employment levels or gross domestic product per head), or social or demographic (such as population or households). There is considerable interest in the role of transport policy in shaping urban development, especially in terms of fostering economic growth.

Still (1998) presented the “transport impacts on land use: potential methods and their relevance to strategic planning” in the UK strategic planning system. Edinburgh (UK) was selected as the study area. It is a clear urban area with a clear urban centre and supporting hinterland. The land area of 1723 sq.km with a population of around 7,50,000, needed strategic planning. The author has systematically examined various methods of assessing transport impacts on land use, which are most relevant to strategic
land use and transport planning. The author has established the comparison of results. The paper found that the LRT forecasts by the models had a much larger impact. This is due to the high frequency of the LRT service, but in DELTA/START it can be seen that over time land use shifts occur which reinforce the patronage of LRT, with higher growth along the LRT corridors. LRT is predicted to encourage strong population centralization, which is partly a feature of the accessibility function (as households find the city attractive as a location from which to get to other parts of the region with ease).

The main findings of transit influence land use (TCRP Report 16, 1996) regions with successful transit have the following characteristics:

- Commitment to a regional vision of high-capacity transit connections between regional centres or in development corridors,
- High-quality transit service that attracts riders,
- Regional growth that provides the development to channel to station areas,
- Transit stations in areas where the market supports development.

3.3.1 Influence Area of Rail Transit

Several analyses have identified the influence area of public transit to support transit systems. In a study by (Taylor and Mahamassani 1996), an acceptable distance of only 2.40 km and (Kaplan and Holly 2000), 1.60 km was suggested. In Indian context, the acceptable distance by walk is suggested as 1.7 km (Arasan et al 1994). Rastogi and Rao (2003) suggested the mean
walking distance of around 2.50 km in Mumbai. They also found that commuters preferred walk as a mode for short access distance of up to 1.25 km and for 1.25 – 2.75 km they preferred walk and other personalized and para transit modes. The categorization was also done based on the level of land development. An area with better access and transport network is termed as developed and trip makers in a less developed area walk for distances of more than 1.50 km, whereas this proportion is less in the case of a developed land.

Calgary’s LRT system found that the average walking distance of suburban stations is 649 m with a 75th percentile distance of 840 m (O’Sullivan and Morrall 2004). At CBD stations the average walking distance is 326 m and 75th percentile distance is 419 m. Mass Rapid Transit System found the influence area of 2 km. Hence, from the reviewed literature, it is found that the average minimum access distance is 1.00 km by walk and 1.00 km - 2.50 km by walk and other personalised and paratransit modes. The minimum access distance in origin and destination is less than 500 m with 45 percent and 38 percent of people. It is found that the average minimum access distance is 1 km.

3.4 TRAVEL CHARACTERISTICS OF THE PEOPLE

Paul (1996) collected information pertaining to socio-economic and travel characteristics of the people by conducting household surveys. He analyzed the data with respect to monthly income of the family, vehicle ownership, purpose of trip, selection of modes for travel, categories of daily trips per household, average length per trip. He revealed that the number of workers in the area primarily influenced work trips and other purpose trips were governed by household size and income. Average family size is 3.80,
although it is 4.60 for the entire households in Tirunelveli. The average monthly income is Rs.2491. The average trip rates per household for work, education and other purposes are 1.34, 1.13 and 1.74, respectively.

The overall mode choice for work trips by income is 32 percent by bus, 22 percent by two-wheeler and 20 percent by walk. HIG and Upper middle income groups used personalized modes for travel. The overall mode choice for the entire purpose trips is 19 percent walk, 36 percent bus, 17 percent cycle, 6 percent cars, 3 percent auto and 19 percent two-wheelers. The overall mode choice for education trips by income is 30 percent bus, 27 percent walk, 22 percent cycle and the remaining is shared by personalized modes of car, two-wheelers, auto and IPT.

Finally from the model, it was revealed that the number of workers in the area primarily influenced work trips and other purpose trips were governed by household size and income. The author has observed that the role of Public Transport in catering to work and education trips is very less. Hence, a comprehensive study is required for current problems. In this study, the variables such as workers, students, income and household size are taken for consideration.

In another research work, an attempt has been made to project the significance of short route operations within the CMA by studying operations of selected long routes along the three major corridors of the CMA viz., the National Highway (NH) 4, NH 5 and NH 45 (Manivannan 1996). The land use and activity pattern, demography, passengers loading pattern and socio-economic and trip characteristics of commuters based on the primary and secondary sources were analysed.
The analysis revealed that the overall occupancy ratio in all corridors were more than 179 percent (standard). It was observed that in particular section Tambaram to Mylapore along the corridor NH 45 and the section Moolakadi Vallalar Nagar along the corridor NH 5 are demanding and heavily loaded, reaching an occupancy ratio as high as 266 percent and 262 percent respectively. The loading along the corridors NH 4 was observed to be relatively uniform and low, reaching a maximum occupancy ratio of 215 percent.

Further, the study revealed that the economic status of people along the southern corridor NH 45 is better than that of other two corridors and 32 percent of the commuters in this corridor are willing to pay 1.5 times more than the ordinary fare for operation of parallel cut services in the demanding section.

A study was conducted (Meiyyappan 1993) on Economics of bus and rail operation along a major transport corridor, Madras beach – Tambaram. The study concluded that there was a need for providing feeder services to rail. Commuters would choose the mode, which has less travel time and distance. So, to attract more number of commuters to travel by train, the rail fare, its travel time and travel distance should be less or to a certain extent equal to bus fare.

Agarwal et al. (1988) gives a clear idea of how Indian railways, i.e., passenger and freight traffic were performing and pointed out the deficiency in the systems. They calculated the growth of total suburban passenger traffic (Mumbai, Kolkatta and Chennai) in different years. Its share in passenger traffic increased to 23 percent in 1978 - 79 from 10 percent in 1950 - 51 an increase of 13 percent in 28 years. They analyzed the growth rate of rolling stock (locomotives, wagons and passenger coaches) and over-crowding of
Indian railways. They concluded that there is an urgent need to make improvements in railways. The parameters in this study are considered useful for the present study.

3.5 LAND USE MODEL AND CHANGES

The study of urban land use (Burgess 1925) generally draws from three different descriptive models. These models were developed to generalize about the patterns of urban land use found in early industrial cities of the U.S. Because the shape and form of American cities changed over time, new models of urban land were developed to describe an urban landscape that was becoming increasingly complex and differentiated. Further, because these are general models devised to understand the overall patterns of land use, none of them can accurately describe patterns of urban land use in all cities. In fact, all of these models have been criticized for being more applicable to cities in the U.S. than to cities of other nations. Other criticisms have focused on the fact that models are static. They describe patterns of urban land use in a generic city, but do not describe the process by which land use changes. Despite these criticisms, these models continue to be useful generalizations of the way in which land is devoted to different uses within the city. Concentric Zone Model, Sector Model and Multiple Nuclei Model of urban land uses are examined below:

3.5.1 Concentric Zone Model

The concentric zone model was among early descriptions of urban form. Originated by Earnest Burgess in the 1920s, the concentric zone model shown in Figure 3.3 depicts the use of urban land as a set of concentric rings with each ring devoted to a different land use. The model was based on Burgess’s observations of Chicago during the early years of the 20th century.
Major routes of transportation emanated from the city’s core, making the CBD the most accessible location in the city. Burgess identified five rings of land use that would form around the CBD. These rings were originally defined as central business district, zone of transition, zone of independent workers’ homes, zone of better residences and zone of commuters. An important feature of this model is the positive correlation of socio-economic status of households with distance from the CBD—more affluent households were observed to live at greater distances from the central city.

Figure 3.3 Various Model Pattern of Urban Form

Burgess (1925) described the changing spatial patterns of residential areas as a process of “invasion” and “succession”. As the city grew and developed over time, the CBD would exert pressure on the zone immediately surrounding it (the zone of transition). Outward expansion of the CBD would invade nearby residential neighborhoods causing them to expand outward. The process was thought to continue with each successive
neighborhood moving further from the CBD. He suggested that inner-city housing was largely occupied by immigrants and households with low socio-economic status. As the city grew and the CBD expanded outward, lower status residents moved to adjacent neighborhoods, and more affluent residents moved further from the CBD.

3.5.2 Sector Model

Soon after Burgess generalized about the concentric zone form of the city, Homer Hoyt re-cast the concentric ring model. While recognizing the value of the concentric ring model, Hoyt also observed some consistent patterns in many American cities. He observed, for example, that it was common for low-income households to be found in close proximity to railroad lines, and commercial establishments to be found along business thorough fares. In 1939, Hoyt modified the concentric zone model to account for major transportation routes. Most major cities evolved around the nexus of several important transport facilities such as railroads, sea ports, and trolley lines that emanated from the city's center. Recognizing that these routes (and later metropolitan expressways and interstate highways) represented lines of greater access, Hoyt theorized that cities would tend to grow in wedge-shaped patterns, or sectors, emanating from the CBD and centered on major transportation routes. Higher levels of access translate to higher land values.

Thus, many commercial functions would remain in the CBD, but manufacturing activity would develop in a wedge surrounding transport routes. Residential land use patterns also would grow in wedge-shaped patterns with a sector of lower-income households bordering the manufacturing/warehousing sector (traffic, noise and pollution making these less desirable locations to live) and sectors of middle- and higher-income households located away from industrial sites. In many respects, Hoyt's sector
model is simply a concentric zone model modified to account for the impact of transportation systems on accessibility.

3.5.3 Multiple Nuclei Model

Many cities did not fit the traditional concentric zone or sector model (Harris and Ullman 1945). Cities of greater size were developing substantial suburban areas and some suburbs, having reached significant size, were functioning like smaller business districts. These smaller business districts acted as satellite nodes, or nuclei, of activity around which land use patterns formed. While Harris and Ullman still saw the CBD as the major center of commerce, they suggested that specialized cells of activity would develop according to specific requirements of certain activities, different rent-paying abilities, and the tendency for some kinds of economic activity to cluster together. At the center of their model is the CBD, with light manufacturing and wholesaling located along transport routes. Heavy industry was thought to locate near the outer edge of city, perhaps surrounded by lower-income households, and suburbs of commuters and smaller service centers would occupy the urban-periphery.

Nithin Kumar (2001) conducted a study on Urban Land use Change Detection of Chennai Metro and Suitability analysis using Remote Sensing and GIS integrated with Analytical Hierarchy Process. CMA spread over 1177 sq.km. is bounded by Latitude 13°20’ to 12° 55’N and Longitude 80°05’ to 80° 20’ E. Multi temporal data were used (Topo Sheet, CMA map of 1974, LANDSAT – TM Data of 1986 and IRS 1C LISS III of 1997) to study the Urban Land use Change Detection of Chennai Metro and Suitability analysis. A change detection analysis was carried out on the data set to assess the change in the land utilization due to urban sprawl. The land use data was obtained using maps and statistical data given in Table 3.4 and the land use
change was found out by integrating the above maps in GIS software ArcGIS and given in Table 3.5.

**Table 3.4 Land Use Dynamics for CMA from 1974 to 1997**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Land Use Category</th>
<th>Area (sq.km.)</th>
<th>Percentage of CMA</th>
<th>Area (sq.km.)</th>
<th>Percentage of CMA</th>
<th>Area (sq.km.)</th>
<th>Percentage of CMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1974</td>
<td>1986</td>
<td>1997</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Residential</td>
<td>147.111</td>
<td>12.59</td>
<td>186.266</td>
<td>15.94</td>
<td>303.276</td>
<td>25.96</td>
</tr>
<tr>
<td>2.</td>
<td>Commercial</td>
<td>22.026</td>
<td>1.89</td>
<td>34.511</td>
<td>2.95</td>
<td>68.083</td>
<td>5.83</td>
</tr>
<tr>
<td>3.</td>
<td>Industrial</td>
<td>21.831</td>
<td>1.87</td>
<td>33.465</td>
<td>2.88</td>
<td>47.220</td>
<td>4.04</td>
</tr>
<tr>
<td>4.</td>
<td>Waste land</td>
<td>59.969</td>
<td>5.13</td>
<td>97.278</td>
<td>8.33</td>
<td>81.848</td>
<td>7.01</td>
</tr>
<tr>
<td>5.</td>
<td>Water bodies</td>
<td>103.894</td>
<td>8.89</td>
<td>101.718</td>
<td>8.70</td>
<td>88.988</td>
<td>7.61</td>
</tr>
<tr>
<td>6.</td>
<td>Agriculture</td>
<td>813.393</td>
<td>69.63</td>
<td>714.986</td>
<td>61.20</td>
<td>578.809</td>
<td>49.55</td>
</tr>
</tbody>
</table>

Source: Nithin Kumar (2001)

**Table 3.5 Land Use Change of CMA for Three Different Time Periods**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Land Use Category</th>
<th>Change in Area (sq.km.)</th>
<th>Percentage Variation</th>
<th>Change in Area (sq.km.)</th>
<th>Percentage Variation</th>
<th>Change in Area (sq.km.)</th>
<th>Percentage Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>1974-86</td>
<td>1986-97</td>
<td>1974-97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Residential</td>
<td>+39.115</td>
<td>21.02</td>
<td>117.010</td>
<td>38.58</td>
<td>156.165</td>
<td>51.49</td>
</tr>
<tr>
<td>2.</td>
<td>Commercial</td>
<td>+12.485</td>
<td>36.18</td>
<td>33.572</td>
<td>9.31</td>
<td>46.057</td>
<td>67.65</td>
</tr>
<tr>
<td>3.</td>
<td>Industrial</td>
<td>+11.634</td>
<td>34.77</td>
<td>13.775</td>
<td>29.13</td>
<td>25.389</td>
<td>53.77</td>
</tr>
<tr>
<td>6.</td>
<td>Agriculture</td>
<td>-98.407</td>
<td>12.10</td>
<td>136.177</td>
<td>19.05</td>
<td>234.584</td>
<td>28.84</td>
</tr>
</tbody>
</table>

Source: Nithin Kumar (2001)

The author had found out that the agriculture land use has been greatly reduced due to the development of built-up lands because migration of
people from rural to urban areas. It is noticed that, there was a notable
decrease in area of water bodies i.e. 14.35 percent compared to 1974. The
procedure followed for the preparation of various maps is suitably studied and
adopted for the present study.

Moon (1990) analyzed land-use patterns surrounding 20 suburban
rail-transit stations in the San Francisco Bay Area and Washington, D.C.
transit systems. The study reviewed the general patterns of land-use, determined what types of land use contributed to station-area development and identified similarities among systems to determine their ability to promote land-use change. The author used aerial photographs and field checking for each station to empirically evaluate land-use trends and validate photographs. Field work identified building types and categorized land uses into transportation-related, vacant, residential, or commercial, institutional, and industrial. The Bay Area Rapid Transit (BART) and Washington, D.C. (METRO) systems were selected because they were in place and operable while current enough to examine contemporary impacts. BART began operation in 1973, and METRO began operation in 1976.

Stations were selected outside the major urbanized portions of the
region to more accurately assess changes in suburban-land use. A 224 acre
area around each of the transit stations was analyzed. The maximum share of
that impact will occur within one third mile of the station in any given
direction. Most stations were highly developed. The author found that the
concentration of residential development varied significantly, ranging from
5.0 percent to 62.8 percent on the BART system and 0.0 percent to
62.2 percent on the METRO system. Based on observation, the overwhelming
majority of station area residential development is single-family in the
middle-income range, occurring in relatively large subdivisions.
The primary contributors to station area development are residential and commercial developers in addition to the transportation providers themselves. The author noted that plans for more dense development e.g., office towers and reverse flows of commuters central city to suburbs may alter land-use patterns around these stations. The observation of the study is transportation-related uses dominated land development. Residential development varied significantly, but was dominated by single-family, middle-income residential uses. Commercial uses tended to be focused on individual consumer needs and included shopping malls and retail centers in addition to small and medium-scale commercial buildings.

Hence there is an urgent need to study policy implications. Both the BART and METRO systems have proven to impact land use around suburban stations. The trend toward more intense development away from the regional CBD toward more suburban station areas indicates a wave of influence moving into the hinterland via transit lines. While a land use pattern is not yet apparent, economic development is most certainly occurring. Most stations, with the exception of three relatively new stations on METRO line were 75 to 100 percent developed. The concept is used for the present study to find the land use changes around suburban rail stations.

Radhika (2005) studied the dynamic variable involved in transitional stage from rural to urban and the formation of peri-urban areas, the interdependency of the fringe area settlements with city and land use change taking place. This study analyzed the reasons for development and assessed the impact of development on the fringe area and vice versa. A system dynamic package ‘STELLA’ package was used to develop the model and tested for various policies.
In this study settlements, which have increased in population less than 25 percent of three decades 1981, 1991 and 2001 were selected. The characteristics of the study areas such as income level, occupation, status of residence, accessibility index were determined. The system dynamic model was developed by taking into account various factors like population, birth rate, death rate, in-migration i.e. accessibility index, out-migration etc. It was concluded that accessibility plays an important role in fostering the development of a settlement.

A study (Students project, 1996) on “Development plan for Tiruvallur” analyzed that demography factors, factors and causes of influence, housing structure, traffic and transportation, infrastructural facilities and land use study. This project mainly found the trend of changing land use patterns. The DCR specified the following classifications of land uses as primary residential and mixed residential, commercial, industrial, institutional, agricultural, public and semi-public. It revealed that the existing pattern of land use of Tiruvallur town clearly shows that developments have mainly occurred along railway station, road and around temple and also the existing services are limited.

The residential area required for the future year is estimated based on the population of the future year and the household size. The total extent of the area required is calculated based on the various income groups residing in Tiruvallur town. The residential land is allocated mainly along the northern part of Tiruvallur and the agricultural land is changed to residential use. Hence, the traffic is increased. Problems can be solved due to increase in the capacity of cars, and probably the demand could be met.

Srivastava (1981) has explained that in the very beginning when the railway line is opened, it is not used fully due to the want of traffic. After a
certain period, the traffic increased due to economic development of the region served by the railway. As a result of the introduction of railways, industries develop near railway stations; commercial concerns are established leading to the growth of cities. In order to cope with the increased demand, more trains are run, further using the line capacity, which had not been fully used up to that time. An important point arises here. That is when traffic increases beyond the point of saturation or the maximum carrying capacity of the line it is required to increase this capacity. Then the law of diminishing returns begins to operate. The cost per unit of traffic continues to decrease as traffic increases until the point of most efficient and most effective utilization of resources i.e. up to the optimum point, and after this it begins to rise. This concept of diminishing returns is considered for the present study.

The land utilization pattern (Padmakumar 1997) is not an exact reflection of the immediate action but over a period of time, which has risen with regard to the accessibility. There is a correlation between the pattern of land use, land values and the intensity of utilization. The greatest demand for sites will be within the position of greatest accessibility and complementarily and will lead to the greatest intensity of use in that position. The position of greatest accessibility will be more intensively used but, in accordance with the law of diminishing returns, the increased intensity of use raises costs and forces a resort to less accessible land and the same cycle comes again in the future.

3.6 STANDARDS FOR MASS TRANSPORTATION AND URBAN DEVELOPMENT

Mass transportation systems (Mitra 2002) in urban areas are extremely vital to limit congestion levels and minimize air pollution. It is essential that mass transportation systems are introduced in the major cities to
provide fast, safe, economic and environmental friendly modes for mass movement of passengers. The rapid mass transit systems can reduce the journey times to a considerable extent.

The total population in the metropolitan cities in India in 2001 was 108 million and it is estimated that by 2025 it will reach to the tune of 200 millions. This will generate about 160 million trips daily to be served by transit and para transit modes. To handle this large volume of passenger trips rapid mass transit modes with high speed, high capacity electrically operated systems need to be introduced. In this context, the existing options of the mass transit systems are to be examined and the appropriate mode selected considering the capacity, facility and the cost. The options for mass transit passenger carrying capacity is given in Table 3.6.

**Table 3.6 Options for Mass Transit Passenger Carrying Capacity**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Passenger Carrying Capacity (passenger / hour)</th>
<th>Approximate Capital Cost / km (Rs. in crores) (excluding land cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburban rail</td>
<td>45,000-50,000</td>
<td>20-30</td>
</tr>
<tr>
<td>Metro rail</td>
<td>30,000-35,000</td>
<td>100-120</td>
</tr>
<tr>
<td>Light rail transit:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>10,000-12,000</td>
<td>50</td>
</tr>
<tr>
<td>Elevated</td>
<td>15,000-20,000</td>
<td>100</td>
</tr>
<tr>
<td>Monorail (elevated straddle type)</td>
<td>20,000-25,000</td>
<td>75-85</td>
</tr>
</tbody>
</table>

Source: Mitra (2002)

The study has emphasized the need for National Policy and Strategy for mass transportation. The national policy for mass transportation should include minimizing the use of personalized motor vehicles in the intra-city movements particularly for the major trip purposes, viz work trips and
educational trips, encouraging the use of rapid mass transit vehicles with high passenger carrying capacity and low energy consumption per passenger. Mass transit modes operated by electric traction should be encouraged as far as practicable. The modes like light rail transit and suburban rail should be introduced as per the present requirements and the future perspective.

Integrated multi-modal transit system should be developed for all major cities taking into consideration optimum utilization of the capacities of the existing modes and the inter-modal transfer facilities for passengers. The strategic points are the peripheral areas where the road network is comparatively poor and lack widths and proper road geometrics. Minibus services, auto rickshaws or cycle rickshaws may be provided to serve the passenger demand. Other strategies for increasing patronage of mass transit system and lesser personalized vehicles include controlling and rationalizing the land use adjoining the major corridors of passenger movements. The uses of high density commercial, business, assembly and institutional land should be located along the corridor and adjacent to the stations. Further, the inter-modal integration is very much essential in order to utilize the optimum capacities of the existing modes.

The study concludes that the mass transit systems are one of the most important elements of the urban transportation system. In countries like India where the vehicle ownership rates are low and the funds for major urban infrastructure development are limited. Urgent actions are needed for introduction of mass transit facilities in major urban areas. The working group revealed to promote environment friendly mass transit modes in all major cities in India during the next 25 years.
3.6.1 Norms and Standards of UDPFI

A basic norm for developed area average densities in small towns is 75 to 125 persons per hectare in plain areas and workforce participation is 33 percent of total population. The details are given in Table 3.7.

**Table 3.7 Percentage of Land Use Developed Area**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Land Use Category</th>
<th>Percentage of Developed Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential</td>
<td>45-50</td>
</tr>
<tr>
<td>2</td>
<td>Commercial</td>
<td>2-3</td>
</tr>
<tr>
<td>3</td>
<td>Industrial</td>
<td>8-10</td>
</tr>
<tr>
<td>4</td>
<td>Public and semipublic</td>
<td>6-8</td>
</tr>
<tr>
<td>5</td>
<td>Recreational</td>
<td>12-14</td>
</tr>
<tr>
<td>6</td>
<td>Transport and communication</td>
<td>10-12</td>
</tr>
<tr>
<td>7</td>
<td>Agriculture and water bodies</td>
<td>Balance</td>
</tr>
</tbody>
</table>

Source: UDPFI (1995)

For the above land use, the area requirements for commercial activities in small sized towns work out about 0.2 – 0.25 ha. / 1000 persons on an average, based on the land use which is governed by the functional character of the town. The standards are used to compare the present analysis.

Earlier studies were reviewed and the variables were identified for further studies. The parameters used for the present study are family size, income, employment, vehicle ownership, purpose of trip, mode used for travel, total journey time, and waiting time.
3.7 REVIEW ON TRANSIT-ORIENTED DEVELOPMENT

Transit-Oriented Developments (TOD) are rapidly gaining nationwide popularity. Station area revitalization and transit supportive development have occurred along rail and bus corridors in several cities, including Washington, D.C., San Francisco, Portland, Atlanta, San Diego, and St. Louis. Cities have found that mixed-use development adds quality and stability, resulting in more efficient land use. TOD promises to reduce family transportation expenses, increase the share of walking and transit trips, and generate revenue for developers, cities and transit agencies.

TOD refers to residential and commercial areas designed to maximize access by transit and non-motorized transportation, and with other features to encourage transit ridership. A TOD neighborhood has a center with a rail or bus station, surrounded by relatively high-density development, with progressively lower-density spreading outwards. For example, the neighborhood center may have a transit station and a few multi-storey commercial and residential buildings surrounded by several blocks of townhouses and small-lot single-family residential and larger-lot single-family housing farther away. TOD neighborhoods typically have a diameter of one-quarter to one-half mile (stations spaced half to one mile apart), which represents pedestrian scale distances.

TOD is a particular category of Smart Growth, New Urbanism and Location Efficient Development. It can do more than simply shift some car trips to transit; it also increases accessibility and transportation options through land use clustering and mix, and non-motorized transportation improvements. This reduces the distance required for car trips, allows a greater portion of trips to be made by walking and cycling, and allows some households to reduce their car ownership, which together can result in large
reductions in vehicle travel. This reduces total transportation costs and helps create a more livable community, in addition to supporting TDM objectives.

TOD can provide a catalyst for urban redevelopment, and help create more accessible communities, where people can obtain the things they need with less physical movement. These indirect impact can be significant: average vehicle ownership, vehicle travel, and vehicle expenditures per household, decline with increasing residential densities, proximity to public transit, and the portion of regional travel by rail transit (Holtzclaw 1994).

In return, the County channeled nearly all development along the Metrorail lines. It promoted high-density development adjacent and above rail stations, with relatively high density housing within convenient walking distance. As a result, the County has grown rapidly without major expansion of the highway network or parking facilities, while maintaining low tax rates. Transit ridership has grown steadily. Mixed land use has resulted in relatively balanced ridership over the day, rather than two sharp peaks experienced on some systems. Because of large residential populations nearby, many riders walk or bicycle to stations rather than driving or riding a bus. TOD uses public transit to create more accessible and livable neighborhoods. Each community is unique and has different demands for transit types, including population size, level of ridership, location and destinations. The closer the development to the transit, the more successful is the TOD. Ideally, the transit village should surround the station in a 360° circle.

3.7.1 Components of Transit - Oriented Design

The components of transit-oriented design are the following:

- Walkable design with pedestrian as the highest priority
- Train station as prominent feature of town center
• A regional node containing a mixture of uses in close proximity including office, residential, retail, and civic uses

• High density, high quality development within 10 minute walk circle surrounding train station

• Collector support transit systems including streetcars, and buses, etc.

• Designed to include the easy use of bicycles, and scooters, as daily support transportation systems

• Reduced and managed parking inside 10-minute walk circle around town center or train station

• Concentrated and highest level of density closest to the transit station, gradually decreasing as development moves away from core, creating the sense of town center.

3.7.2 Benefits of Transit - Oriented Design

The benefits of transit-oriented design are the following:

• Higher quality of life.

• Better places to live, work, and play

• Greater mobility with ease of moving around

• Increased transit ridership

• Reduced traffic congestion and driving

• Reduced car accidents and injuries

• Reduced household spending on transportation, resulting in more affordable housing

• Healthier lifestyle with more walking, and less stress
• Greatly reduced dependence on foreign oil
• Greatly reduced pollution and environmental destruction
• Reduced incentive to sprawl, increased incentive for compact development
• Less expensive than building roads and sprawl and
• Enhanced ability to maintain economic competitiveness

3.8 INFERENCES FROM REVIEW OF LITERATURE

It is clear from the review of literature that most of the major studies conducted so far are mostly related to the developed countries. The Transit -Oriented Development (TOD) has widely been used in many foreign countries. As far as the Indian cities are concerned, TOD has not yet been widely implemented despite its enormous benefits in terms of environmental sustainability.

Transport and land use forms are integral part of any planning process. Land use is dynamic in nature since it gets altered, with the slightest change in the influential factors like the transport infrastructures, population etc. Similarly the changes in land use, directly have an adverse impact on the transport services provided. Since, land use, population and transport services are dynamic in nature, these three sectors are identified and integrated. To study the interaction among the various sectors a dynamic systems simulation model development is needed, to address the dynamisms in each sector in a co-ordinated way.

3.8.1 Need for System Dynamic Model

The demand for intensive use of land has brought in drastic changes in the land use dynamics in the recent years. In the absence of well planned
land use dispositions, the land, particularly along the major transport corridor is subjected to high order change for intensified land use developments.

Thus in any pocket of the city, where there is a major transport corridor the land use dynamic is highly pronounced, two important phenomena take place. One is the conversion of land use from lower order use to higher order use. The second is the intensification of the same use to which the land has been designated for. In both the cases, land use undergo changes. Thus, there is a dynamic change in the trip production characteristics. While the land use has undergone a dynamic change, the rail network remains constant and is expected to provide mobility to the increasing traffic and facilitate parking. In this study, to find the interaction among the various sectors, a land use-transport dynamics model is developed to address the complex and dynamic issues in a logical manner.

All these suggest that there is need for a TOD approach appropriate to Indian conditions which would provide not only efficient service quality of transit system but also ensure augmentation of public transportation towards sustainable transport environment. Hence, there is an imperative need to develop a model using systems approach and to test various policy options to encourage TOD and thereby achieving sustainable environment.