DEMAND ESTIMATION WITH SPATIAL SPECIFICATIONS
CHAPTER - 4
DEMAND ESTIMATION WITH SPATIAL SPECIFICATIONS

4.0 GENERAL

It has been shown in the previous chapter that even a simple specification about the spatial concept could improve the travel demand estimation model. Then it becomes relevant to explore how a detailed specification of spatial structure will improve the model. A computer package, named EDETUSS, has been developed for this purpose. EDETUSS group of models can accommodate both the urban structure specification and supply accessibility factors in its fold.

4.1 DESCRIPTION OF THE SPATIAL STRUCTURE FOR THE STUDY AREA

The urban spatial specification specifies the distribution of population and employment, vis-a-vis the transportation network integrating them.

The purpose of this article is to present the details of the existing urban structure of the intended study area.

4.1.1 Location of Trivandrum and its historical importance

Trivandrum city is located on the west coast of India at (latitude of 8°25'N; and longitude 76°55'E). It is the capital of the state of Kerala. In view of its administrative importance, it is connected to other major cities in India through well-connected transportation system. The city offers considerable employment potential in administration and commerce.
4.1.2 Population and employment particulars

As described in chapter 3, the study area is divided into 41 zones. It has 4 gateways. Out of these, 25 zones together form a compact urban area as per the administrative decision. However, the city has grown far beyond this administrative jurisdiction. Table 4.1 presents the population, employment and floor area statistics of the various zones projected for the year 1986. It can be seen from this table that there are many zones, where the population/employment ratio is very high. These zones are mostly located in the outer suburbs. On the other hand, in the urban area, there are some pockets, which are having very high employment concentrations, relative to the population. These zones together form the CBD of Trivandrum city. Fig.4.1 shows the delineated zones of the study area, along with the major travel corridors within the city. Fig.4.2, on the other hand, shows the major activity locations. The population density, a factor which is reflective of the activity system characteristics, is shown in Fig.4.3. It can be seen from the above figures, that major activity concentrations in the form of commercial complexes, transportation termini, major office establishments and educational institutions, are located in five zones only. The zones are No.33, 40, 39, 27 and 30. Thus, they form the hub of the activity system in Trivandrum city. Apart from this, the activities are spread out only along two or three transportation routes, as illustrated in Fig.4.2.
Table 4.1

Population, Employment and Activity floor area of study area

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Population</th>
<th>Employment</th>
<th>Activity floor area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18117</td>
<td>2824</td>
<td>0.81</td>
</tr>
<tr>
<td>2</td>
<td>9058</td>
<td>1412</td>
<td>0.51</td>
</tr>
<tr>
<td>3</td>
<td>11642</td>
<td>1772</td>
<td>1.251</td>
</tr>
<tr>
<td>4</td>
<td>30372</td>
<td>8027</td>
<td>1.538</td>
</tr>
<tr>
<td>5</td>
<td>14444</td>
<td>3157</td>
<td>0.606</td>
</tr>
<tr>
<td>6</td>
<td>22419</td>
<td>2662</td>
<td>0.637</td>
</tr>
<tr>
<td>7</td>
<td>42750</td>
<td>8727</td>
<td>1.165</td>
</tr>
<tr>
<td>8</td>
<td>28246</td>
<td>4711</td>
<td>0.56</td>
</tr>
<tr>
<td>9</td>
<td>18433</td>
<td>2012</td>
<td>0.721</td>
</tr>
<tr>
<td>10</td>
<td>46358</td>
<td>14993</td>
<td>2.436</td>
</tr>
<tr>
<td>11</td>
<td>42223</td>
<td>4429</td>
<td>1.302</td>
</tr>
<tr>
<td>12</td>
<td>33999</td>
<td>5725</td>
<td>0.816</td>
</tr>
<tr>
<td>13</td>
<td>22290</td>
<td>5029</td>
<td>1.304</td>
</tr>
<tr>
<td>14</td>
<td>12113</td>
<td>3712</td>
<td>0.607</td>
</tr>
<tr>
<td>15</td>
<td>12175</td>
<td>6765</td>
<td>0.757</td>
</tr>
<tr>
<td>16</td>
<td>23587</td>
<td>3112</td>
<td>0.451</td>
</tr>
<tr>
<td>17</td>
<td>21540</td>
<td>7870</td>
<td>0.513</td>
</tr>
<tr>
<td>18</td>
<td>11757</td>
<td>2237</td>
<td>0.227</td>
</tr>
<tr>
<td>19</td>
<td>9462</td>
<td>2291</td>
<td>0.391</td>
</tr>
<tr>
<td>20</td>
<td>22063</td>
<td>4839</td>
<td>1.450</td>
</tr>
</tbody>
</table>

Contd...
Table 4.1 contd.

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Population</th>
<th>Employment</th>
<th>Activity floor area</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>34926</td>
<td>9316</td>
<td>4.746</td>
</tr>
<tr>
<td>22</td>
<td>43542</td>
<td>4777</td>
<td>1.000</td>
</tr>
<tr>
<td>23</td>
<td>13705</td>
<td>3988</td>
<td>0.869</td>
</tr>
<tr>
<td>24</td>
<td>25323</td>
<td>6348</td>
<td>0.883</td>
</tr>
<tr>
<td>25</td>
<td>22109</td>
<td>4285</td>
<td>0.594</td>
</tr>
<tr>
<td>26</td>
<td>13299</td>
<td>1693</td>
<td>0.314</td>
</tr>
<tr>
<td>27</td>
<td>12201</td>
<td>3406</td>
<td>0.601</td>
</tr>
<tr>
<td>28</td>
<td>12106</td>
<td>1081</td>
<td>0.572</td>
</tr>
<tr>
<td>29</td>
<td>10162</td>
<td>1892</td>
<td>0.213</td>
</tr>
<tr>
<td>30</td>
<td>18374</td>
<td>6625</td>
<td>0.437</td>
</tr>
<tr>
<td>31</td>
<td>23345</td>
<td>7595</td>
<td>0.689</td>
</tr>
<tr>
<td>32</td>
<td>29673</td>
<td>9713</td>
<td>0.654</td>
</tr>
<tr>
<td>33</td>
<td>36109</td>
<td>11930</td>
<td>0.855</td>
</tr>
<tr>
<td>34</td>
<td>34715</td>
<td>2950</td>
<td>0.398</td>
</tr>
<tr>
<td>35</td>
<td>38959</td>
<td>4599</td>
<td>0.219</td>
</tr>
<tr>
<td>36</td>
<td>10516</td>
<td>1603</td>
<td>0.373</td>
</tr>
<tr>
<td>37</td>
<td>15736</td>
<td>4766</td>
<td>1.443</td>
</tr>
<tr>
<td>38</td>
<td>19549</td>
<td>4707</td>
<td>0.675</td>
</tr>
<tr>
<td>39</td>
<td>6682</td>
<td>8052</td>
<td>0.489</td>
</tr>
<tr>
<td>40</td>
<td>14765</td>
<td>13296</td>
<td>0.336</td>
</tr>
<tr>
<td>41</td>
<td>15313</td>
<td>6333</td>
<td>0.182</td>
</tr>
</tbody>
</table>
FIG. 4.2 MAJOR ACTIVITY LOCATIONS.

1. KERALA UNIVERSITY  2. VSSC  3. ENGG.COLLEGE  
4. S.N.COLLEGE  5. GOVT. PRESS  6. MAR IVANIDS COLLEGE  
7. M.G.COLLEGE  8. TRAVANCORE TITANIUM PRODUCTS  
9. ALL SAINTS COLLEGE  10. RUBBER WORKS  
11. MEDICAL COLLEGE  12. P.S.C.OFFICE  
13. KSEB OFFICE COMPLEX  14. VIKAS BHAVAN (PUBLIC OFFICE)  
15. UNIVERSITY OFFICE  16. UNIV.COLLEGE  
17. COLLECTORATE  18. SECRETARIAT  
19. GOVT. WOMEN'S COLLEGE  20. PUBLIC OFFICE COMPLEX  
21. WATERWORKS  22. KELTRON OFFICE COMPLEX  
23. TOWN PLANNERS OFFICE  24. GOVT. ARTS COLLEGE  
25. DPI OFFICE  26. MOFFUSIL BUS STATION  
27. RAILWAY STATION  28. PADMANABHASAMY TEMPLE  
29. EAST FORT  30. PAREEKSHABHAVAN  
31. S.B.T.OFFICE COMPLEX  32. N.S.S.WOMEN'S COLLEGE  
33. INDUSTRIAL ESTATE  34. AGRICULTURAL COLLEGE  
35. KOVALAM BEACH  36. VIZHINJAM FISHING HARBOUR
FIG 4.3 POPULATION DENSITY OF THE STUDY AREA
Since, Trivandrum is the administrative headquarters, the activity system in the city is centred around zone No.40 (Secretariat). Equally important in the city are zone No.33, which houses the famous Padmanabhaswamy temple, and zone No.39, which contains commercial activity, educational activity and administrative functions. The transport link connecting zones 33, 39 and 40 forms the busiest corridor.

4.1.3 Land use description

Fig. 4.4 shows the land use map of the urban area of Trivandrum, as per the census of India 1981. It can be seen from this map that, while the land is used most extensively for residential activity, approximately 9% of the land is reported to be devoted to administrative and institutional functions. Thus, administration, education, commerce and marginal industry are the major activities in which the people are engaged. In order to understand the intensity of the activity in each zone of the study area, the best measure would be the number of total trips in each, produced and attracted. Fig 4.5 shows the position of the various zones of the study area in relation to the total trip attractions and productions. In this figure, zones have been classified as low, middle and high type for both trip productions and attractions. As can be noticed, Trivandrum does not have exclusively trip attraction oriented zones.
Fig 4.5 DISTRIBUTION OF STUDY ZONES IN RELATION TO TRIP PRODUCTIONS AND TRIP ATTRACTION
4.1.4 Travel characteristics

The description of the urban structure will be incomplete without reference to the Transportation system interlinking the various activities. Since zone No. 40 is the prime mover of the city, the trip attractions to this zone from various parts of the city represented in the form of desire lines along corridors is prepared and presented in Fig. 4.6.

Closer examination of this spider desire pattern indicates that there are frequency breaks approximately at 4, 8, 12 and 16 km from the city centre, the desires decreasing with increasing distance. In view of this, it appears that the activity system in the city can be studied in annular bands of 4 km, starting from zone No. 40. Probable exceptions to this rule may be zones located along the coastal belt.

In order to understand the structure of the city in greater detail, the intensity of interactions between these annular bands would be further helpful. Using the one percent direct O-D matrix from the survey (HOLD), trip length frequency distribution curves for various zones located in each of these rings, aggregated together have been prepared. These are presented in Fig. 4.7.

It can be seen from this figure that in zones belonging to rings 1 and 2 the trip length frequency distribution follows a gamma model or Tanner's model, mostly seen in
Fig 4.6 TRIPS TO ZONE No. 40
Fig. 4.7
RING - WISE TRIP LENGTH
FREQUENCY DISTRIBUTION
almost all the cities. In rings 3 and 4, on the other hand, we can clearly see that the distribution itself is split into two halves. The zones located in these belts mostly contain educational institutions. The trips are attracted from zones located on either side of these rings. In Trivandrum, depending on the needs of the people, settled in quieter suburbs, many of the educational institutions have sprung up far away from the CBD. In view of this fact, there is a definite break in the trip length frequency curves.

The behaviour of the zones located in ring No. 5 appears to be obscure, because of the three peak distribution. However, a closer examination shows that while the first peak is towards the employment centres within the outer suburbs, the last peak is due to the travel from the zones located in the CBD. The middle peak contributes towards the flow from rings 3 and 4 predominantly. But, the traffic attracted to zones in ring 5 forms only a small percentage of the total traffic.

Thus, it appears that the urban structure of Trivandrum could be described by formulating annular rings with 4 km band width. Even the development of the city, as illustrated in the land use map, is suggestive of this pattern.

4.1.5 Classification of zones into activity and non-activity zones

Depending upon the floor area ratio, or employment to population ratio, it is possible to designate zones into activity and non activity zones. Correlation analysis of
population and trip production and, employment and trip attractions is another method to classify the zones into activity and non-activity types. Based on these analyses, 14 zones marked as shown in Fig. 4.8 have been accepted as activity zones. These 14 zones appear in the middle and high ranges of trip productions and attractions in Fig. 4.5.

**4.1.6 Operational ranges for various categories of zones**

Operational range of a zone is defined as the distance from which the trips are attracted to it. This is specified in kilometers. This can be worked out based on cumulative frequency curves of the trip distribution. 90-95 percent cut off limit can be accepted as the higher limit of this operational range. Similarly, 5-10 percent cut off can be used for specifying the lower cut off points. Using these limits, operational ranges of both activity and nonactivity zones in all the rings have been worked out and presented in Table 4.2.

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Category I (Activity zones)</th>
<th>Category II (Nonactivity zones)</th>
<th>Dist. from zone 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 16 km</td>
<td>2 - 14 km</td>
<td>4 km</td>
</tr>
<tr>
<td>2</td>
<td>0 - 14</td>
<td>2 - 14</td>
<td>4.1 to 8</td>
</tr>
<tr>
<td>3</td>
<td>0 - 14</td>
<td>0 - 14</td>
<td>8.1 to 12</td>
</tr>
<tr>
<td>4</td>
<td>2 - 16</td>
<td>2 - 16</td>
<td>12.1 to 16</td>
</tr>
<tr>
<td>5</td>
<td>0 - 16</td>
<td>0 - 16</td>
<td>16.1 to 20</td>
</tr>
</tbody>
</table>
4.2 DEVELOPMENT OF EDETUSS PROGRAM

A computer program called EDETUSS, which stands for Estimation of Demand Through Urban Structure Specifications, has been developed in this work. The flow chart of this program is presented in fig. 4.9. This model simulates the flows on the network through Entropy Maximisation, and estimates the travel demand in two stages. While the first stage gives parameters to generate a seed matrix through gravity formulation approach, the second stage, using the calibrated values of link volume models, generates travel demand through Entropy Maximisation.

There are five subroutines in the first stage. While the first one is to read the data, the second traces the shortest path from all zones to all other zones. The third subroutine called STRUCTURE introduces the urban structure specifications into the model. The fourth one calculates the trip probability factors; and the fifth subroutine selects the best seed matrix by statistical methods.

In the second stage, EDETUSS generates the seed matrix and adjusts it with known extra information, like trip length frequency distribution for each spatial band, total trip ends etc.

Then the O-D matrix is updated with the known link volumes. The trip end frequency adjustment, however, is kept optional, depending on the availability of the data.
DELINEATE STUDY AREA

DEMOGRAPHIC PARTICULARS

LAND USE CHARACTERISTICS

IDENTIFY ACTIVITY, RESIDENTIAL CENTRES etc.

TRAFFIC SURVEY IN SELECTED ZONES

SELECTED TRAVEL CHARACTERISTICS

INTEGRATE URBAN SPATIAL STRUCTURE

ASSIGNMENT NETWORK

CALCULATE TRIP PROBABILITY FACTORS FOR EACH LINK

MULTIPLE REGRESSION ANALYSIS, SELECTION OF VARIABLES

STATISTICAL CHECKS, SELECT THE BEST MODEL

VALIDATION SATISFIED

NO

REVISE PROXIES

YES

SELECTED MODEL - REGRESSION CONSTANTS

TRIP OPPORTUNITY PAIRS; DETERRENCE FUNCTION

LIST OF INTERCHANGES USED BY COUNTED LINKS

SUPPLY ACCESSIBILITY

GENERATE SEED D-D MATRIX

AND LOAD ON THE NETWORK

URBAN STRUCTURE SPECIFICATIONS

ADJUST FOR TRIP ENDS

ADJUST FOR RINGWISE TRIP LENGTH

FREQUENCY DISTRIBUTION

UPDATE D-D MATRIX BY MULTIPROPORTIONAL

ALGORITHM WITH ESTIMATED AND

OBSERVED VOLUMES ON COUNTED LINKS

OUTPUT D-D MATRIX

ESTIMATE VOLUMES ON ALL LINKS

OBTAIN RMS.X FOR LINK VOLUMES,

TRIP LENGTH FREQUENCY, DENSITY OF

POINTS IN VARIOUS TRIP RANGES

Fig 4.9 EDETUSS PROGRAM FLOW CHART

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4.2.1 Validation by EDETUSS

The last subroutine of EDETUSS validates the model by computing R.M.S. percentages of a set of link volumes and by the overall trip length frequency comparison.

4.2.2 Inputs and outputs of EDETUSS

The inputs to the EDETUSS are:

i) Network description in the form of node link description.

ii) Population and employment/floor area index of zones

iii) List of zones in each category

iv) Operational ranges of zones in km, category wise.

v) Ground counts or link volumes.

The output from the EDETUSS are:

i) O-D matrix

ii) Volumes on all links

iii) R.M.S. percentage of link volumes

iv) Overall trip length frequency

4.3 TRAVEL DEMAND ESTIMATION THROUGH URBAN STRUCTURE SPECIFICATION

Using the developed computer package and the urban structure specification, described in Art. 4.1, the spatial travel demand in Trivandrum during the morning peak hour has been estimated. While Table 4.3 gives the best gravity seed acceptable for link volume modelling, Table 4.4 compares the results of the link volumes simulated by the EDETUSS program
Table 4.3 Description of models - EDETUSS series

EDETUSS I

\[ V_e = 693.7 + 0.03235 \sum P_i E_j d_{ij} -0.9 \sum E_j d_{ij} -0.9 \]

\[ R = 0.765 \quad t = 6.4 \]

EDETUSS 2

\[ t_{ij} = \frac{P_i E_j A_{Cij} 0.3}{\sum E_j A_{Cij} 0.3} \]

where

\[ A_{Cij} = \frac{B_{ij} 0.5 N{S_j} 0.5}{A_{Zj} d_{ij} 2.5} \]

without specification of urban structure

EDETUSS 3

\[ t_{ij} = \frac{P_i E_j A_{Cij} 0.3}{\sum E_j A_{Cij} 0.3} \]

with full specification of urban structure

Note: For EDETUSS 1 and EDETUSS 3, operational ranges are as given in Table 4.2.
Table 4.4 COMPARISON OF LINK VOLUME (GRASE5 AND EDETUSS Series)

<table>
<thead>
<tr>
<th>Link No.</th>
<th>Observed volume $V_o$</th>
<th>Estimated volumes $V_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GRASE 5</td>
</tr>
<tr>
<td>156</td>
<td>546</td>
<td>476 ($+70$)</td>
</tr>
<tr>
<td>161</td>
<td>300</td>
<td>170 ($+130$)</td>
</tr>
<tr>
<td>162</td>
<td>2443</td>
<td>2819 ($-376$)</td>
</tr>
<tr>
<td>187</td>
<td>1259</td>
<td>1381 ($-122$)</td>
</tr>
<tr>
<td>201</td>
<td>1432</td>
<td>854 ($+578$)</td>
</tr>
<tr>
<td>218</td>
<td>3457</td>
<td>3261 ($+196$)</td>
</tr>
<tr>
<td>223</td>
<td>2192</td>
<td>2490 ($-298$)</td>
</tr>
<tr>
<td>243</td>
<td>2689</td>
<td>2267 ($+422$)</td>
</tr>
<tr>
<td>248</td>
<td>954</td>
<td>1200 ($-246$)</td>
</tr>
<tr>
<td>252</td>
<td>1762</td>
<td>1687 ($+75$)</td>
</tr>
</tbody>
</table>

R.M.S. % 17.45 16.03 32.1 15.7

Note: $(V_o - V_e)$ is given in brackets.
with the observed volumes and the best model obtained in pilot study without urban structure specification (GRASE 5). From this table it can be seen that the EDETUSS 1 model is slightly superior to GRASE 5 model with respect to link volume simulation. However, better comparison could be obtained by comparing the trip length frequency distribution of the models and the density of points in various trip ranges. Fig. 4.10 and 4.11 present these distributions. These comparisons indicate that EDETUSS model with full urban structure description is superior to the model without urban structure. The point of investigation further is whether the model could be improved by supply accessibility specifications.

4.4 SUPPLY ACCESSIBILITY

In this study, the transport accessibility is assumed as a function of the service frequency and the extent of service coverage, where, the extent of service coverage is represented by the number of bus stops and the area covered. The data for these are obtained from network inventory and route operation details of the management concern.

The methodology proposed requires conversion of route frequency into the frequency of buses between each pair of zones. Ignoring accessibility between zones via transfers, the accessibility has been calculated taking only the number of direct buses. This simple (though not perfect) assumption makes it possible to build an accessibility matrix using
FIG 4.10 TRIP LENGTH FREQUENCY DISTRIBUTION GRASE 5 & EDETUSS 1
Fig 4.11 COMPARISON OF DENSITY OF POINTS IN VARIOUS TRIP RANGES
GRASE 5 & EDETUSS 1
only the route operation statistics as shown in the flow chart exhibited in Fig 4.12.

A route by zone bus matrix is prepared from the bus time table. Knowing the number of stops in each zone on these routes, an accessibility matrix is worked out as:

\[ AC_{ij} = \frac{B_{ij}^b N_{Sj}^c}{A_{Zj} d_{ij}^c} \]  ... (4.1)

Where

- \( AC_{ij} \) is the accessibility index between i and j
- \( B_{ij} \) - frequency of buses being operated between i and j
- \( A_{Zj} \) - area of zone j
- \( N_{Sj} \) - Number of stops in j
- b and c - exponents
- \( d_{ij} \) - distance between i and j on the minimum path

4.4.1 Generation of seed matrix to reflect accessibility virtue

Seed matrix is generated with trip probability factors, which are themselves a function of accessibility.

\[ t_{ij} = \frac{P_i E_j AC_{ij}}{\sum E_j AC_{ij}} \]  ... (4.2)

where

- \( P_i \) - Population of zone i
- \( E_j \) - floor area index of j
- \( AC_{ij} \) - accessibility index between i and j
READ NO. OF ZONES N, NO. OF ROUTES NB, ROUTE BY ZONE MATRIX ((BZ(I,J), J=1,N) I=1,NB) NO. OF STOPS (NS(I), AREA AZ(I), J=1,N), DISTANCE MATRIX ((D(I,J), J=1,N) I=1,N)

INITIALIZE ((T(I,J)=0, J=1,N), I=1,N)

DO 10 J=1, N-1

J = J + 1

DO 20 L = J, N
DO 30 I = 1, NB

MIN = BZ (I,J)

IS BZ(I,J) < BZ(I,L) ?

T(J,L) = T(J,L) + MIN
T(I,J) = T(I,J)

CONTINUE

CONTINUE 30

CONTINUE 20

CONTINUE 10

INITIALIZE ((AC(I,J) = 0, J= 1,N), I= 1,N)

DO 50 I= 1, N
DO 60 J = 1,N

AC(I,J) = AC(I,J) + T(I,J) NS(U) * D(I,J) ** c

CONTINUE 50

CONTINUE GO

STOP

Fig.4..12 SUBROUTINE ACCESSIBILITY - FLOWCHART
4.4.2 Development of travel demand with accessibility specification

In this series, two models have been developed. While one model is without urban structure specifications, in the other, full specification of urban structure as described in Art. 4.1 is provided. These have been named as EDETUSS 2 and EDETUSS 3 respectively. While the link volumes of these models are compared with the other models in Table 4.1 itself, the trip length frequency and density of points are compared in Figs. 4.13 and 4.14 respectively.

From the comparison of link volumes and the above frequency distributions, it is observed that the model EDETUSS 3 with accessibility and urban structure specification is superior to the other models.

4.5 CONCLUSIONS

In this chapter, a method for incorporating spatial structure and supply accessibility into the travel demand estimation models has been proposed; and a computer program called EDETUSS was developed for the implementation. Experiments conducted with the package have demonstrated that it can be successfully used for the estimation of demand. It is seen that with refined urban structure specification and supply accessibility factors incorporated into the model, better simulation of travel demands is
Figure 4.13 TRIP LENGTH FREQUENCY DISTRIBUTION EDETUSS 2 & EDETUSS 3
Fig 4.14 COMPARISON OF DENSITY OF POINTS IN VARIOUS TRIP RANGES
-EDETUSS 2 & EDETUSS 3
possible. The objective of further investigation is the study of the effect of dynamic urban structure changes on temporal travel demands during different time periods of the day. This is detailed in chapter 5.