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ROAD NETWORK MODELING OF JALAN TANJUNG LUMPUR – PEKAN AND FEDERAL ROAD 3 USING EMME/3

AISHAH BINTI SHAHID-DIN

A final year project submitted in partial fulfillment of the

requirements for the award of

Bachelor Degree of Civil Engineering.

Faculty of Civil Engineering and Earth Resources

Universiti Malaysia Pahang

NOVEMBER 2009

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Specially dedicated to my beloved father, mother, brothers, sisters and all my friends.

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ABSTRACT

Urban transportation planning is the process that leads to decisions on transportation policies and programs. The transportation planning process relies on travel demand forecasting, which involves predicting the impacts that various policies and programs will have on travel in the urban area. The forecasting process also provides detailed information, such as traffic volumes, bus patronage, and turning movements, to be used by engineers and planners in designs. EMME/3 is an urban transportation planning system that helps transportation planners and traffic engineers to model the travel demand. All the data related to urban activities, network data, model definitions and travel demand can be unified as the EMME/3 database. The accuracy of modeling system is how we performed in constructing the computerized network representation. For this study, this road network is modeled by using origin destination (OD) table based on gravity model. The gravity model illustrates the macroscopic relationships between places for example like homes and workplaces or in other words, the gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination. Therefore this is an vital scenario to the authorities in prediction for the future traffic forecast in managing the future development.

ABSTRAK

Perancangan pengangkutan bandar adalah proses petunjuk-petunjuk itu untuk keputusan mengenai pengangkutan dasar-dasar dan program-program. Proses perancangan pengangkutan berharap tentang permintaan perjalanan peramalan, yang melibatkan meramal kesan-kesan itu pelbagai dasar itu dan program-program akan memakai sesuatu perjalanan dalam kawasan bandar. Proses ramalan itu juga menyediakan maklumat terperinci, seperti jumlah trafik, naungan bas, dan pergerakan pusingan, untuk digunapakai jurutera-jurutera dan perancang-perancang suka jurutera-jurutera dalam reka. EMME/3 adalah satu sistem perancangan pengangkutan bandar bantuan iaitu perancang-perancang pengangkutan dan jurutera-jurutera lalu lintas untuk memperagakan permintaan perjalanan. Semua data berkaitan untuk aktiviti-aktiviti bandar, data rangkaian, takrif-takrif model dan permintaan perjalanan boleh disatupadukan sebagai pangkalan data EMME/3. Ketepatan memperagakan sistem adalah bagaimana kami mempersembahkan dalam membina rangkaian berkomputer perwakilan. Untuk kajian ini, rangkaian jalan dimodelkan dengan menggunakan destinasi asal (OD) dengan menggunakan model graviti. Model graviti ini menjelaskan makroskopik hubungan-hubungan antara meletakkan sebagai contoh rumah-rumah serupa dan tempat kerja atau dengan kata lain, model graviti itu menganggap yang perjalanan itu dikeluarkan di satu punca dan tertarik ke satu destinasi adalah berkadar langsung untuk perjalanan jumlah pengeluaran di asal dan tarikan-tarikan jumlah di destinasi. Oleh itu, ini merupakan sebuah senario amat penting untuk pihak berkuasa dalam ramalan trafik untuk masa depan serta menguruskan pembangunan untuk masa depan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In this development era, transportation industries plays a vital role. Metropolitan areas have come under intense pressure to respond to federal mandates to link planning of land use, transportation and environmental quality. Hence, traffic prediction is increasingly becoming important to ensure a smooth traffic movement for the future route planning.

It is thus becoming increasingly relevant to use a data model where transportation network can be encoded, stored, modified, analyzed and displayed. Obviously, Geographical Information System (GIS) is the among best tools to be stored and use network data model for this study. GIS of Pahang State is used in building this network.

Road network can evaluate scenarios and help managers in operation and planning. Simulations is widely used and have lighter requirements. Simulations are still driven directly by factors derived from traffic model.

1.2 Objectives

The study has two objectives, namely:

1.2.1 To develop a network traffic modeling connecting Jalan Tanjung Lumpur-Pekan and Federal Road 3 .

1.2.2 To create Origin destination (OD) matrix modeling using gravity method.

1.3 Scope of study

The scope of study includes:

1.3.1 The study involve carrying out by building a network modeling of Jalan Tanjung Lumpur-Pekan and Federal road 3 using EMME3.

1.3.2 Data collection using important tools such as Geographical Information System Of Pahang State and Google maps.

1.3.3 Analyzing data using EMME/3.

1.4 Problem statement

The main issues in transportation planning is about the ability to control traffic flow entering Kuantan town centers particularly for future needs. This ability is not currently posses by the authority , namely Majlis Perbandaran Kuantan (MPK).

1.5 Significant of study

The selected links Jalan Tanjung Lumpur-Pekan and Faderal Road 3 are the least to be considered in MPK transportation planning due to it low demand.

This study will help MPK to focus effort at more relevant town attractions such as Jalan Kuantan-Gambang , Kuantan Bypass and Jalan Kuantan-Beserah.

1.6 Expected outcomes.

One of the expected outcomes of the study will be the traffic model for the base year. Combining with a well planned O-D matrices, the base year traffic model can be developed into future years model which will help authorities to understand the future traffic demand.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will define all the terms such traffic prediction. Origin Destination matrix (OD), and more.

2.2 Basic Representation

Constructing the geometry of network depends on the mode and the scale is being investigated. For urban road network, information can be extracted from aerial photographs or topographic maps. Two fundamental tables are required for the basic representation of a network data model that can be stored in data base.

2.2.1 Node table

This table contains at least three field. One is to store a unique identifier and the others is to store the node of X and Y coordinates. Although this coordinate can be define by any Cartesian reference system, longitudes and latitudes would insure an easy portability to a GIS (Dr. Jean Paul Rodrigue).

2.2.2 Link table

This table also contains at least three field. One is storing identifier and the other is to store the node of origin and destination. A fourth field can be use to state if the link is unidirectional or not.

Once the two tables are relationally linked, a basic network topography can be constructed and all the indexes and measures can be calculated. Attributes such as the connectivity and the matrix can also easily be derived from the link table. This basic representation enables to define the topology of networks as structured.

Many efforts have been made to cerate comprehensive transportation network database to address a wide variety of transportation problems ranging form public transit to package distribution.

Initially, these effort were undertaken within transportation network optimization packages such as EMME/3 or TransCad which created topologically sound representations (Dr. Jean Paul Rodrigue).

2.3 Layer-Based Approach

Most conventional GIS data models separate information in layers. Each representing class of geographical elements symbolized as points line and polygons in the majority cases. For network data model must be constructed with the limitation of having points and lines in two separate layers. Further, an important requirement is that the geometry of the network matches the reality as closely as possible since this networks are often part of GIS where an accurate location and visualization is a requisite (Dr. Jean Paul Rodrigue).

2.3.1 Classification and labeling

Each segment can be classified into categories such as its function such as street or highways, importance such as number of lanes (Dr. Jean Paul Rodrigue).

2.3.2 Direction

To avoid unnecessary and often unrealistic duplication of links, especially at the street level, a directional attributes can be included in the attribute table (Dr. Jean Paul Rodrigue).

2.3.3 Turn penalties

An important attribute to insure accurate routing within a network. Each intersection has different turn constrains and possibilities. Conventionally, in road transportation, a right turn is assumed to have a lesser penalty than a left turn (Dr. Jean Paul Rodrigue).

2.4 Traffic prediction

Traffic prediction is one of the way for engineers to plan the future network. It is very important in planning so that it is trustworthiness of future traffic movement. It is also one of the potential to improve traffic and reduce delays with a better quality (Balakrishnan Chandrasekaran).

2.5 Traffic models

The design of strong and reliable network and network services is becoming increasingly difficult in today's world. The only path to achieved this is to develop a detailed understanding of the traffic characteristics of the network (Balakrishnan Chandrasekaran).

The network represents the major routes for getting around within the study area. In simple models this is the road system. Overall, the network shows the supply of transportation.

The road network as for Figure 2.1 is represented by nodes and links which connect roads. Each node and link also have information about their real physical data, such as capacity and speed. The network ends at external stations.

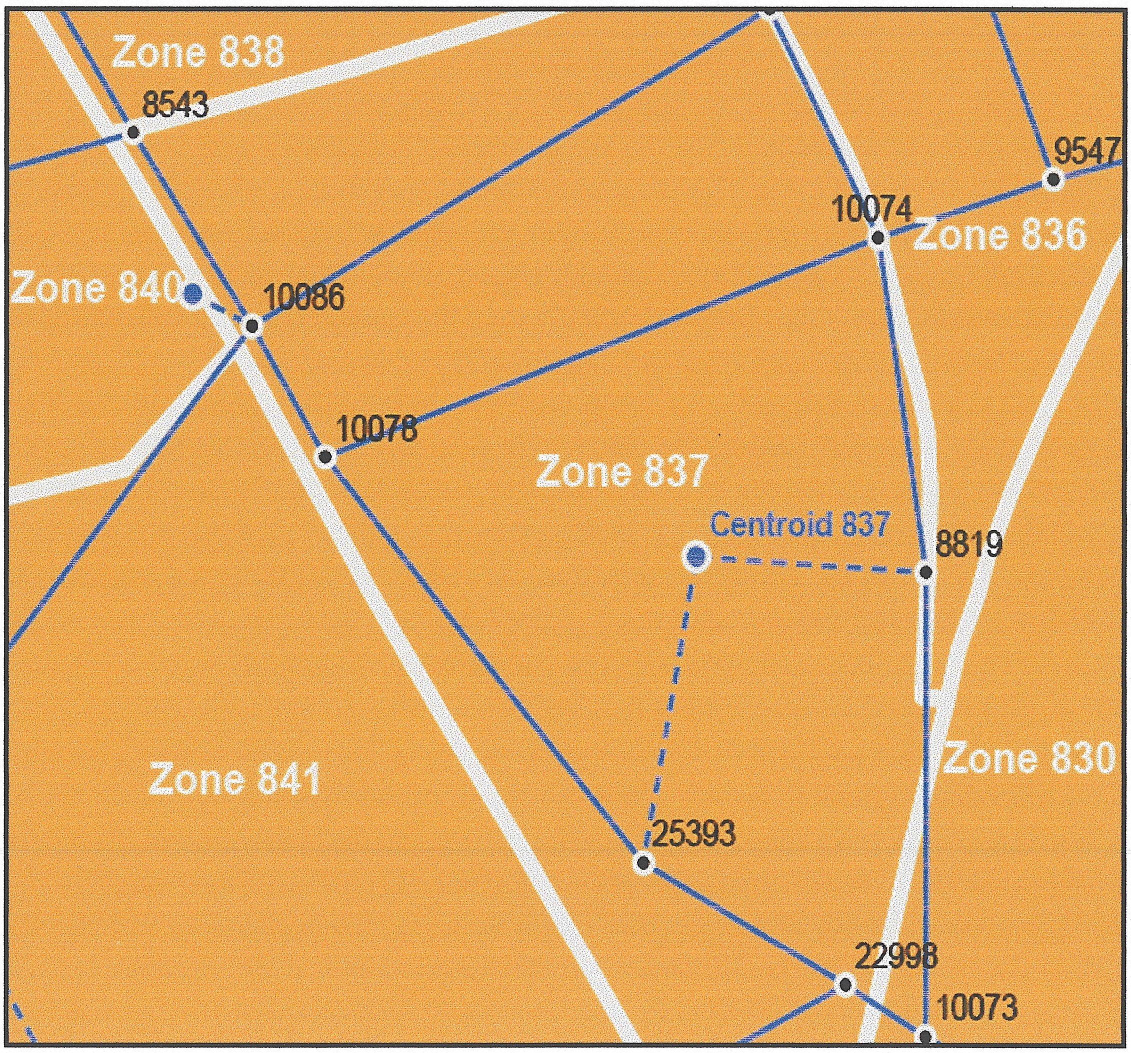

Figure 2.1 : Traffic model network with a road inventory (David Knudsen,2007)

2.6 Trip distribution

The purpose of traffic distribution is to produce a trip table of the estimated number of trips form each traffic analysis zone to every other traffic analysis zone within the study area. Trip distribution for this study was estimated using EMME/3 gravity model programmed as shown in Table 2.1. The programmed assumes that the number of trip between two zones is

i) Directly proportional to the trips produced and attracted to both zones.

ii) Inversely proportional to the travel time between the zones.

Table 2.1 : Illustrative trip table

Origin / Destination	**1**	**2**	**3**	**Z**
1	T_{11}	T_{12}		
2	T_{21}			
3	T_{31}			
4	T_{41}			T_{ZZ}

2.6.1 The gravity model

A model that is usually used for trip distribution is that of the gravity function, an application of Newton's fundamental law of attraction (Oppenheim,1980). The gravity model illustrates the macroscopic relationships between places for example like homes and workplaces or in other words, the gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination.

It has long been posited that the interaction between two locations declines with increasing between distance, time, and cost. But is positively associated with the amount of activity at each location (Isard, 1956).

In analogy with physics, (Reilly, 1929) formulated Reilly's law of retail gravitation, and J. Q. Stewart,1948 formulated definitions of demographic gravitation, force, energy, and potential, now called accessibility (Hansen, 1959). The distance decay factor of 1 per distance has been updated to more comprehensive function of generalized cost, which is not necessarily linear a negative exponential tends to be the preferred form.

Figure 2.2 shows that zone B, C, E, F is more attractive going to compare going to zone D. This is because it is related to the distance. This also effects of time, and also cost. This is called gravity model (Cascetta and Nguyen, 1998).

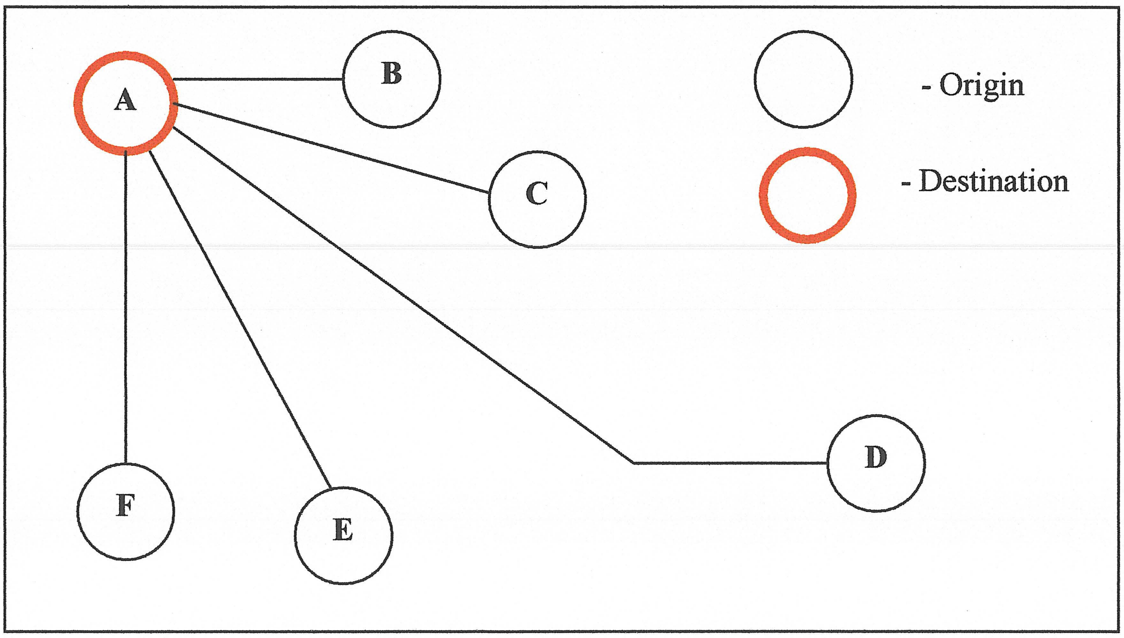

Figure 2.2 : Gravity model

While the gravity model is very successful in explaining the choice of a large number of individuals, the choice of any given individual varies greatly from the predicted value. As applied in an urban travel demand context, the disutility are primarily time, distance, and cost, although discrete choice models with the application of more expansive utility expressions are sometimes used, as is stratification by income or auto ownership (Cascetta and Nguyen, 1998).

2.7 Origin destination (OD) matrix

The origin–destination (OD)-matrix estimation problem is to find an estimate of some travel demand between pairs of zones in a region. OD-matrices are essential inputs in many transportation analysis models and are useful for example when making decisions about how to modify the traffic network, evaluating the accessibility to different commercial areas or when making forecasts of traffic emissions. Many time dependent systems also require a static OD-matrix as a base or default value. It is therefore of great importance to develop accurate models and methods for estimating OD-matrices (Cascetta and Nguyen, 1998).

The estimation is made by using available information about the unknown matrix. Usually this information includes traffic count data, observed traffic flows on a subset of the links in the network, and an initial approximate OD-matrix. This matrix can be an out-dated matrix, for example obtained from surveys or sample data and possibly updated by some growth factors to account for changes in the total flow in the network. When making short time OD-matrix estimations, this matrix typically represents the average traffic situation (Cascetta and Nguyen, 1998).

In practice, there are always inconsistencies in the observed count information, and there may be no matrix satisfying the observed counts. Therefore most models allow matrices, which do not exactly reproduce the observed counts (Cascetta and Nguyen, 1998).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The study involves with the execution of using EMME/3 to produce network model. EMME/3 is a complete travel demand forecasting system for urban, regional, and national transportation planning. Transportation policy decisions for demand modeling, multimodal network modeling, visualization and analysis can be modeled using EMME/3. In this study, gravity model method is used to form up the base year O-D matrices.

3.3 Data collection

3.3.1 Planning system

First, modeled zones and nodes need to be indentified using Geographical Information System (GIS) data base. All the primary and secondary roads will be considered to produce base year road network model. Node representation of the internal and external zones are as follows.

Table 3.1 : Modeled internal and external zones

ZONE	NODE REPRESENTED
Internal	
10509	Taman Indera Pura
10530	Taman Kempadang Makmur
10543	Kampung Peramu Hulu
10546	Kampung Peramu Maju
10551	Kampung Teluk Baharu
10555	Sekolah Kebangsaan Tanjung Lumpur
10504	KIPSAS
External	
10001	Terus Maju
10002	Perumahan Sg. Isap
10003	Kampung Sri Melati
10004	Kampung Rhu Bongkok
10005	Perkampungan Kempadang
10006	BMW show room,Kopitiam (Bandar Kuantan)

In the table internal and external zones need to be systematically numbered. The attributes such as the coordinates shall be obtain from Kuantan's GIS. Figure 3.2 shows the study area.

3.3.2 Junction and links modeling

Junctions and corners are represented by nodes numbered from 10510 until 19999. Again the junctions and corners attributes are obtained from GIS data base and similarly the links length.

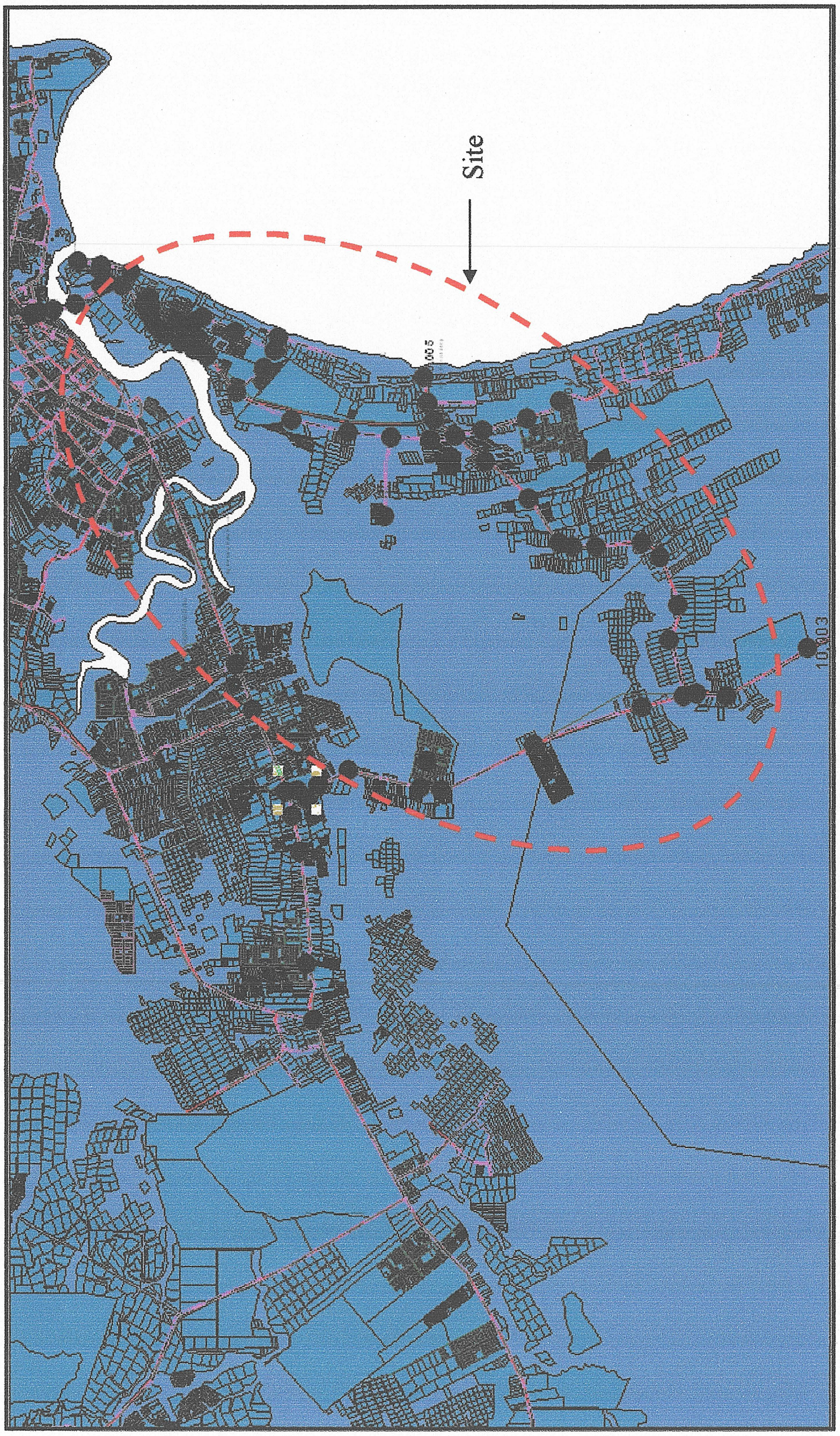

Figure 3.2 : ArcView GIS Version 3.0 for study area.

3.4 Road network modeling

To develop a traffic model, collection of data was necessary trough site observation and surveys. The essential item for road network modeling are as follows:

i. network inventory
ii. junction layouts
iii. junction signal timings; link capacities
iv. turn table penalties
v. volume delay functions (VDF)
vi. vehicle demand patterns
vii. vehicle volume counts

Coordinate that had been retrieved from GIS then need to be converted to .prn format so that the EMME/3 program can run it. Table 3.2 and Table 3.3 shows the example of data for nodes and link that should be insert to the software EMME/3 to generate road network modeling while Figure 3.3 shows the road network modeling that need to be created.

Table 3.2 : Example of data for nodes

	NODES	COORDINATE X	COORDINATE Y	DATA 1	DATA 2	DATA 3
a*	10504	92306.22	4495.73	0	0	0
a*	10509	96407.72	5212.91	0	0	0
a*	10530	99339.27	8408.26	0	0	0
a*	10543	99714.67	8774.68	0	0	0
a*	10546	100094.59	9253.86	0	0	0
a*	10551	100527.45	10085.90	0	0	0
a*	10555	91822.30	6724.37	0	0	0
a*	10001	87771.87	6061.30	0	0	0
a*	10002	93908.06	7773.04	0	0	0
a*	10003	94183.41	-2037.69	0	0	0
a*	10004	98337.28	2209.80	0	0	0
a*	10005	98754.55	4538.72	0	0	0
a*	10006	99798.50	11301.57	0	0	0
a	10500	88901.08	6570.94	0	0	0
a	10501	90781.27	6679.77	0	0	0
a	10502	91391.67	6811.74	0	0	0
a	10503	91789.00	6916.82	0	0	0
a	10562	93905.90	7766.60	0	0	0

Table 3.3 : Example of data for links

	FROM	TO	LENGTH (km)	MODE	LINK TYPE	NO OF LANE	VDF	DATA 1	DATA 2	DATA 3
a	10001	10500	0.94	atc	2	2	2	0	0	0
a	10500	10501	1.87	atc	2	2	2	0	0	0
a	10501	10502	0.62	atc	2	2	2	0	0	0
a	10502	10505	0.40	atc	2	1	2	0	0	0
a	10505	10506	0.29	atc	2	1	2	0	0	0
a	10506	10507	0.58	atc	2	1	2	0	0	0
a	10507	10508	1.27	atc	2	1	2	0	0	0
a	10508	10509	0.46	atc	99	1	5	0	0	0
a	10508	10510	0.35	atc	2	1	2	0	0	0
a	10510	10511	3.81	atc	2	1	2	0	0	0
a	10511	10512	1.94	atc	2	1	2	0	0	0
a	10512	10513	0.004	atc	2	1	2	0	0	0
a	10514	10563	0.52	atc	2	1	2	0	0	0
a	10563	10003	1.62	atc	2	1	2	0	0	0
a	10513	10515	0.98	atc	2	1	2	0	0	0

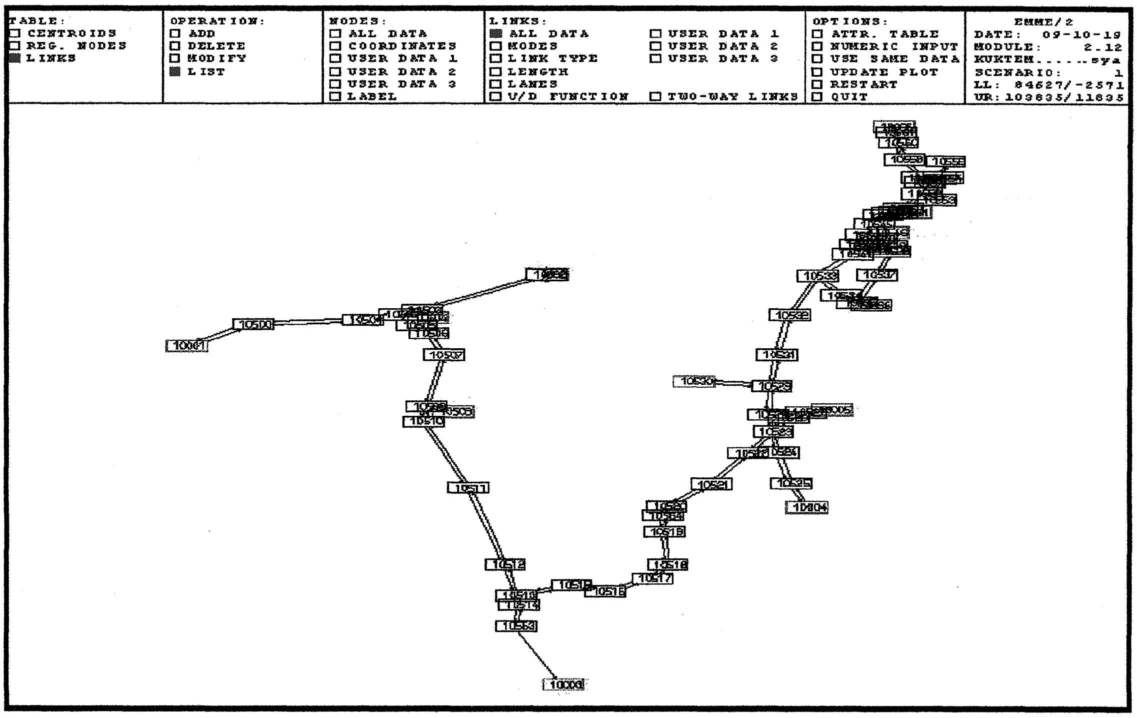

Figure 3.3 : Example of road network model of study area

The network ends at external stations, which represent connections to the other zoning system. “Dummy” zone connectors were then defined to link the catchments centroids to the sub-section midpoints. Connector distances were defined manually by examining the geographical and land-use characteristics of each specific route sub-section. The road network within the study area was modeled to reflect the existing traffic conditions during the morning (AM) and afternoon (PM) peak periods (*Introduction to transportation modeling* 1999).

3.5 OD matrix

In creating origin destination (OD) matrix, the most important thing that should take into account is surrounding area such as building and area of study. This can be obtain from GIS or other sources such as Wikimapia or Google Earth.

Knowledge about the origin-destination (OD) traffic matrix allows us to solve problems in design, routing, configuration debugging and monitoring. In fact the OD traffic matrix provides us with valuable information about who is communicating with whom in a local area network, at any given time. Most routers are not able to measure the OD traffic flows (Airoldi 2003).

3.6 Volume delay function (VDF)

Here, we must identify the roadway classification, link type and the capacity for your study area. Table 3.4 can be referred to identify all the items needed. Figure 3.4 shows the relevant function VDF for applicant EMME/3. These are to express the travel time (or cost) on a road link as a function of the traffic volume.

Table 3.4 : Volume for speed and capacity by roadway type (PerundingAturSdn.Bhd, 2006)

Roadway classification	Link Type	Speed (km/hr)	VDF	Capacity (PCUphpI)
Highway	1	110	1	1800
Primary Road	2	80	2	1500
Secondary Road	3	60	3	1020
Local Road	4	40	4	750
Centroid Connector	99	NA	5	NA

3.7 Trip distribution

Once the O-d matrices has been computed, the trips can be distributed among the zones using Trip Distribution Models. Trip distribution has traditionally been based on the gravity model.

3.8 Turning penalties

Turn table here shows road direction were accessible. If the traffic movement exist, the turn penalty function is -1 and will be 0 if there is no movements at the junction or node. This is an important consideration when determining travel time and routing while using a network

There will be two 'Dummy' at the external. The dummy zone connectors were then defined to link the catchment centroids to the sub section midpoints as shown in Figure 3.4. Each record in a turn tables shows the street segments for each turn and the turn impedance measured in minutes or seconds. Every intersection in a network may not have to be included in a turn table.

A turn table with partial listings involving only intersections at stoplights may be all that is needed for a network application. 12 possible turns at most intersections involving four street segments. U-turns are excluded because they are only involved in some cases.

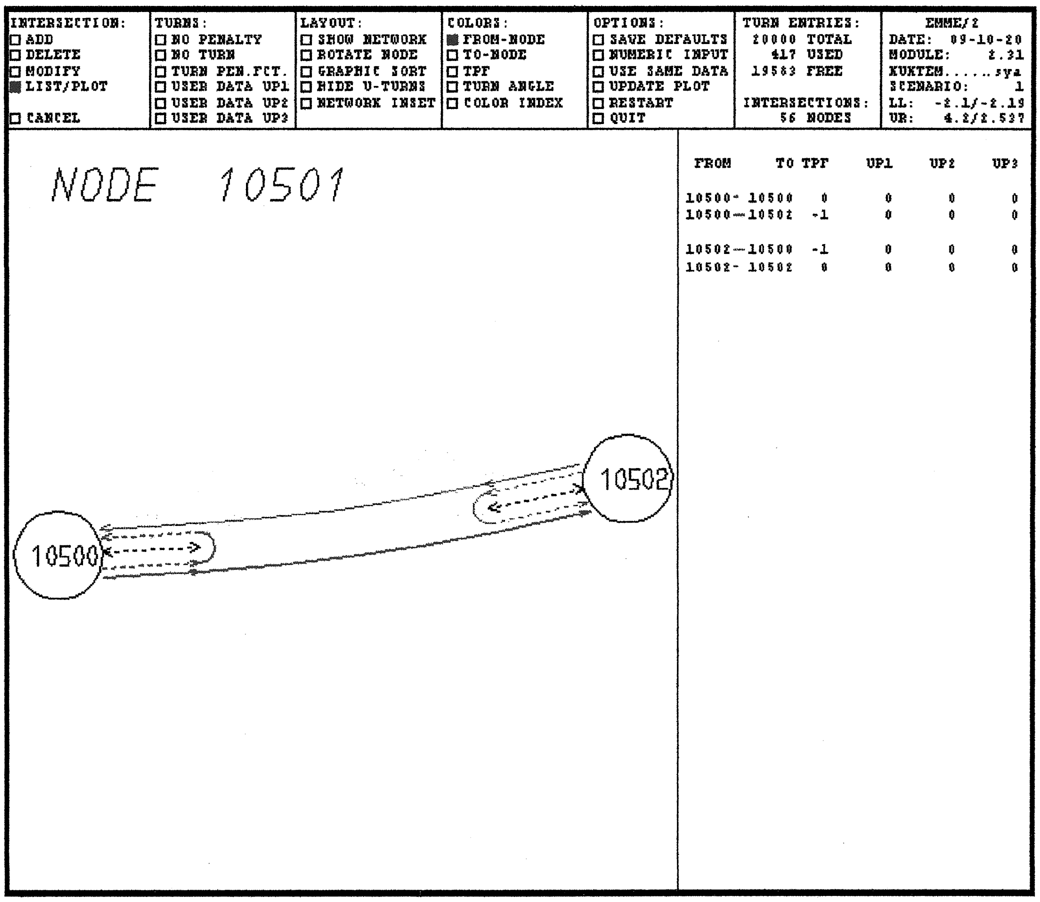

Figure 3.4 : Turn table at dummy centroid

3.9 Trip assignment

Trip assignment exercise is conducted by regressing the network model, the O-D matrices model and the VDF in the trip assignment node. The process in considered successful once the modeled and the actual traffic on selected links margin of errors is ± 10%.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

Network traffic modeling have been developed significantly over the lifetime of the internet. The results that obtain from EMME/3 are presented in this chapter.

4.2 Analysis

The network has been analysis by the EMME/3 and it consists of centroid, links and nodes. In summary, the network contains:

i- 13 centroids.
ii- 58 regular nodes.
iii- 141 links.

4.3 Network file analysis

For network analysis, links is produce in network file. It contains origin and destination, nodes, length, type, modes and lanes of links. Table below shows the link attributes for the study area.

Table 4.1 : Link attributes

From	To	Length (m)	Mode	Type	Lane	VDF
10001	10500	0.94	act	2	2	2
10500	10501	1.87	act	2	2	2
10501	10502	0.62	act	2	2	2
10502	10505	0.40	act	2	1	2
10505	10506	0.29	act	2	1	2
10506	10507	0.58	act	2	1	2
10507	10508	1.27	act	2	1	2
10508	10509	0.46	act	99	1	5
10508	10510	0.35	act	2	1	2
10510	10511	3.81	act	2	1	2
10511	10512	1.94	act	2	1	2
10512	10513	0.004	act	2	1	2
10514	10563	0.52	act	2	1	2
10563	10003	1.62	act	2	1	2
10513	10515	0.98	act	2	1	2
10515	10516	0.97	act	2	1	2
10516	10517	0.86	act	2	1	2
10517	10518	0.42	act	2	1	2
10518	10519	0.80	act	2	1	2
10519	10564	0.39	act	2	1	2
10564	10520	0.39	act	2	1	2
10520	10521	0.92	act	2	1	2
10521	10522	0.98	act	2	1	2
10522	10523	0.66	act	2	1	2
10523	10524	0.50	act	2	1	2
10524	10525	0.78	act	2	1	2
10525	10004	0.63	act	2	1	2
10523	10526	0.43	act	4	1	4
10526	10527	0.33	act	4	1	4
10527	10005	0.43	act	4	1	4
10523	10528	0.42	act	2	1	2
10528	10529	0.68	act	2	1	2
10529	10530	1.33	act	99	1	5

10529	10531	0.75	act	2	1	2
10531	10532	1.00	act	2	1	2
10532	10533	1.06	act	2	1	2
10533	10534	0.63	act	4	1	4
10534	10535	0.32	act	4	1	4
10535	10536	0.25	act	4	1	4
10535	10537	0.74	act	4	1	4
10537	10538	0.61	act	4	1	4
10538	10539	0.14	act	4	1	4
10539	10540	0.24	act	4	1	4
10540	10544	0.21	act	4	1	4
10533	10541	0.80	act	2	1	2
10541	10542	0.004	act	2	1	2
10542	10543	0.21	act	99	1	5
10542	10544	0.25	act	2	1	2
10544	10545	0.29	act	2	1	2
10545	10546	0.32	act	99	1	5
10545	10547	0.26	act	2	1	2
10547	10548	0.17	act	2	1	2
10548	10549	0.11	act	2	1	2
10549	10550	0.12	act	2	1	2
10550	10551	0.16	act	99	1	5
10550	10552	0.49	act	2	1	2
10552	10553	0.30	act	4	1	4
10553	10554	0.55	act	4	1	4
10554	10556	0.40	act	4	1	4
10554	10555	0.12	act	4	1	4
10552	10557	0.26	act	2	1	2
10557	10558	0.13	act	2	1	2
10558	10559	0.55	act	2	2	2
10559	10560	0.40	act	2	2	2
10560	10561	0.24	act	2	2	2
10561	10006	0.14	act	2	2	2
10502	10503	0.14	act	2	2	2
10503	10504	0.20	act	99	1	5
10503	10562	1.47	act	2	2	2
10562	10002	0.82	act	2	2	2

4.4 Base network

Figures 4. 1 and 4.2 shows base network in network worksheet. This is used to show plot of base network such as modes, link types, link length, centroids, lanes or volume-delay functions. Modification to the network model can be done interactively or in a batch file.

The following Figures 4.3 to 4.9 shows the attributes of the base year network model.

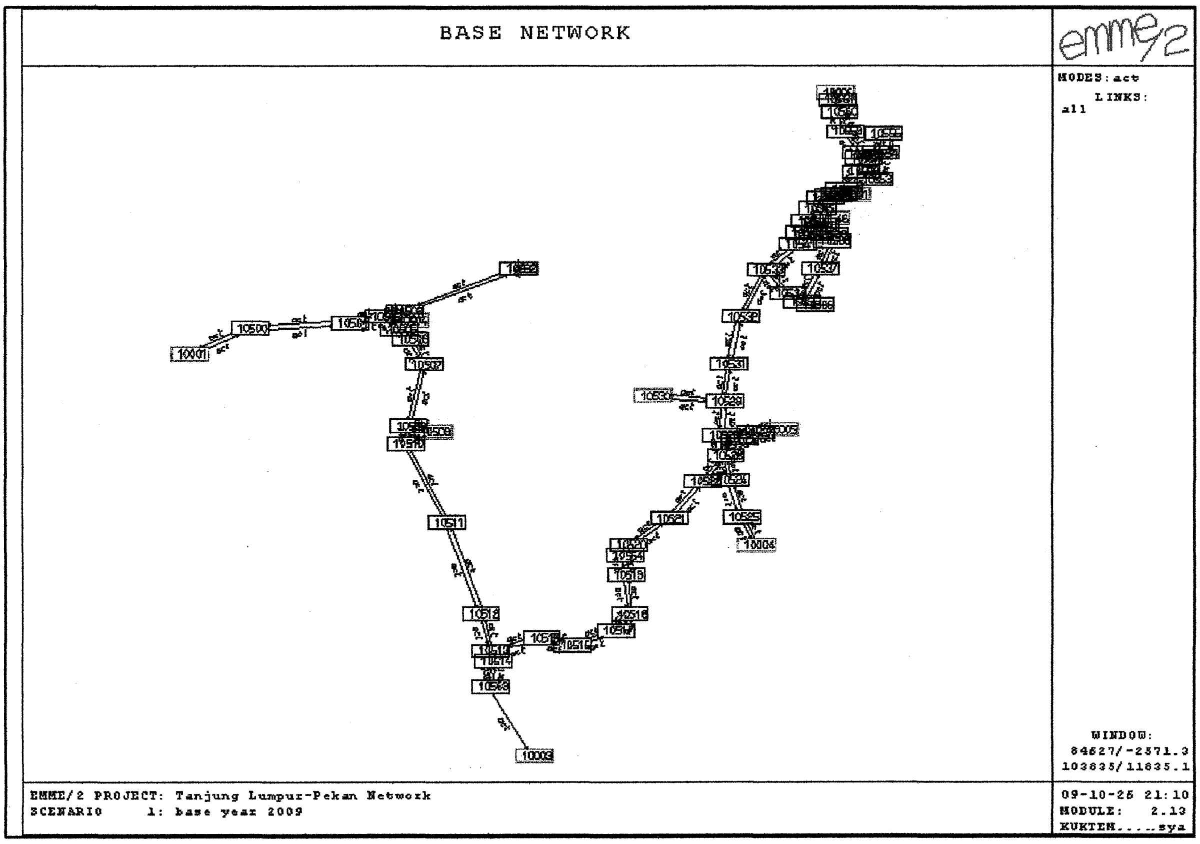

Figure 4.1 : Base year network model

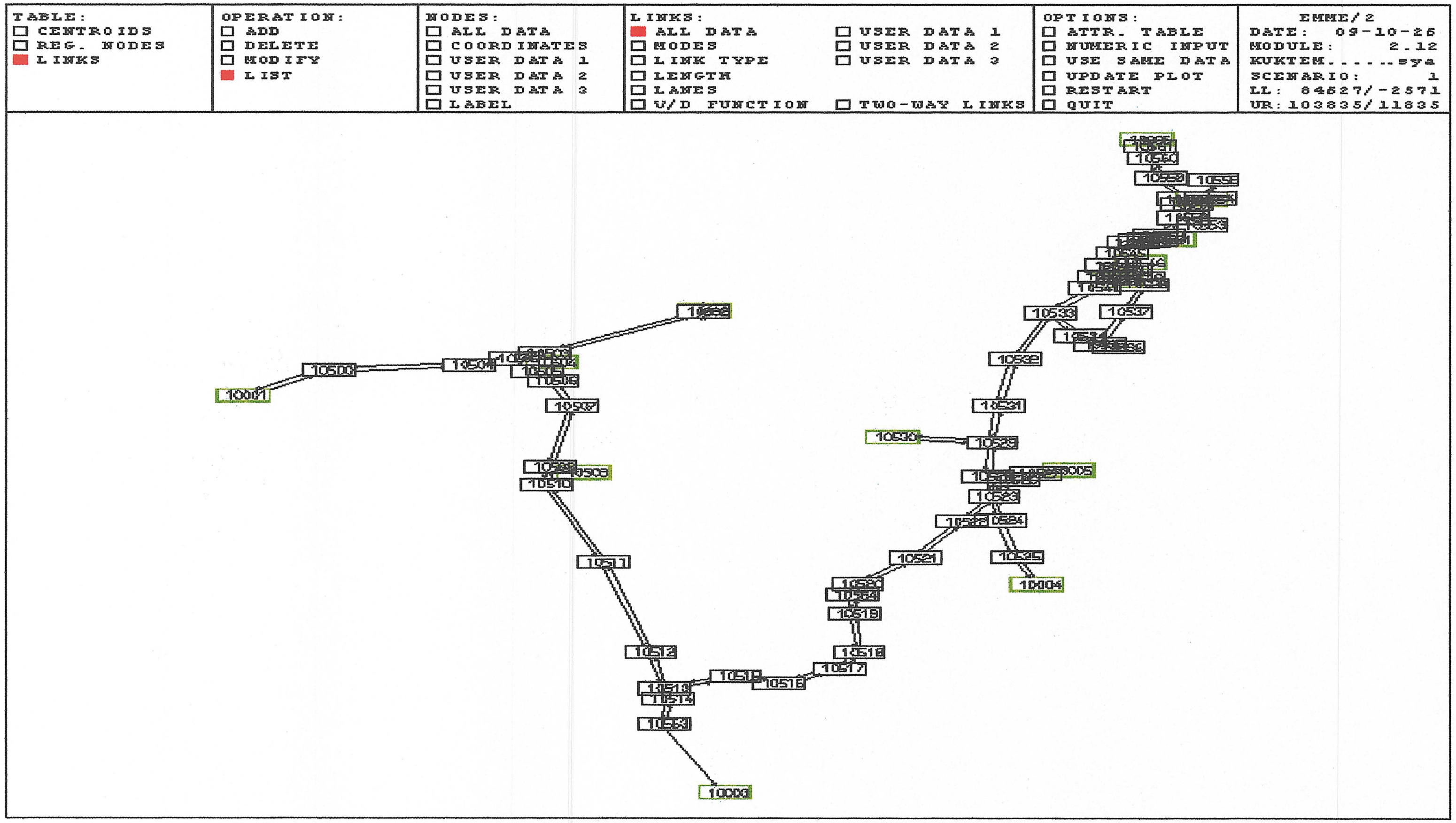

Figure 4.2 : Road network model showing centroids, nodes and links.

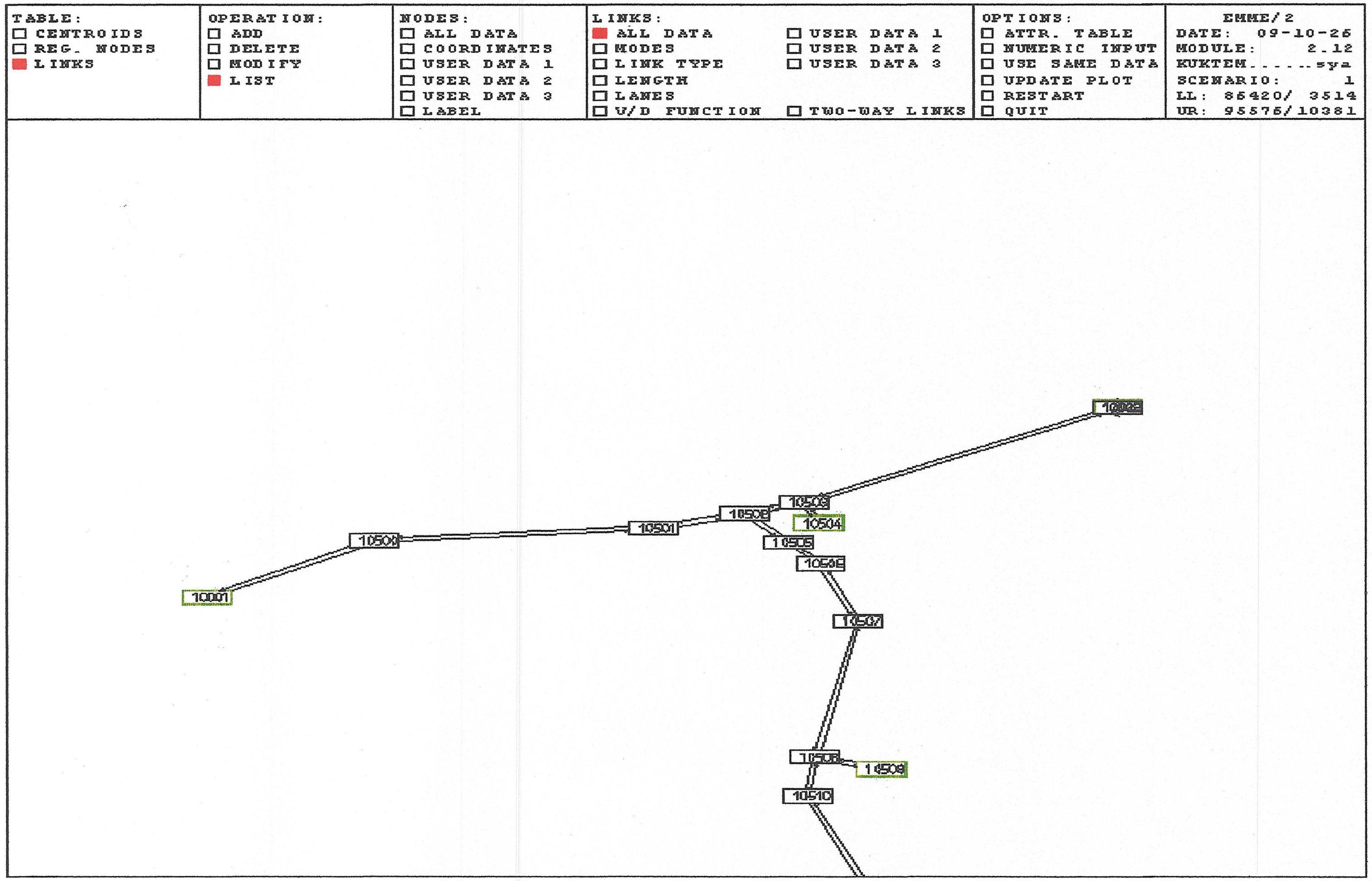

Figure 4.3 : Zoom of road network model showing centroids, nodes and links.
(zoom 1)

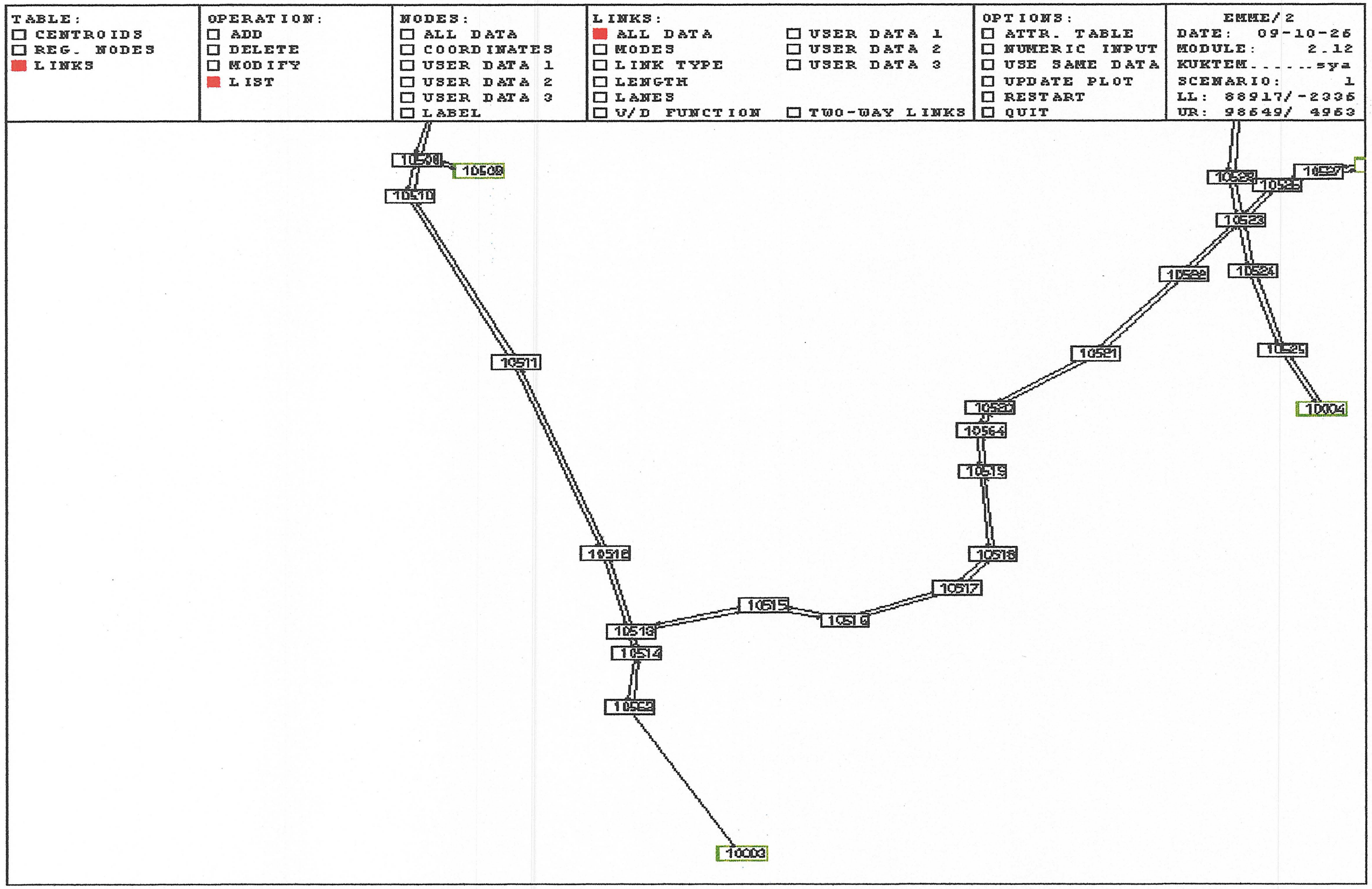

Figure 4.4 : Zoom of road network model showing centroids, nodes and links.

(zoom 2)

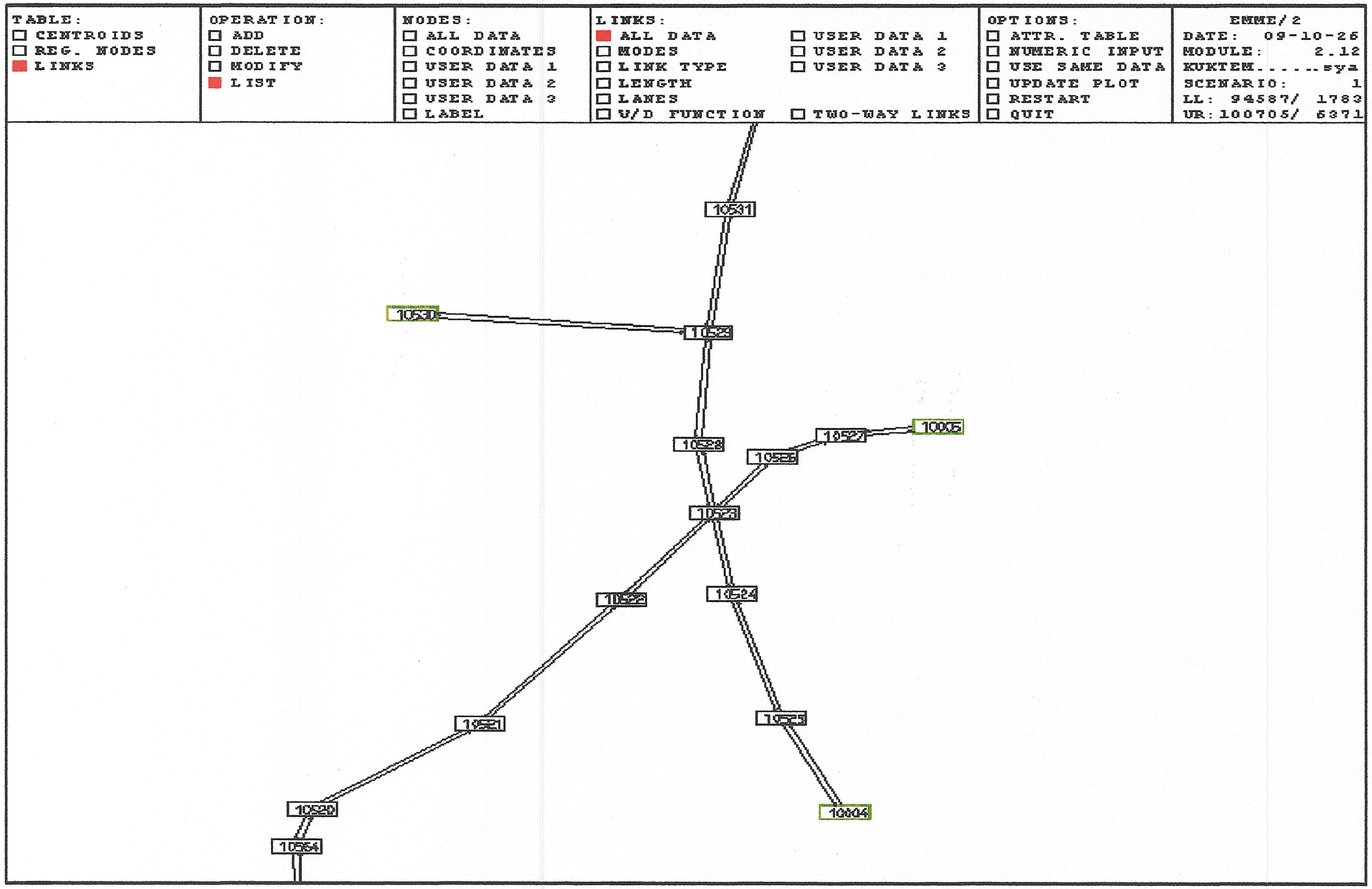

Figure 4.5 : Zoom of road network model showing centroids, nodes and links.

(zoom 3)

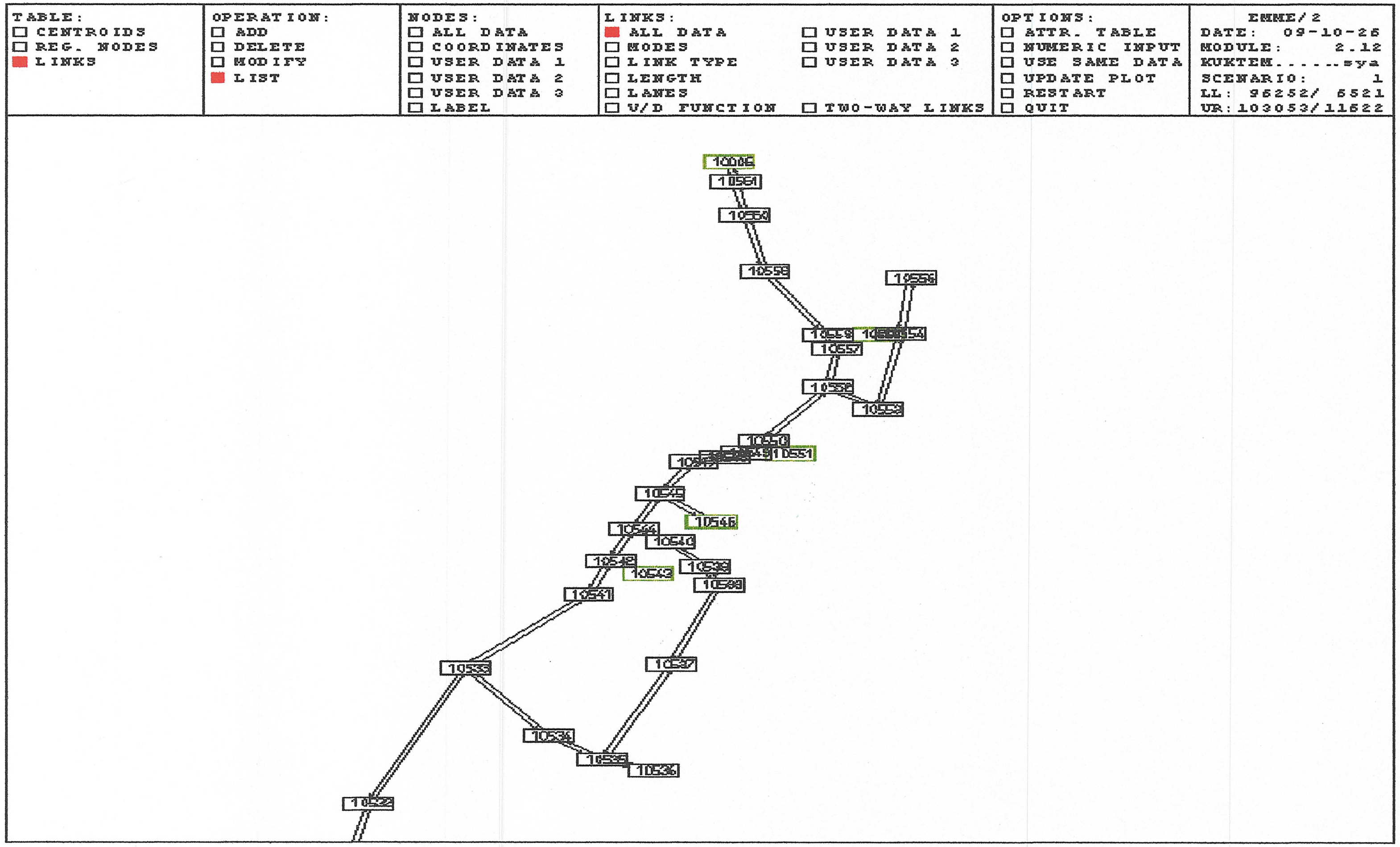

Figure 4.6 : Zoom of road network model showing centroids, nodes and links.

(zoom 4)

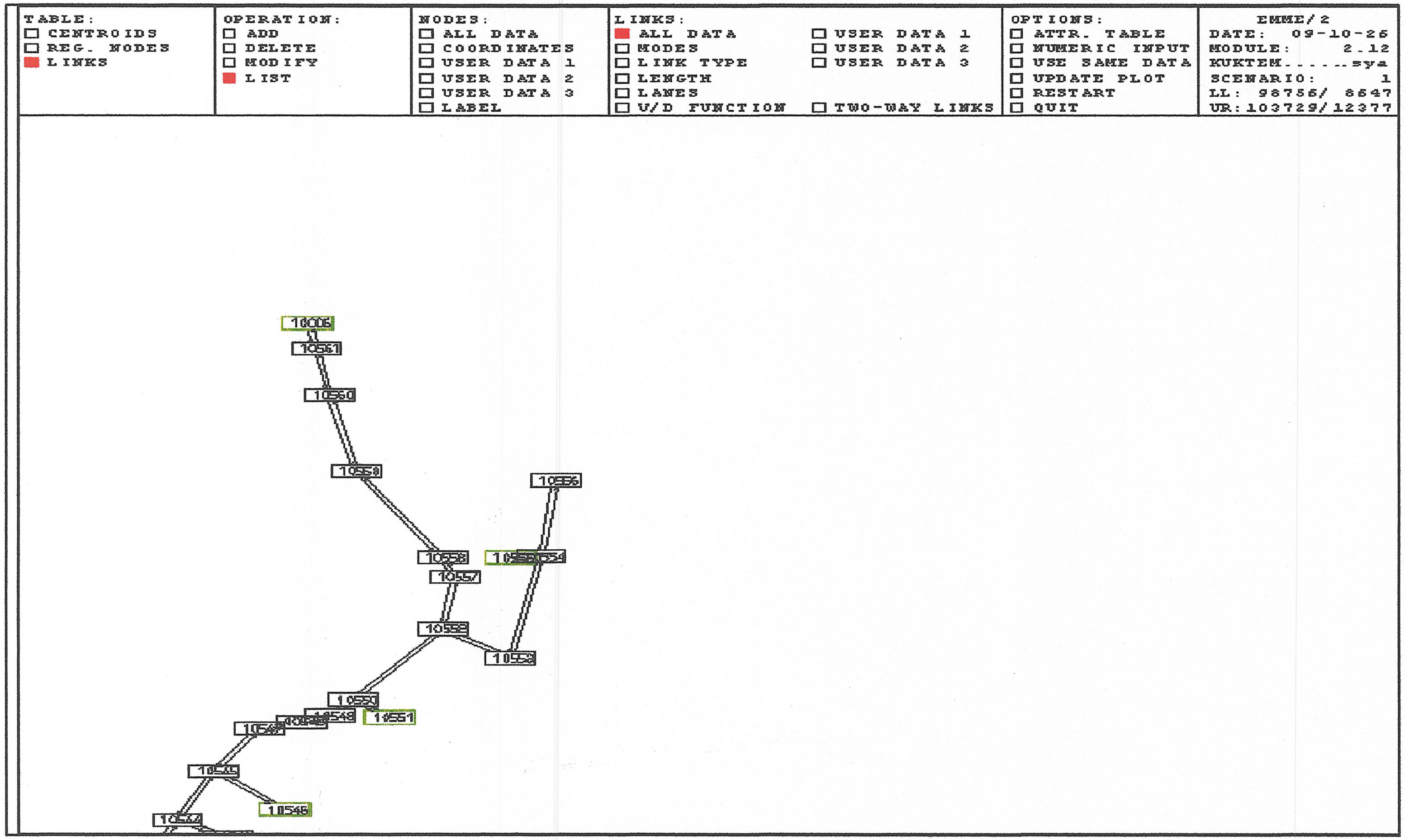

Figure 4.7 : Zoom of road network model showing centroids, nodes and links.

(zoom 5)

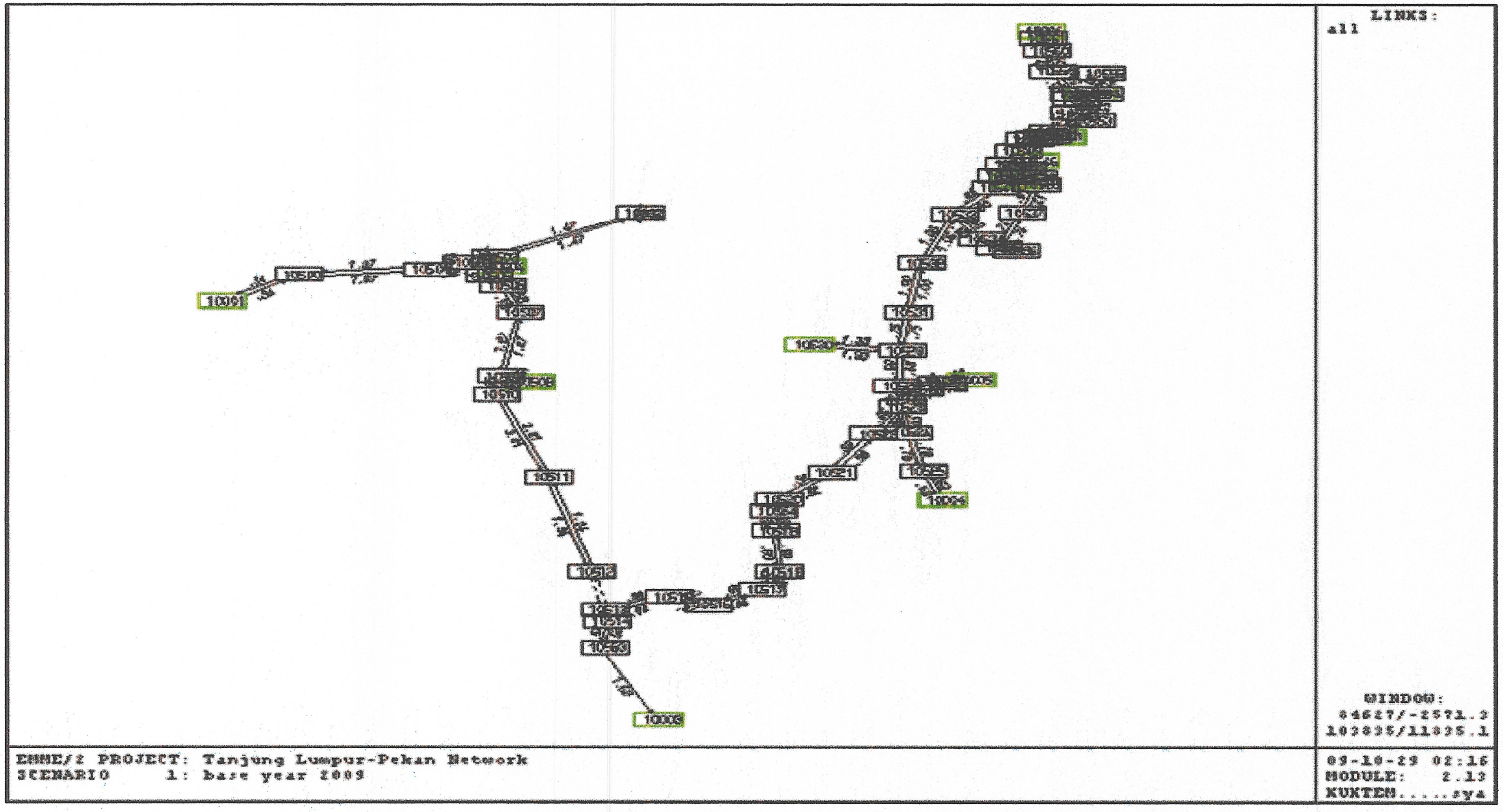

Figure 4.8 : Road network showing link length

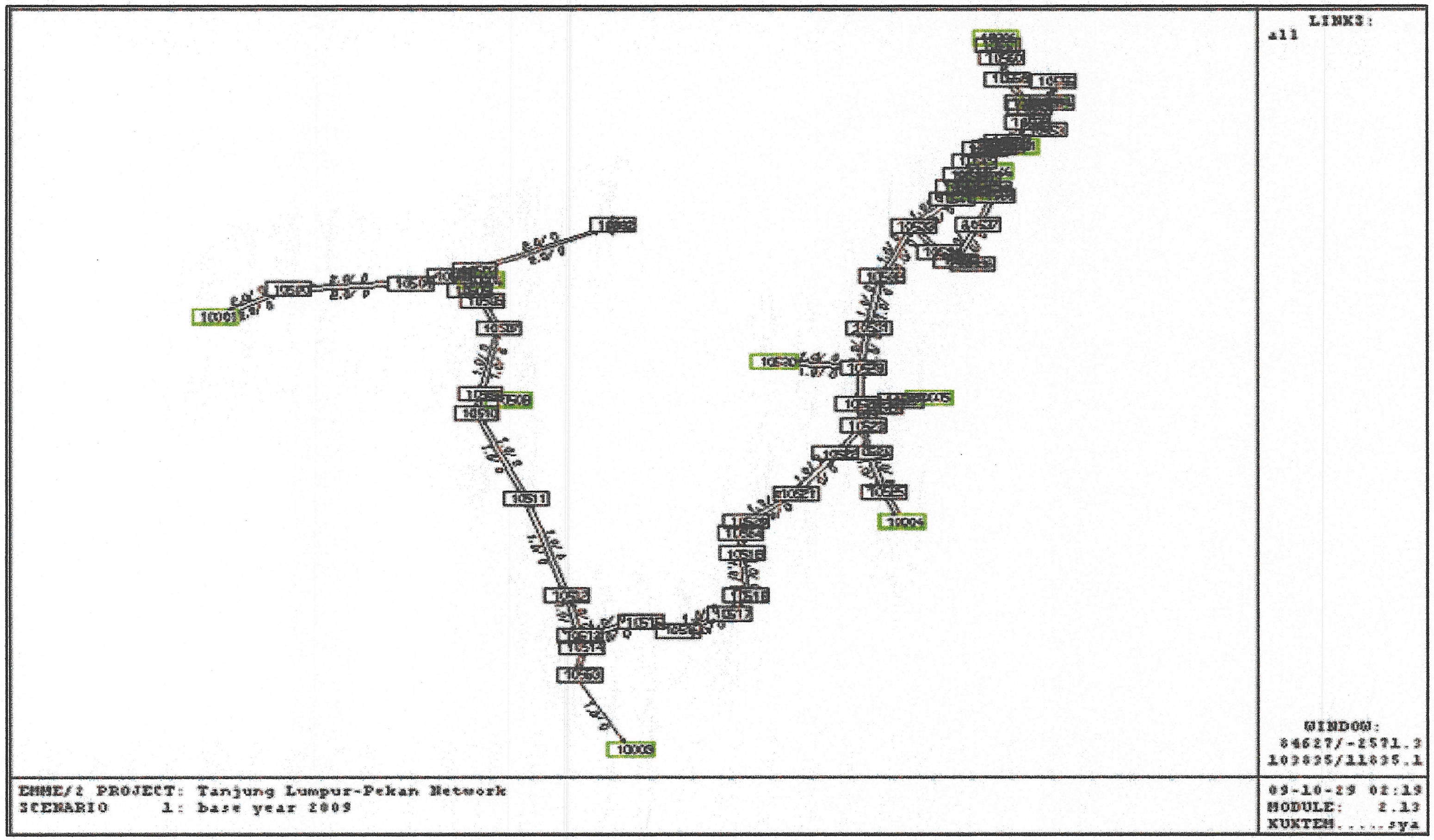

Figure 4.9 : Road network model showing number of lanes

4.5 Turn tables

There are three types of turn tables that can be found in Tanjung Lumpur-Pekan network modeling. The data had been key in module 2.31. the types of turn table are as below.

i- Turn table for 3 way junction (Figure 4.8)

ii- Turn table for 4 way junction (Figure 4.9)

iii- Turn table at dummy intersection (Figure 4.10)

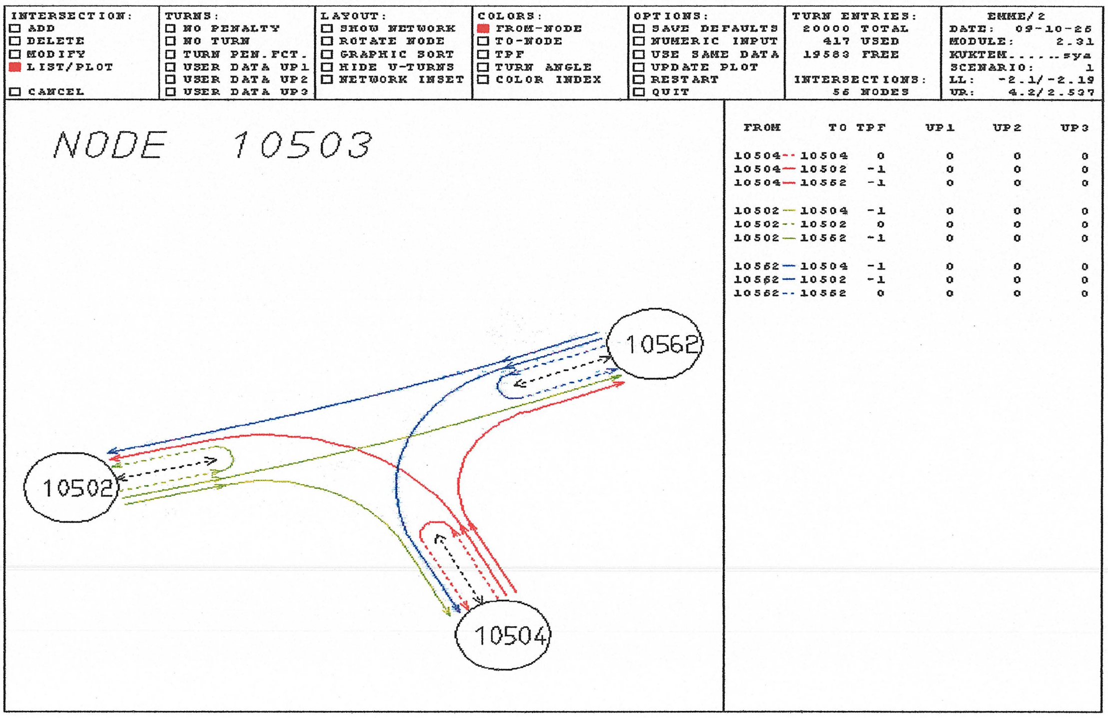

Figure 4.8 : Turn table at 3 way junction

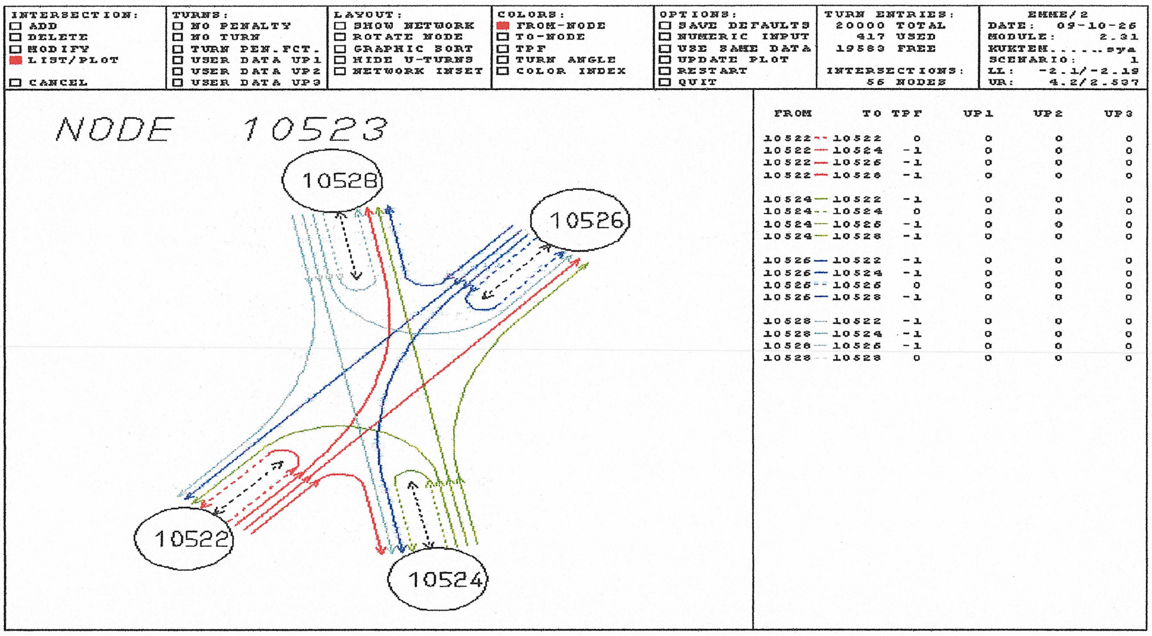

Figure 4.9 : Turn table at 4 way junction

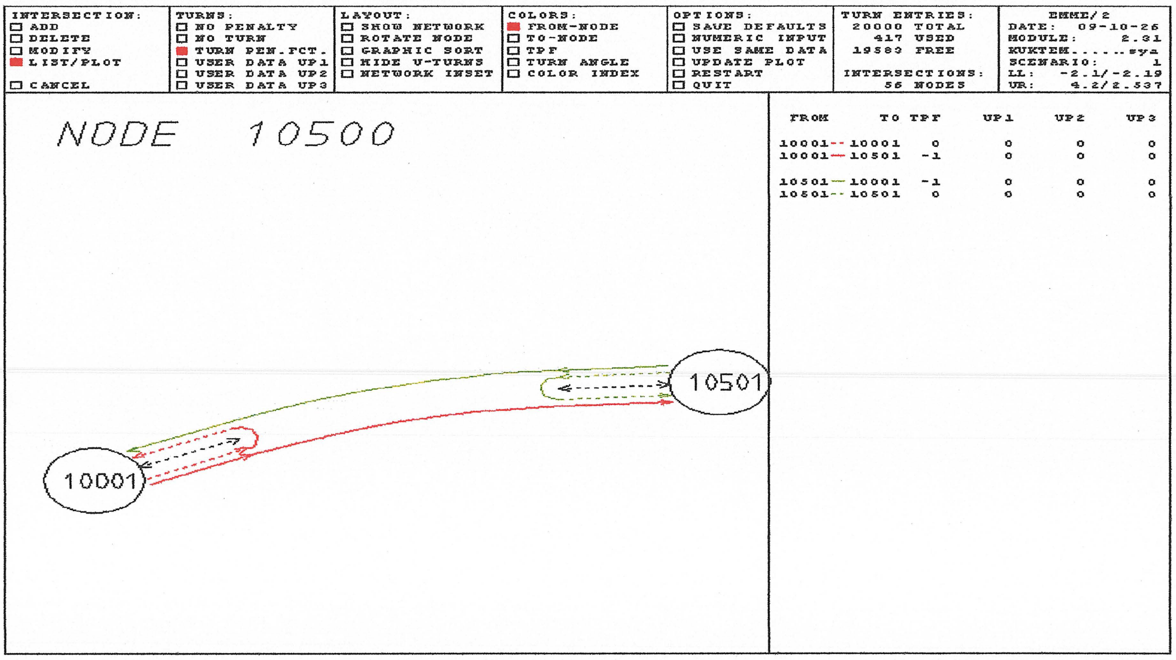

Figure 4.10 : Turn table at dummy intersection

4.6 OD table using gravity method

Base year O-D matrices of the study area is developed using excel as shown in Table 4.2 to 4.4 in which trip to/from origin and destination zone is estimated. The completed O-D is then transformed into .prn file for O-D model and test using the trip assignment node. Convergences of the modeled versus actual traffic volume on selected links to be within ±10% margin of errors will indicate that the base year O-D modeled has been established.

Table 4.2 : Base Year OD Model - AM Peak Hour Distribution to Destination

				in	out	20000	10001	10002	10003	10004	10005	10006	10500
Origin (From)			Generated	to	from	Internal	Terus Maju	Perumahan Sg. Isap	Kampung Sri Melati	Kampung Rhu Bongkok	Kampung Kempadang	BMW show room,Kopitiam	External
10509	Taman Indera Pura	10509	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
10530	Taman Kempadang Makmur	10530	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
10543	Kampung Peramu Hulu	10543	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
10546	Kampung Peramu Maju	10546	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
10551	Kampung Teluk Baharu	10551	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
10555	Sekolah Kebangsaan Tanjung Lumpur	10555	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
10504	KIPSAS	10504	500	400	100	70%	3%	3%	3%	3%	3%	3%	18%
20000	Total for Internal Zones	20000	3500	2800	700								
10001	Terus Maju	10001	500	100	400	70%	3%	3%	3%	3%	3%	3%	18%
10002	Perumahan Sg. Isap	10002	500	100	400	70%	3%	3%	3%	3%	3%	3%	18%
10003	Kampung Sri Melati	10003	500	100	400	70%	3%	3%	3%	3%	3%	3%	18%
10004	Kampung Rhu Bongkok	10004	500	100	400	70%	3%	3%	3%	3%	3%	3%	18%
10005	Kampung Kempadang	10005	500	100	400	70%	3%	3%	3%	3%	3%	3%	18%
10006	BMW show room,Kopitiam	10006	500	100	400	70%	3%	3%	3%	3%	3%	3%	18%
10500	Total for External Zones		3000	600	2400								
Total			6500	3400	3100								

Table 4.3 : Base Year OD Model - Length between zone's centroids

Origin	Destination		10509	10530	10543	10546	10551	10555	10504	20000	10001	10002	10003	10004	10005	10006	10500
10509	Taman Indera Pura	1	0	4,2	8,1	8,6	9,1	9,9	2,3		4,8	3,7	6,8	6,5	6,5	10,2	
10530	Taman Kempadang Makmur	2	4,2	0	4,4	4,9	5,5	6,4	4,8		8,6	3,6	7,6	3,6	2,4	7	
10543	Kampung Peramu Hulu	3	8,1	4,4	0	0,5	1,1	2	7,8		11,6	5,5	11,7	6,3	3,9	2,9	
10546	Kampung Peramu Maju	4	8,6	4,9	0,5	0	0,6	1,5	8,2		12	5,9	19,4	6,7	4,3	2,5	
10551	Kampung Teluk Baharu	5	9,1	5,5	1,1	0,6	0	0,9	8,7		12,5	6,4	12,7	7,3	4,9	2,1	
10555	Sekolah Kebangsaan Tanjung Lumpur	6	9,9	6,4	2	1,5	0,9	0	9,4		12,1	7	13,7	8,2	5,8	1,4	
10504	KIPSAS	7	2,3	4,8	7,8	8,2	8,7	9,4	0		11,7	2,4	9,1	7,9	7,3	9,2	
20000	Total for Internal Zones																
10001	Terus Maju	1	4,8	8,6	11,6	12	12,5	12,1	11,7		0	6,1	10,5	12,2	11	11,9	
10002	Perumahan Sg. Isap	2	3,7	3,6	5,5	5,9	6,4	7	2,4		6,1	0	9,8	7,1	5,8	6,8	
10003	Kampung Sri Melati	3	6,8	7,6	11,7	19,4	12,7	13,7	9,1		10,5	9,8	0	6	14,5	14,5	
10004	Kampung Rhu Bongkok	4	6,5	3,6	6,3	6,7	7,3	8,2	7,9		12,2	7,1	6	0	2,4	9,2	
10005	Perkampungan Kempadang	5	6,5	2,4	3,9	4,3	4,9	5,8	7,3		11	5,8	8	2,4	0	0,9	
10006	BMW show room,Kopitiam	6	10,2	7	2,9	2,5	2,1	1,4	9,2		11,9	6,8	14,5	9,2	0,9	0	
10500	Total for External Zones																

Table 4.4 : Base Year OD Model - Trip Distribution Based on Gravity Model

	Destination		10509	10530	10543	10546	10551	10555	10504	20000	10001	10002	10003	10004	10005	10006	9999
Origin																	
10509	Taman Indera Pura	1	175	17	34	36	38	41	10	350	19	14	26	25	25	40	**150**
10530	Taman Kempadang Makmur	2	24	175	25	28	32	37	28	350	39	16	35	16	11	32	**150**
10543	Kampung Peramu Hulu	3	59	32	175	4	8	15	57	350	42	20	42	23	14	10	**150**
10546	Kampung Peramu Maju	4	62	35	4	175	4	11	59	350	35	17	57	20	13	7	**150**
10551	Kampung Teluk Baharu	5	61	37	7	4	175	6	59	350	41	21	42	24	16	7	**150**
10555	Sekolah Kebangsaan Tanjung Lumpur	6	58	37	12	9	5	175	55	350	38	22	43	26	18	4	**150**
10504	KIPSAS	7	10	20	33	35	37	40	175	350	37	8	29	25	23	29	**150**
20000	Total for Internal Zones		**449**	**355**	**290**	**290**	**299**	**325**	**442**	**2450**	**250**	**118**	**273**	**158**	**120**	**130**	**1050**
10001	Terus Maju	1	23	41	55	57	60	58	56	350	75	9	15	18	16	17	**150**
10002	Perumahan Sg. Isap	2	38	37	56	60	65	71	24	350	13	75	21	15	12	14	**150**
10003	Kampung Sri Melati	3	29	33	51	84	55	59	39	350	14	13	75	8	20	20	**150**
10004	Kampung Rhu Bongkok	4	49	27	47	50	55	62	59	350	25	14	12	75	5	19	**150**
10005	Perkampungan Kempadang	5	65	24	39	43	49	58	73	350	29	15	21	6	75	2	**150**
10006	BMW show room,Kopitiam	6	101	69	29	25	21	14	91	350	21	12	25	16	2	75	**150**
10500	Total for External Zones		**305**	**231**	**277**	**319**	**304**	**321**	**343**	**2100**	**177**	**139**	**170**	**138**	**129**	**147**	**490**
	Total for Town Center		**754**	**586**	**567**	**609**	**603**	**646**	**785**	**4550**	**427**	**257**	**443**	**297**	**249**	**277**	**1062**

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The main objective of the project to develop a base network modeling connecting Jalan Tunjung Lumpur-Pekan and creating OD table using gravity method has been achieved. This project is done by using EMME/3 software. It is use worldwide in the development of transportation project. EMME is a complete travel demand forecasting system for urban, regional, and national transportation planning.

There are two steps required in creating traffic model using EMME/3 project. Steps the formation of the base year network model and the base year OD model. The network model for the study area consist of 13 centroids, 58 regular nodes and 141 links. Besides that, the network modeling is based on scenario 2009 by using the gravity model.

5.2 Recommendations

Since scope of work for this study is only to produce a base year network modeling for 2009 and to create OD matrix modeling using gravity model, for the future work of this project, it is proposed that the calibration process must continue until the difference between the modeled and actual traffic at selected links is less than 10%. This network can be calibrated as many time as required. Furthermore, we can also run a new scenario and trip assignment to obtained the desired traffic model. Figure 5.1 shows the complete modeling using EMME/3 with aim to obtain a calibrated Base Year Traffic Model.

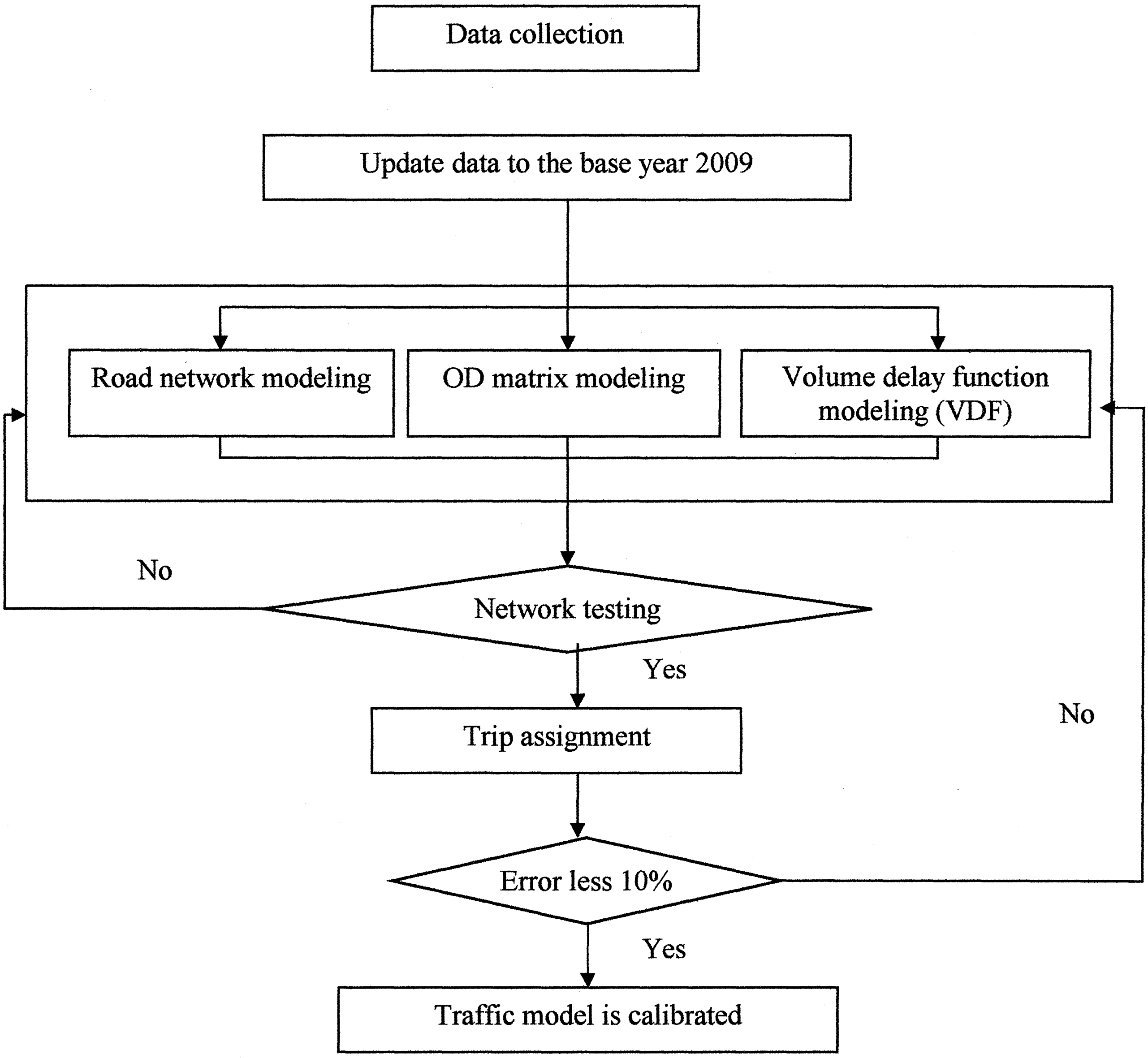

Figure 5.1 : Recommendation for further works

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APPENDIX
TABLE OF NODES

	NODES	COORDINATE X	COORDINATE Y	DATA 1	DATA 2	DATA 3
a*	10504	92306.22	4495.73	0	0	0
a*	10509	96407.72	5212.91	0	0	0
a*	10530	99339.27	8408.26	0	0	0
a*	10543	99714.67	8774.68	0	0	0
a*	10546	100094.59	9253.86	0	0	0
a*	10551	100527.45	10085.90	0	0	0
a*	10555	91822.30	6724.37	0	0	0
a*	10001	87771.87	6061.30	0	0	0
a*	10002	93908.06	7773.04	0	0	0
a*	10003	94183.41	-2037.69	0	0	0
a*	10004	98337.28	2209.80	0	0	0
a*	10005	98754.55	4538.72	0	0	0
a*	10006	99798.50	11301.57	0	0	0
a	10500	88901.08	6570.94	0	0	0
a	10501	90781.27	6679.77	0	0	0
a	10502	91391.67	6811.74	0	0	0
a	10503	91789.00	6916.82	0	0	0
a	10562	93905.90	7766.60	0	0	0
a	10505	91685.82	6553.76	0	0	0
a	10506	91895.07	6359.23	0	0	0
a	10507	92150.55	5841.08	0	0	0
a	10508	91859.83	4605.50	0	0	0
a	10510	91809.40	4256.63	0	0	0
a	10511	92569.04	2662.39	0	0	0
a	10512	93204.64	832.25	0	0	0
a	10513	93386.51	94.72	0	0	0
a	10514	93432.73	-117.27	0	0	0
a	10563	93379.36	-631.58	0	0	0
a	10515	94335.43	339.75	0	0	0
a	10516	94910.20	196.06	0	0	0
a	10517	95708.58	500.85	0	0	0
a	10518	95967.37	822.15	0	0	0
a	10519	95897.50	614.86	0	0	0
a	10564	95885.25	2001.52	0	0	0
a	10520	95953.17	2224.71	0	0	0
a	10521	96710.07	2743.86	0	0	0
a	10522	97341.32	3493.02	0	0	0
a	10523	97755.05	4014.71	0	0	0
a	10524	97838.26	3526.51	0	0	0
a	10525	98055.87	2777.48	0	0	0
a	10526	98017.06	4354.35	0	0	0
a	10527	98322.18	4482.67	0	0	0
a	10528	97688.34	4428.34	0	0	0
a	10529	97731.52	5103.38	0	0	0
a	10531	97824.03	5850.89	0	0	0

a	10532	98032.16	6799.43	0	0	0
a	10533	98507.83	7747.67	0	0	0
a	10534	98911.79	7272.25	0	0	0
a	10535	99182.24	7107.22	0	0	0
a	10536	99425.49	7032.87	0	0	0
a	10537	99516.77	7772.38	0	0	0
a	10538	99751.24	8334.28	0	0	0
a	10539	99679.24	8458.92	0	0	0
a	10540	99510.31	8633.81	0	0	0
a	10541	99111.76	8265.34	0	0	0
a	10542	99216.20	8499.72	0	0	0
a	10544	99327.80	8722.90	0	0	0
a	10545	99461.88	8976.59	0	0	0
a	10547	99623.76	9196.28	0	0	0
a	10548	99774.17	9232.35	0	0	0
a	10549	99880.92	9261.47	0	0	0
a	10550	99963.40	9343.95	0	0	0
a	10552	100283.62	9717.55	0	0	0
a	10553	100527.05	9561.80	0	0	0
a	10554	100637.81	10091.14	0	0	0
a	10556	100690.25	10482.73	0	0	0
a	10557	100327.76	9986.73	0	0	0
a	10558	100281.48	10086.60	0	0	0
a	10559	99972.13	10532.36	0	0	0
a	10560	99878.66	10928.51	0	0	0
a	10561	99830.36	11167.96	0	0	0

APPENDIX

TABLE OF LINKS

	FROM	TO	LENGTH(km)	MODE	LINK TYPE	NO OF LANE	VDF
a	10001	10500	0.94	atc	2	2	2
a	10500	10501	1.87	atc	2	2	2
a	10501	10502	0.62	atc	2	2	2
a	10502	10505	0.40	atc	2	1	2
a	10505	10506	0.29	atc	2	1	2
a	10506	10507	0.58	atc	2	1	2
a	10507	10508	1.27	atc	2	1	2
a	10508	10509	0.46	atc	99	1	5
a	10508	10510	0.35	atc	2	1	2
a	10510	10511	3.81	atc	2	1	2
a	10511	10512	1.94	atc	2	1	2
a	10512	10513	0.004	atc	2	1	2
a	10514	10563	0.52	atc	2	1	2
a	10563	10003	1.62	atc	2	1	2
a	10513	10515	0.98	atc	2	1	2
a	10515	10516	0.97	atc	2	1	2
a	10516	10517	0.86	atc	2	1	2
a	10517	10518	0.42	atc	2	1	2
a	10518	10519	0.80	atc	2	1	2
a	10519	10564	0.39	atc	2	1	2
a	10564	10520	0.39	atc	2	1	2
a	10520	10521	0.92	atc	2	1	2
a	10521	10522	0.98	atc	2	1	2
a	10522	10523	0.66	atc	2	1	2
a	10523	10524	0.50	atc	2	1	2
a	10524	10525	0.78	atc	2	1	2
a	10525	10004	0.63	atc	2	1	2
a	10523	10526	0.43	atc	4	1	4
a	10526	10527	0.33	atc	4	1	4
a	10527	10005	0.43	atc	4	1	4
a	10523	10528	0.42	atc	2	1	2
a	10528	10529	0.68	atc	2	1	2
a	10529	10530	1.33	atc	99	1	5
a	10529	10531	0.75	atc	2	1	2
a	10531	10532	1.00	atc	2	1	2
a	10532	10533	1.06	atc	2	1	2
a	10533	10534	0.63	atc	4	1	4
a	10534	10535	0.32	atc	4	1	4
a	10535	10536	0.25	atc	4	1	4
a	10535	10537	0.74	atc	4	1	4
a	10537	10538	0.61	atc	4	1	4
a	10538	10539	0.14	atc	4	1	4
a	10539	10540	0.24	atc	4	1	4
a	10540	10544	0.21	atc	4	1	4
a	10533	10541	0.80	atc	2	1	2
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a	10545	10547	0.26	atc	2	1	2
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APPENDIX
MATRIX EDITOR

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10509	10551	38
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10530	10509	24
10530	10530	175
10530	10543	25
10530	10546	28
10530	10551	32
10530	10555	37
10530	10504	28
10531	10001	39
10531	10002	16
10531	10003	35
10531	10004	16
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10531	10006	32
10543	10509	59
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10543	10543	175
10543	10546	4
10543	10551	8
10543	10555	15
10543	10504	57
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10543	10002	20
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10006	10005	5
10006	10006	19

THE GEOGRAPHY OF TRANSPORT SYSTEMS

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Network Data Models

Author: Dr. Jean-Paul Rodrigue

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1. Nature and Utility

Graph theory developed a topological and mathematical representation of the nature and structure of transportation networks. However, graph theory can be expanded for the analysis of real-world transport networks by encoding them in an information system. In the process, a digital representation of the network is created, which can then be used for a variety of purposes such as managing deliveries or planning the construction of transport infrastructure. This digital representation is highly complex, since transportation data is often multi-modal, can span several local, national and international jurisdictions and has different logical views depending on the particular user [Miller and Shaw, 2001]. In addition, while transport infrastructures are relatively stable components, vehicles are very dynamic elements.

It is thus becoming increasingly relevant to use a data model where a transportation network can be encoded, stored, retrieved, modified, analyzed and displayed. Obviously, Geographic Information Systems have received a lot of attention over this issue since they are among the best tools to store and use network data models. Network data models are an implicit part of many GIS, if not an entire GIS package of its own. There are four basic application areas of network data models:

- Topology. The core purpose of a network data model is to provide an accurate representation of a network as a set of links and nodes. Topology is the arrangement of nodes and links in a network. Of particular relevance are the representations of location, direction and connectivity. Even if graph theory aims at the abstraction of transportation networks, the topology of a network data model should be as close as possible to the real world structure it represents. This is especially true for the usage of network data models in a GIS.
- Cartography. Allows the visualization of a transport network for the purpose of reckoning and simple navigation and serves to indicate the existence of a network. Different elements of the network can have a symbolism defined by some their attributes. For instance, a highway link may be symbolized as a thick line with a label such as its number, while a street may be symbolized as an unlabeled simple line. The symbolized network can also be combined with other features such as landmarks to provide a better level of orientation to the user. This is commonly the case for road maps used by the general public.
- Geocoding. Transportation network models can be used to derive a precise location, notably through a **linear referencing system**. For instance, the great majority of addresses are defined according to a number and a street. If address information in imbedded in the attributes of a network data model, it becomes possible to use this network for geocoding and pinpoint the location of an address, or any location along the network, with reasonable accuracy.

- Routing **and assignment**. Network data models may be used to find optimal paths and assign flows with capacity constraints in a network. While routing is concerned by the specific behavior of a limited number of vehicles, traffic assignment is mainly concerned by the system-wide behavior of traffic in a transport network. This requires a topology in which the relationship of each link with other intersecting segments is explicitly specified. Impedance measures (e.g. distance) are also attributed to each link and will have an impact on the chosen path or on how flows are assigned in the network. Routing and traffic assignment at the continental level is generally simple since small variations in impedance are of limited consequences. Routing and traffic assignment in an urban area is much more complex as it must consider stop signs, traffic lights and congestion, in determining the impedance of a route.

2. Basic Representation

Constructing the geometry of a network depends on the mode and the scale being investigated. For urban road networks, information can be extracted from aerial photographs or topographic maps. Air transport networks are derived from airport locations (nodes) and scheduled flights between them (links). Two fundamental tables are required in the basic representation of a network data model that can be stored in a database:

- **Node table**. This table contains at least three fields; one to store a unique identifier and the others to store the node's X and Y coordinates. Although these coordinates can be defined by any Cartesian reference system, longitudes and latitudes would insure an easy portability to a GIS.
- **Link table**. This table also contains at least three fields; one to store an unique identifier, one to store the node of origin and one to store the node of destination. A fourth field can be used to state if the link is unidirectional or not.

Once those two tables are relationally linked, a basic network topology can be constructed and all the indexes and measures of graph theory can be calculated. Attributes such as the connectivity and the shimbel matrix can also easily be derived from the link table. This basic representation enables to define the topology of networks as structured by graph theory. Many efforts have been made to create comprehensive transportation network databases to address a wide variety of transportation problems ranging from public transit to package distribution. Initially, these efforts were undertaken within transportation network optimization packages (e.g. EMME/2, TransCAD) which created topologically sound representations. Many of these representations were however geographically inaccurate and had limited visual and geocoding capabilities. Using a network data model for the purposes of cartography, geocoding and routing requires further developments.

3. Layer-Based Approach

Most conventional GIS data models separate information in **layers**, each representing a different class of geographical elements symbolized as points, lines and polygons in the majority of cases. As such, a network data model must be constructed with the limitation of having points and lines in two separate layers; thus the layer-based approach. Further, an important requirement is that the geometry of the network matches the reality as closely as possible since these networks are often part of a geographic information system where an accurate **location and visualization** is a requisite. This has commonly resulted in the fragmentation of each logical link into a multitude of segments, with most of the nodes of these segments mere intermediate cosmetic elements. The topology of such network data models is not well defined, and has to be inferred. However, these network data models benefit from the attribute linking capabilities of the spatial database models they are derived from. Among the most significant attributes that can be attached to network layers are:

- **Classification and labeling.** Each segment can be classified into categories such as its function (street, highway, railway, etc.), importance (number of lanes) and type (paved, non-paved). Also, a complex labeling structure can be established with prefixes, proper names and suffixes.

- **Linear referencing system**. Several systems to locate elements along a segment have been established. One of the most common is the address system where each segment is provided with an address range. Through linear interpolation, a specific location can be derived (geocoding).
- **Segment travel costs**. Can consider a vast array of impedance measures. Among the most common is the length of the segment, a typical travel time or a speed limit. Congestion can also be assessed, either as a specific value of impedance or as a mathematical function.
- **Direction**. To avoid unnecessary, and often unrealistic duplication of links, especially at the street level, a directional attribute can be included in the attribute table.
- **Overcrossing and undercrossing**. Since the great majority of layer-based network models are planar, they are ill designed to deal with non-planar representations. A provision must be made in the attribute table to identify segments that are overcrossing or undercrossing a segment they are intersecting with.
- Turn penalties. An important attribute to insure accurate routing within a network. Each intersection has different turn constraints and possibilities. Conventionally in road transportation, a right turn is assumed to have a lesser penalty than a left turn.

The **TIGER** (Topologically Integrated Geographic Encoding and Referencing) model is a notable example of a layer-based structure which has been widely accepted. TIGER was developed by the US Census Bureau to store street information constructed for the 1990 census. It contains complete geographic coordinates and in a line-based structure. The most important attributes include street name and address information, offering an efficient linear referencing system for geocoding. The layer-based approach is consequently good to solve the cartography and geocoding issues. However, it is ill-suited to comprehensively address routing and assignment transport problems.

4. Object-Oriented Approach

The object-oriented approach represents the latest development in spatial data models. It assumes that each geographical feature is an object having a set of properties and a set of relationships with other objects. As such, a transportation network is an object composed of other objects, namely nodes and links. Since topology is one of the core concepts defining transportation networks, relationships expressing it are imbedded in object-oriented representations. The basic elements of an object-oriented transportation network data model are:

- **Classes**. They categorize objects in a specific taxonomy, which has a proper set of properties and relationships. The two basic classes of a network are obviously nodes and links, but each of these classes can be subdivided into subclasses. For instance, a link can be subdivided as a road link, a rail link, a walkway, etc.
- **Properties**. They refer to a set of measurable characteristics that are associated with a specific class. For instance, the properties of a road class could be its length, number of lanes, name, surface, speed limit, etc.
- **Relationships**. They describe the type of logical relations objects have with one another. Instance (is-a) and membership (is-in) are among the most common relations. For example, a street is an instance of the road class, which itself is an instance of a transport infrastructure. A specific road segment can be considered part of a specific transport system through a membership relation. From these relations inheritance can be derived, where the characteristics of one object can be passed to another. Using the previous example, it is logical to derive that a street is a transport infrastructure, thus the object street inherits the properties of the object transport infrastructure.

By their structure, especially with their embedded topology, an object-oriented transport network data model would be effective to solve the routing issue in transport. However, object-oriented data models are still in the design phase with proposals such as UNETRANS (Unified NEtwork-TRANSportation data model) hoping to become accepted standards. The potential of the object-oriented approach for

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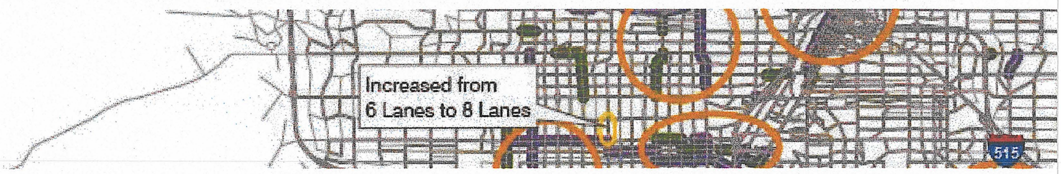
TRAVEL DEMAND FORECASTING



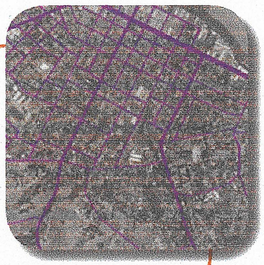
Bicycle & Pedestrian Planning
Intelligent Transportation Systems
Land Use & Transportation Planning
Parking
Smart Growth
Traffic Calming
Traffic Engineering Design
Traffic Operations & Simulation
Transit Planning & Simulation
Transportation Systems Planning
Travel Demand Forecasting

Forecasting future travel demand is a key step in almost every major transportation planning project, providing the foundation for the detailed operational analysis and design that follows. Fehr & Peers is a leader in the development and application of models used to predict travel demand. We use the latest technology to efficiently develop and update models, and apply innovative techniques that allow travel demand models to capture the interactions between neighborhood-scale land use characteristics and travel patterns. We also bring to modeling a deep understanding not only of the latest academic research and statistical analysis techniques, but also the real-world needs of the practicing planner.

Our staff has developed and applied models in all of the major modeling software packages, including TransCAD, TP+/CUBE, EMME/2, MINUTP, and Tranplan. We integrate GIS capabilities into our models to improve the accuracy and efficiency of the modeling process. The spatial analysis tools available through GIS are used to better define the geographic units of analysis, to spatially rectify the roadway network, and to conduct reasonableness checks of land use and trip table data.

Models developed by Fehr & Peers routinely exceed published guidelines for model accuracy. Fehr & Peers staff published a professional paper recommending more stringent California model validation criteria for small urbanized and rural areas after demonstrating usable techniques that substantially improved the validation performance of many models.

We understand how travel demand models are used in practice because we have wide-ranging experience in model applications for city and county transportation master plans, environmental review of large land development projects, and alternatives analysis for major highway and transit improvement projects. We have also applied models to determine the quantitative relationship (or "nexus") between land development and the need for future roadway network improvements, often as part of developing or updating traffic impact fee programs.



TRAVEL DEMAND MODEL – PETALUMA, CA

Peak-hour traffic in Petaluma is dominated by vehicles traveling to and from U.S. 101, the primary regional route connecting Petaluma to the rest of the San Francisco Bay Area. Therefore, when Fehr & Peers updated the city's model and converted it to TransCAD, special attention was paid to the observed internal-external trip patterns. Realistic traffic routing through the city's grid street network was achieved through the use of a true shape roadway network with accurate distances, in combination with turn penalties that reflect the effect of delays at key intersections near freeway access points. All available GIS information has been fully integrated into the model, including city-wide land parcels, truck and transit routes, and data on traffic accidents. The model was used to support development of an updated long-range city-wide circulation plan.

WASATCH FRONT TRAVEL DEMAND MODEL APPLICATIONS – SALT LAKE CITY, UT

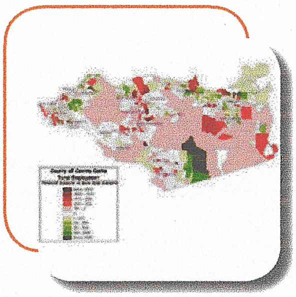
Fehr & Peers has been an active user of the Wasatch Front Regional Travel Demand Model for several years, using it to support long-range transportation master plan updates for a number of local jurisdictions and to meet environmental review requirements for major land development projects throughout the fast-growing Salt Lake City metropolitan area. This complex, large-scale TP+ model has recently been modified and applied by Fehr & Peers to produce transportation data necessary to meet Federal Transit Administration (FTA) requirements for new start transit projects. Local transit agencies are considering the development of several light rail and commuter rail corridors to accommodate the growing demand for travel in this physically- and environmentally-constrained region, and are applying for funding through FTA's New Starts program. The New Starts application requires detailed travel demand data that allows for calculation of several program-specific metrics to quantify the costs and benefits of each transit proposal. Fehr & Peers has provided key transportation modeling expertise that allowed the local New Starts applications to be one of the first in the nation to include the newest FTA-required measure of user benefit.

TRAVEL DEMAND MODEL – DAVIS, CA

The City of Davis is host to the University of California, Davis, which is the largest single traffic generator in the city and surrounding county. As a result, plans to expand the university have important implications for local and regional traffic patterns. Fehr & Peers, under contract to both the City and UC Davis, developed a travel demand model using TransCAD, and designed it to fit the needs of both clients. The model treats trips to and from the university as a special trip purpose and distinguishes between campus groups that have different trip-making characteristics. As an example, freshmen living on-campus are not permitted to keep private vehicles in campus parking lots; treating those students as a separate category in the trip generation module allows for their unique travel characteristics to be represented. This feature facilitated the analysis of different policy options that the university was considering as part of its long-range development plan.

TRAVEL DEMAND MODEL AND TRAFFIC IMPACT FEE PROGRAM - EL DORADO COUNTY, CA

Voters in El Dorado County, California passed a strong local growth control measure by a wide margin, and a lawsuit resulted in a determination that the environmental review of the county's long-range development plans had been inadequate. In response to these issues, Fehr & Peers was asked to update the county's travel demand forecasting model such that it made use of the most up-to-date techniques for analyzing the potential impacts of new development. Special attention was paid to constructing a model that fully accounted for the extent to which available road capacity would be absorbed by land uses that were already entitled, and a direct linkage to the regional model was developed to ensure that the county's model would reflect the most current regional growth assumptions. Model results were used to support an updated county-wide traffic impact fee program, a mechanism for the county to ensure that new development pays its fair share in transportation infrastructure and capital improvements.



TRAVEL DEMAND MODEL APPLICATIONS - CONTRA COSTA COUNTY, CA

Fehr & Peers has worked in Contra Costa County, California for many years, and has developed strong expertise in the modification and application of the four sub-regional EMME/2 models maintained by the Contra Costa Transportation Authority. Recent projects involving major travel demand forecasting components include:

- Long-range land use and transportation plans for the cities of San Ramon, Brentwood, Oakley, Antioch, and Pittsburg.
- Environmental review for large-scale residential and commercial development projects throughout the County.
- Alternatives analysis for major freeway mainline and interchange improvement projects on Interstate 680 and State Route 4.

In addition, Fehr & Peers has conducted all of the transportation analysis for the recent county-wide visioning process called Shaping Our Future, in which innovative modeling techniques were required to capture the effects of land use alternatives focused on clustering development into village centers that would promote walking, bicycling, and transit usage.

REGIONAL TRAVEL DEMAND MODEL APPLICATIONS – DENVER, CO

Fehr & Peers has worked with the regional travel demand model on several recent projects that required expertise not only in standard modeling techniques, but also in the complicated relationships between land use patterns and travel characteristics. The Blueprint Denver project was a ground-breaking examination of potential future visions for this extremely fast-growing region, looking at how development could be organized to minimize impacts on the environment and quality of life. Fehr & Peers conducted detailed assessments of the Blueprint Denver alternatives, evaluating the effects of changes in land use patterns, parking costs, transit availability, and other key inputs. The redevelopment of the former Stapleton Airport site is by far the largest development project to occur within the City and County of Denver for many decades, and Fehr & Peers has been involved in modeling the land use alternatives developed by the project team and determining the transportation infrastructure necessary to serve this city-within-a-city.

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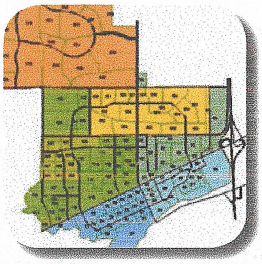
TRAVEL DEMAND MODEL AND STREET MASTER PLAN – WOODLAND, CA

Fehr & Peers recently reviewed the City of Woodland's Travel Demand Model for use in updating its street master plan and associated traffic impact fee program. This update included a conversion of the model from its original MINUTP format to TransCAD. TransCAD was selected over other competing software packages by the city due its strong GIS capabilities. Unique steps in the model development process included a detailed land use review using aerial photography and trip-rate estimation using traffic counts at existing residential subdivisions.

The aerial photography review was useful in identifying unique commercial and industrial uses based on differences in parking. This type of review is important in communities like Woodland with substantial industrial and heavy commercial uses. For example, traditional parcel data was limited to identifying the size of buildings and their general use. Based solely on this data, two 300,000 square feet industrial buildings located in an industrially zoned area would have been coded as the same type and size of use in the model. The detailed aerial photography was used to confirm the amount of parking at each location to verify that an industrial use was the appropriate designation for trip generation purposes. In this example, one of the two buildings had three times the parking expected from an industrial use building of that size. A field check was made to determine the specific use of the building with the higher parking demand, which revealed a commercial use within the building that was consistent with the industrial zoning of the area.

Traffic counts were conducted in select locations around the city to isolate specific types of neighborhoods for the purpose of estimating trip generation rates. The results of this effort revealed that single family households in Woodland generate more vehicle trips than the national average cited in Trip Generation, Institute of Transportation Engineers, 1997.

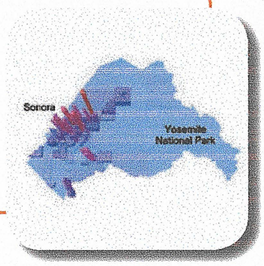
These unique aspects of the model development process helped the final model exceed all recommended validation thresholds contained in Travel Forecasting Guidelines, Caltrans, 1992.



TRAVEL DEMAND MODEL – WINTERS, CA

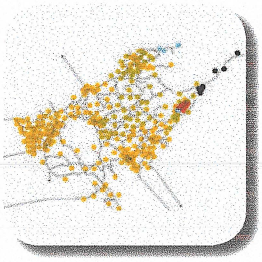
The City of Winters is considering two proposed housing developments that would nearly double the size of the city. Fehr & Peers was contracted to create a travel demand model that would be accurate even for very large changes in local traffic.

Another key feature of the Winters Model is the fact that the city has been divided into districts for traffic analysis purposes. Similar types of dwellings can be assigned different trip generation characteristics depending on which district they are located in. For example, one option under consideration would have one of the major developments be designated entirely for seniors. The district structure of the model enables analysts to change the trip-generation rates for, say, work trips and school trips to reflect the fact that seniors make fewer such trips than other types of households.



TRAVEL DEMAND MODEL – TUOLUMNE COUNTY, CA

Travel patterns in Tuolumne County are dominated by the State highway system, which provides the primary connections between most residential communities in the county. Tuolumne County is also home to several major recreational destinations for regional travelers, including a large casino and the world-renowned Yosemite National Park. The key to modeling the county's traffic was in correctly disaggregating the traffic by trip purpose. Fehr & Peers created a separate trip purpose for recreational trips to capture travel to and from Yosemite, and treated the casino as a special generator with travel patterns reflecting the results of earlier traffic studies.



TRAVEL DEMAND MODEL – CALAVERAS COUNTY, CA

Calaveras County has two features that present a challenge to travel demand forecasters. First, residents of the western part of the county often work and shop in Central Valley cities that are outside the study area and second, much of the housing stock in the eastern part of the county are used only seasonally.

Fehr & Peers converted the previous Calaveras model to TransCAD, developed a new roadway network file based on a TIGER (U.S. Census) file and developed a new Traffic Analysis Zone (TAZ) system consistent with census geography. The model used different trip generation rates for communities in different parts of the county depending on the percentage of seasonal housing stock. The model also gave special attention to the interaction between Calaveras County and adjoining counties.