



Tech Memo

DATE: December 20, 1998.	PROJECT: Estudio Integral de Transporte (II) / Juarez Data Analysis and Model Development (TTISL#40733)
TO: Ken Mora, Project Director / TxDOT Jim Yarbrough / EPA David Pearson / TTI	
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SUBJ: Progress under Task 2: Transportation Networks.	

Overview

Continuing with the modeling process, and having cleaned all of the travel survey databases, the next major step has consisted in developing a mathematical representation of the physical transportation infrastructure in the city, through which travel flows would be channeled. This abstract composition is basically a simplified version of the street layout, depicted graphically as an interconnected web of links and nodes with attached attributes, describing individual physical and operational characteristics.

This information has been stored and organized in a geographic information system environment (GIS), using TransCAD. This software, which in addition to GIS has transportation modeling capabilities, has been selected in order to work in a compatible and consistent format to that used by TxDOT to develop the El Paso network. Under TransCAD, the base link-node information along with its attached attribute database is known as the GIS link coverage and thus will also be referred to as the roadway system or roadway geographic file. A transportation network, on the other hand, is a special data structure under TransCAD that uses the roadway geographic file to solve transportation problems.

For purposes of the present project, the Juarez transportation network has been organized characterizing two major components: 1) the main roadway system where all types of motorized vehicles can travel, and 2) the transit route system, which laid out over the roadway system, depicts specific trajectories and operation conditions of urban public transportation.

The present tech memo summarizes the work undertaken to develop the base year 1996 transportation network.

Background

During the fall of 1996 and spring of 1997, the IMIP team conducted a thorough field data collection effort intended to fully characterize the Juarez transportation network. This effort was aimed at two fronts: an infrastructure inventory, and a travel time-delay evaluation.

Infrastructure inventory

This one was intended to establish the physical characteristics of the system. Using aerial photographs and maps, the main roadway system was identified and marked, and the component streets were further categorized as primary or secondary level. These categories are equivalent to arterial type and higher hierarchy roadways according to U.S. standards (most collector and local streets were intentionally left out of this inventory). At this point no functional classification was assigned, but the streets were additionally characterized by their direction of flow, number of traffic lanes in each direction, presence of on-street parking, presence of median, and whether the riding surface was paved or not. Also, traffic lights and stop signs were located and marked.

In addition to the street characterization, the information developed under the on-board transit count¹ was used to establish transit routes. These were superimposed on the main roadway layout to see if

¹ Tech Memo EITII-01 (Rev 01), "Editing/analysis of the on-board transit count database", IMIP (January 1998).

additional streets needed to be included. As a result, some lower hierarchy streets were added to the main system.

Using this information a draft layout of links and nodes was developed on paper. On this preliminary layout, nodes were provided only at intersections between streets identified in the main roadway system where traffic flow exchange takes place, or at the location of a traffic light or stop sign, or to indicate changes in the physical characteristics of a street. This graphical outline of the main system allowed the selection of specific streets for further operational evaluation.

Travel time-delay evaluation

This task was intended to establish the operational nature of the main system at peak and off-peak periods of the day. Travel time and delay at the streets and intersections on the main roadway system was obtained using a methodology known as the "floating vehicle", which can be summarized as follows:

- a) A study vehicle is driven through the full length of the street under analysis, "floating" in the traffic stream.
- b) Every time a vehicle passes the study vehicle, this one is allowed to pass another vehicle in the stream.
- c) In the case of very light traffic, the study vehicle will run at the maximum allowed speed (posted speed).
- d) Times are recorded at the beginning and end of the run, as well as at each signalized intersection or stop sign, or other points along the route whenever the speed falls to 15.5 MPH or less.

This operation was executed at least four times at peak periods and four times at off-peak periods for each street in the main roadway system. As a result peak and off-peak average travel times and speeds were established for each direction on every link, as well as average delay times at every signalized node in the system. Special computer procedures were designed and programmed for this purpose, in order to handle the large amount of information collected, and to detect inconsistent input data and results.

Turning movement delay was also established at all non-signalized intersections (at signalized intersections it was assumed to be similar to through movement delay). For this purpose, a sample of representative intersections was repeatedly traveled to obtain this information. The following movements were specifically evaluated:

- Right-turn from primary street to secondary street (Delay due to decel-accel process only).
- Left-turn from primary street to secondary street (Delay due to decel-accel process and waiting for gap in opposing traffic).
- Right-turn from secondary street to primary street (Delay due to decel-accel process and waiting for gap in perpendicular left-right traffic).
- Left turn from secondary street to primary street (Delay due to decel-accel process and waiting for gap in perpendicular left-right and right-left traffic).
- Through movement on a secondary street, crossing a primary street (Delay due to decel-accel process and waiting for gap in perpendicular left-right and right-left traffic).

For the transit route system, the travel time information was extracted also from the on-board transit count database, which included delay for boarding-deboarding.

Zoning Design

Having developed the base link-node layout, it was then necessary to develop a compatible zoning design, commonly referred to as the traffic analysis zone (TAZ) structure. Each TAZ serves, for modeling purposes, as a coarse geographic reference of the origins and destinations of urban travel; therefore the zoning structure allows the aggregation of travel exchange between different points of the transportation study area. In theory, the area boundaries of a TAZ should try to follow surrounding links of the main roadway system, so travel with destination to, or originating in the TAZ would use the surrounding links as immediate access to the system. In practice this was accomplished in most cases as shown in Figure 1; yet since other recommendations are that TAZs be homogeneous and follow other administrative divisions (such as census tracts), in some cases TAZ boundaries did not follow the exact delineation of the roadway system. This also was the case at paired one-way arterials, commonly encountered at the CBD, where TAZ boundaries were assigned to follow only one of the streets in the pair.

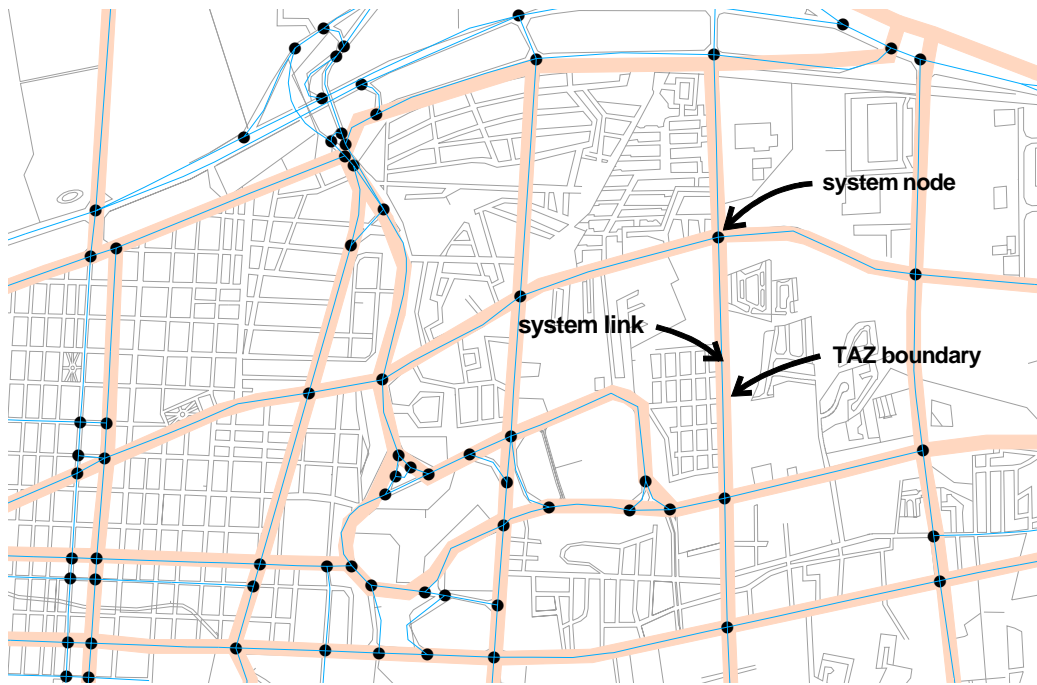


Figure 1. In general TAZ boundaries follow surrounding roadway links.

In transportation networks, TAZs are represented as if all their attributes and properties were concentrated in a single point known as the zone centroid. Centroids are attached to the roadway system through centroid connectors, simulating the net of local and collector streets leading to the main system; as such, centroid connectors represent the average cost (time, distance) of reaching any point in the TAZ from the main roadway system. Nearly as important as the cost associated to each centroid connector is the node in the roadway system it connects to. These should be close to natural access/egress points for the TAZ itself, thus in most cases this meant the middle point of the link surrounding the TAZ. As a result, most of the links originally established were segmented, and additional nodes were introduced to tie centroid connectors to the main roadway system. There is only one centroid for each TAZ, but each centroid could have several connections to the roadway system. An actual example resulting from this process is shown on Figure 2.

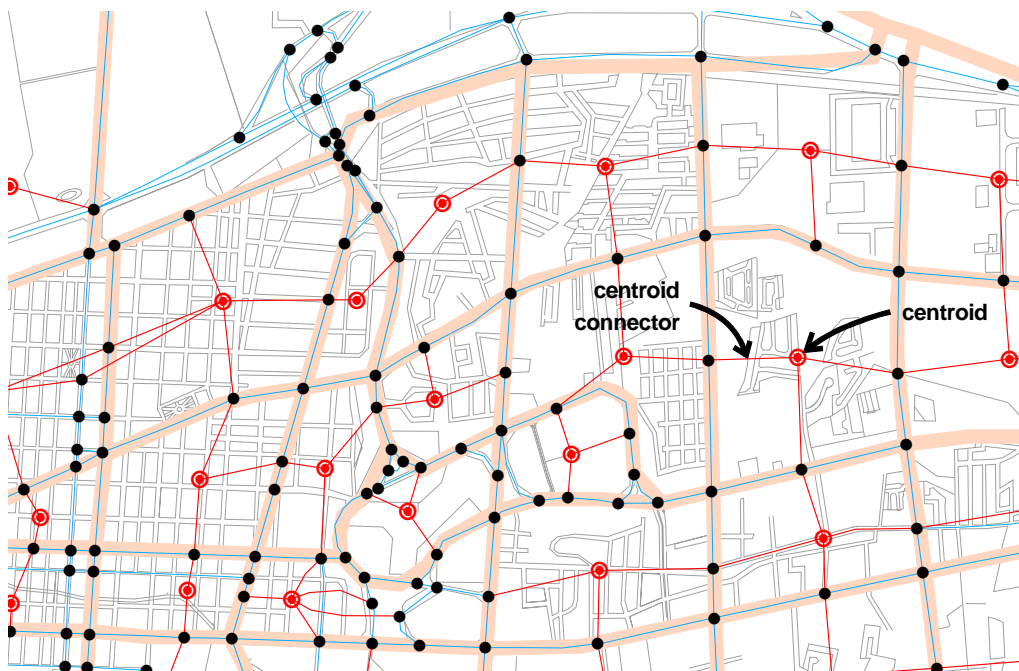


Figure 2. Centroid connectors tied to main roadway system.

After evaluating different zoning configurations, a final one was selected containing a total of 425 TAZs. This zoning design was reproduced in TransCAD as a GIS area coverage, attached with base year 1996 socioeconomic attributes, shown in Table 1.

Table 1. Attribute fields for TAZ structure.

Field	Description
ID	TAZ unique number (index)
Area	Surface in square kilometers
TAZ	TAZ consecutive identification number
ACTDENS96	Activity density for 1996
POP96	Total population for 1996
HH96	Total households for 1996
EMP96	Total employment for 1996
EMPB96	Basic employment for 1996
EMPR96	Retail employment for 1996
EMPS96	Services employment for 1996

This TAZ structure was the one used to establish area type categories² according to the activity density concept.

Street system coding

The final layout of links and nodes was reproduced in TransCAD as a geographic file (identified by the TransCAD file extension *.dbd*) which included centroid nodes and centroid connector links. The physical and operational characteristics inventoried for each street were recorded in the attached attribute database, using as a start the fields described in Table 2. At this point, and as shown in Table 2, the field LINK_TYPE was introduced to depict each link's functional classification as defined by TxDOT; this field is also used to differentiate centroid connector links from roadway links.

Table 2. Attribute fields for main roadway geographic file

Field	Description
ID	Link unique number (index)
Length	Length in kilometers
Dir	0: Two-direction flow, 1: One-direction flow
NAME	Street name
LANES	Total traffic lanes
MEDIAN	Existance of median
PAV_TYPE	Pavement type
PARKING	Existance of on-street parking
AREA_TYPE	Area type where the link is located
SpeedP_AB	Peak period travel speed, in typological AB direction
SpeedP_BA	Peak period travel speed, in typological BA direction
SpeedV_AB	Off-peak period travel speed, in typological AB direction
SpeedV_BA	Off-peak period travel speed, in typological BA direction
TimeP_AB	Peak period travel time (sec), in typological AB direction
TimeP_BA	Peak period travel time (sec), in typological BA direction
TimeV_AB	Off-peak period travel time (sec), in typological AB direction
TimeV_BA	Off-peak period travel time (sec), in typological BA direction
Time_AB	Overall average travel time (sec), in typological AB direction
Time_BA	Overall average travel time (sec), in typological BA direction
LINK_TYPE	Functional classification

² Tech Memo EITII-03, "Editing/analysis of the workplace/special generator survey database", IMIP (December 1998).

Figure 3 shows the final version of the main roadway system, as a link-node layout. For ease of identification, centroid nodes and centroid connector links are displayed in red. The TAZ structure is also provided. As summary, the main roadway system for 1996 is composed of a total of 3,490 links (857 centroid connectors, and 2,633 roadway links), as well as 2,628 nodes (434 centroid nodes for both internal and external zones, and 2,194 roadway nodes).

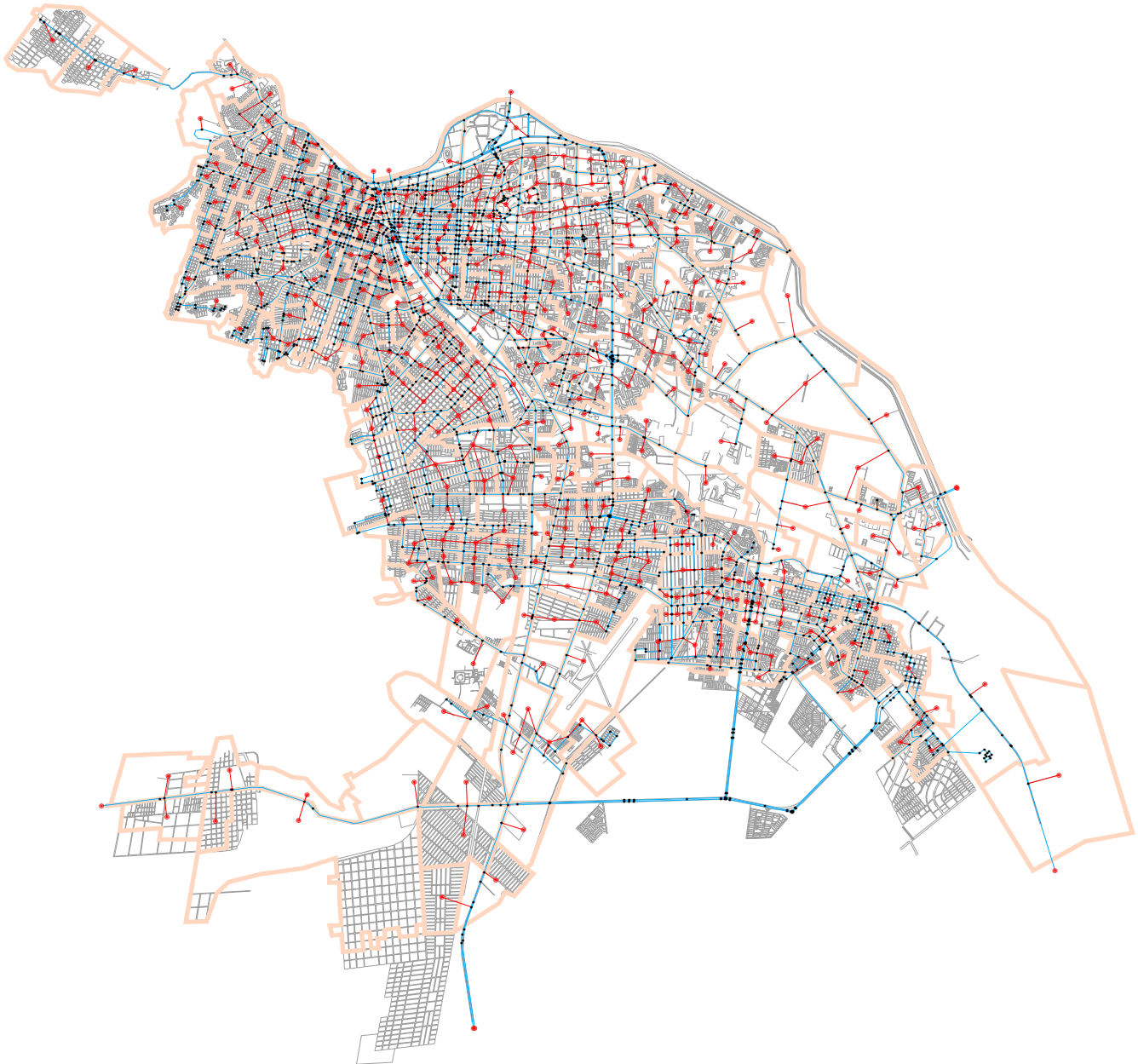


Figure 3. Main roadway system. Link-node GIS coverage superimposed over TAZ GIS coverage.

Figure 4 shows the main roadway system categorized according to the functional classification of each link. For a better interpretation of the layout, centroid connectors are not included. The following codes identify each functional classification under the LINK_TYP field: Expressway: 3, Principal arterial divided: 4, Principal arterial undivided: 5, Minor arterial divided: 6, Minor arterial undivided: 7, Minor arterial unpaved: 8, Ramp: 12, and Centroid connector: 0.



Figure 4. Main roadway system according to functional classification (centroid connectors not included).

Through special TransCAD commands, the roadway geographic file was then used as the base reference to create a roadway network (identified by the TransCAD file extension *.net*); this file configuration allows the introduction of additional transportation operational variables, and furthermore the manipulation of the link-node coverage to work transportation problems. Node delay and turn penalties obtained as part of the filed data collection effort were introduced as operational attributes of the network. Also, through this configuration the traffic flow direction of the links were assigned, allowing one-way or two-way flow.

Transit route system coding

Having necessarily created a roadway network, TransCAD allows the establishment of specific trajectories over the link layout, termed route systems, intended for the operation of special transportation modes on fixed paths. Thus, to portray public transportation service, a transit route system was developed over the main roadway network that included all of the different bus routes operating by 1996, as well as each route's performance data. Table 3 presents general information pertaining to these bus routes, including an ID

Table 3. General information on bus routes

COMPANY	ROUTE NAME	CODE	COMPANY	ROUTE NAME	CODE	COMPANY	ROUTE NAME	CODE
1A	MORELOS I, II, III	1A01	5B	TERCERA X CURVA	5B01	JUAREZ ZARAGOZA	SALVARCAR	JZ01
	JUAREZ NUEVO	1A02		REV. MEXICANA X CURVA	5B02		JILOTEPEC	JZ02
	LOMAS ALCALDES	1A03		PRESA-GRANJAS	5B03		SATELITE	JZ03
	LOMAS TEC	1A04		JUAREZ SAMALAYUCA	5B04		BARRIO AZUL-TIERRA NUEVA	JZ04
	PARQUES INDUSTRIALES	1A05		EJE VIAL X DIVISION	5B05		RECINTO	JZ05
	JARUDO	1A06		EJE VIAL X REVOLUCION	5B06		SAUZAL	JZ06
	NOT WORKING AT THE TIME	1A07		EJE VIAL X TERCERA	5B07		TORRES	JZ07
	PRADERA	1A08	6	27	6R01		ZARAGOZA DIRECTO	JZ08
	PIE DE CASA-LUCIO BLANCO	1A09		28	6R02		IMSS 48-TIERRA NUEVA	JZ09
	MORELOS 1 Y 2 POR ECO 2000	1A10		29	6R03	LINEAS DE JUAREZ	NOT WORKING AT THE TIME	LJ01
	TORRES X HIEDRA	1A11		30	6R04		NOT WORKING AT THE TIME	LJ02
	MORELOS I, II, III X JUAREZ NUEVO	1A12	RUTA NUEVA	6R05	NOT WORKING AT THE TIME		LJ03	
	MORELOS I, II, III X ECO 2000	1A13	28 SEGURO NUEVO	6R06	CRUCERO ALTAVISTA	LJ04		
	FUTURAMA X 16	1A14	7	MORELOS	7R01	LAZARO-FRONTE	LJ05	
	PARQUES (SORIANA) X JMAS	1A15		NOT WORKING AT THE TIME	7R02	NOT WORKING AT THE TIME	LJ06	
	MACHADO	1A16		MIRADOR	7R03	PERIODISTA-FRONTE	LJ07	
	JARUDO X JMAS	1A17		GRECIA	7R04	MERCADO DE ABASTOS	GALEANA X EJE	MA01
	PRADERA X JMAS	1A18		AZTECAS X NAHOAS	7R05		GALEANA X LIBERTAD	MA02
	PARQUES INDUSTRIALES X JMAS	1A19		NOT WORKING AT THE TIME	7R06		FLORES MAGON	MA03
1B	MORELOS X ERENDIRA	1B01	SANTA MARIA	7R07	JMAS X EJE	MA04		
	MORELOS X JILOTEPEC	1B02	MEXICO 68	7R08	GALEANA X CARRIZAL	MA05		
	TORRES X HIEDRA	1B03	8A	SEGURO SOCIAL NUEVO	8A01	PALO CHINO	MA06	
	TORRES X AVENIDA	1B04		CURVA	8A02	ORIENTE PONIENTE	ARROYO	OP01
2A	FARMACIA	2A01	8B	FUTURAMA	8B01		PERIODISTA	OP02
	JAZMINES	2A02		S.S. NUEVO (RUTA LOCA LARGA)	8B02	PERMISION UNIDOS	LOMAS	PU01
2B	CHIHUAHUA X CAMPA	2B01	PRESID (RUTA LOCA CORTA)	8B03	GRANJERO		PU02	
	CHIHUAHUA X HIMNO NACIONAL	2B02	10	AVICOLA X ABAJO	1001		NOT WORKING AT THE TIME	PU03
	SIERRA	2B03		SARABIA X ARRIBA	1002		DIVISION SUR	PU04
	BARRIO ALTO	2B04		MESA	1003		KM 30	PU05
	FIGUEROA	2B05		RANCHO	1004		REVOLUCION X EJE	PU06
2L	LAZARO-FRONTE	2L01		RETIRO	1005		REVOLUCION X REFORMA	PU07
	PERIODISTA-FRONTE	2L02		SALINAS	1006		NOT WORKING AT THE TIME	PU08
3A	ESCOBEDO X ALTAMIRANO	3A01		SARABIA X ABAJO	1007	TIERRA NVA TRANSP URBANOS	TIERRA NUEVA	TN01
	NOT WORKING AT THE TIME	3A02		SALINAS X PERIODISTA	1008		CERESO (NORTE-SUR)	TU01
	ESCOBEDO X VELARDE	3A03	AVICOLA X ARRIBA	1009	CERESO (SUR-NORTE)		TU02	
3B	IZQUIERDA X ARRIBA	3B01	SALINAS X ARROYO	1010	DIVISION MADERO (NORTE-SUR)		TU03	
	ZAPATA	3B02	CENTRAL	CENTRAL X 16	CE01		DIVISION MADERO (SUR-NORTE)	TU04
	IZQUIERDA X ABAJO	3B03		NOT WORKING AT THE TIME	CE02		NOT WORKING AT THE TIME	TU05
	NAVARRO	3B04		TLXCALA	CE03		DIVISION PONCIANO (NORTE-SUR)	TU06
	DERECHA	3B05	CIRCUNV ROJO	NOT WORKING AT THE TIME	CR01		DIVISION PONCIANO (SUR-NORTE)	TU07
	ANEXAS	3B06		NOT WORKING AT THE TIME	CR02	INDUSTRIAL	TU08	
4	NOT WORKING AT THE TIME	4R01	JUAREZ AEROP	CABLEADOS X ESCOBAR	CR03	CIRCUITO PIEDRERA X VELARDE	TU09	
	RIVERENO-CONIFER	4R02		CHAPULTEPEC	CR04	CIRCUITO PIEDRERA X CARRIZAL	TU10	
	RIVERENO X FIDEL VELAZQUEZ	4R03		RIVERENO	CR05	ESCOBEDO X AHUMADA	TU11	
	FRONTERA-SMART COUNTRY	4R04		CENTRO-ERENDIRA	JA01	PIEDRERA X VELARDE	TU12	
	MAQUILAS X 16	4R05		SAN LORENZO-ERENDIRA	JA02	VALLE DE JUAREZ	KM 20	VJ01
	JARDINES DEL BOSQUE	4R06	CENTRO-LUCIO BLANCO	JA03	PORVENIR		VJ02	
	MAQUILAS X RIVERENO	4R07	SAN LORENZO-LUCIO BLANCO	JA04	NOT WORKING AT THE TIME		VJ03	
5A	NOT WORKING AT THE TIME	5A01	CENTRO-KM 20	JA05	TIERRA NUEVA		VJ04	
	CERESO	5A02	SAN LORENZO-KM 20	JA06	ZARAGOZA		VJ05	
	PANTOJA	5A03	CENTRO-KM 18	JA07	KM 14		VJ06	
	CERESO X EJE VIAL	5A04	CENTRO-VIRREYES	JA08	KM 18		VJ07	
	DIVISION X MADERO	5A05	SAN LORENZO-KM 18	JA09				
	PORTILLO	5A06	SAN LORENZO-VIRREYES	JA10				
	CERESO X RUTA NUEVA	5A07						

code given by IMIP. A total of 144 different routes operated in the city by 1996, and 143 of these were coded as part of the transit route system. Figure 5 presents just two of these routes over the main roadway network, as an example of how these are displayed using TransCAD. The only route left out was not included due to its minimal operation schedule and limited coverage.

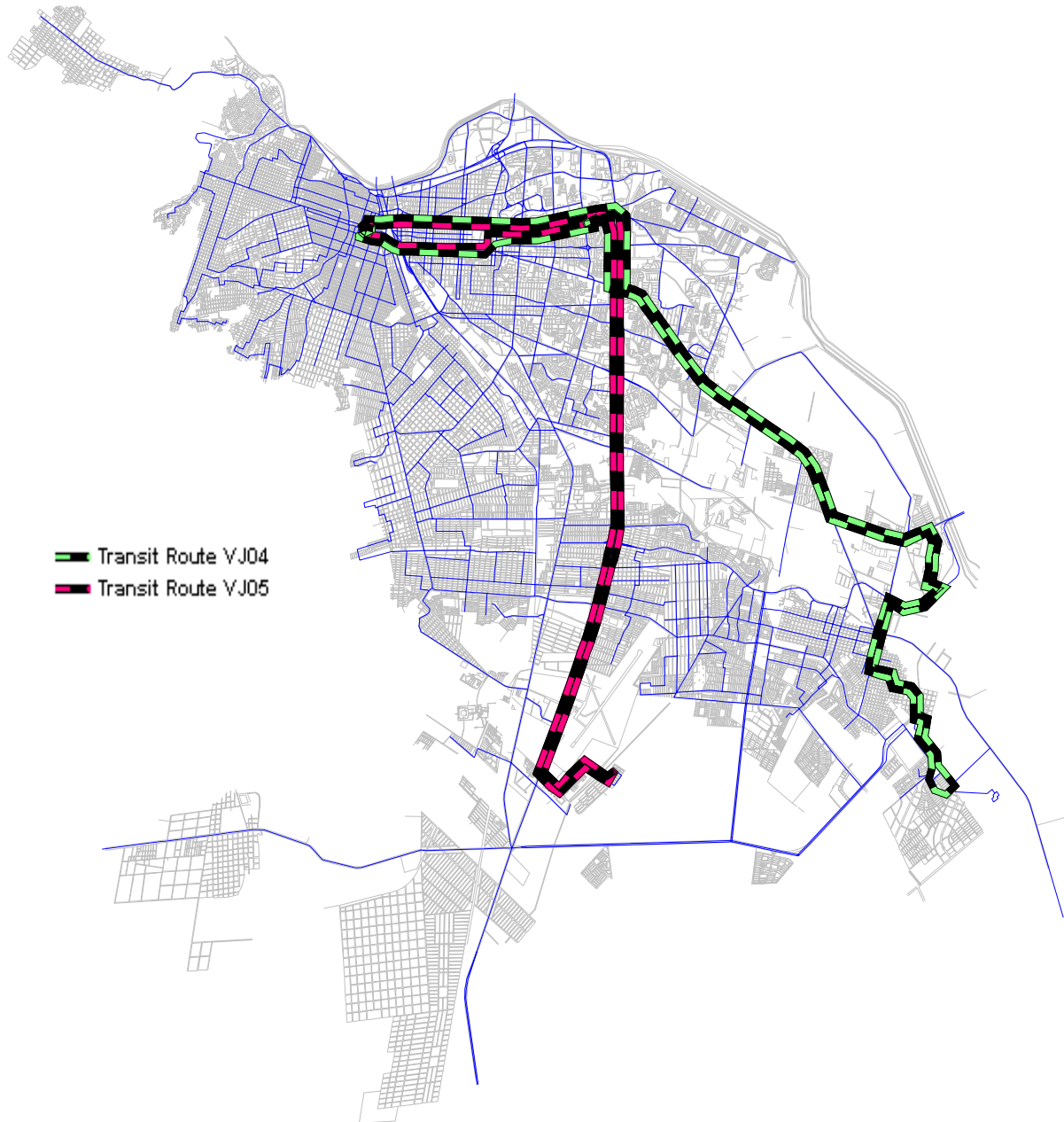


Figure 5. Example of transit routes, over main roadway system.

Components of the route system

Besides its graphical representation on a map, a route system is defined by 3 blocks of information, displayed in TransCAD as fixed-format binary tables (identified by the TransCAD file extension *.bin*): 1) a route table, a 2) a stop table, and 3) a link table. The route and the stop tables are automatically converted into map layers (with dataviews available) when a route system is created. Yet, a special command is required to convert the link table into a map layer; the reason being that the link table seldom could be fed practical meaningful data for operation analysis not covered already by both the route and stop tables.

1) Route table.

This table identifies the individual routes in a route system. The route table generated for the 1996 base year route system has the following fields:

Field	Description
ROUTE_ID	Route unique number (index)
ROUTE_NAME	Route code
SIDE	Side of centerline for route display
HEADP	Headway time in minutes at peak periods
HEADV	Headway time in minutes at off-peak periods
SPEEDP	Overall travel speed in Km/hr at peak periods
SPEEDV	Overall travel speed in Km/hr at off-peak periods
SPEED	Overall travel speed in Km/hr, averaged for all periods
FARE	Flat fare paid for boarding a transit unit
TFARE	Special fare (if any) for transferring between transit units
CAPACITY	Number of seat per hour provided
ALPHA	First parameter of the congestion function
BETA	Second parameter of the congestion function

Fields in **bold** are required by TransCAD

As previously mentioned, this table is available as a dataview under the TransCAD map layer "TC96".

2) Stop table.

This table lists the stops for all individual routes in a route system. The stop table generated for the 1996 base year route system has the following fields:

Field	Description
ID	Stop unique number (index)
Longitude	Longitude coordinates of the stop
Latitude	Latitude coordinates of the stop
Route_ID	ID of the route on which the stop is located
Link_ID	ID of the link along which the stop is located
Pass_Count	The pass over the link on which the stop is located
MilePost	Location measurement from the start of the route

Fields in **bold** are required by TransCAD

As previously mentioned, this table is available as a dataview under the TransCAD map layer "Parad". In the case of the 1996 base year route system, all transit stops were located either at the intersection between different routes, at the intersection of the routes with centroid connectors, or at the end nodes of each route, and not necessarily at the actual location where the buses stop. This was necessary since under the current operation scheme only a small number of the official stops are actually used as such; most of the time bus drivers and passengers select at will the stop locations along a route. Therefore the stops assigned to the model are only intended to serve as access/egress points of the transit network and interroute transfer points. To properly account for the actual boarding/deboarding delay on this simplified stop layout, an overall travel speed was computed for each of the routes, which included boarding/deboarding stop time. This overall travel speed is provided under the fields SPEEDP, SPEEDV, and SPEED on the route table, for different periods of the day.

Figure 6 shows an example of the previously described route/stop location layout for the 1996 base year route system. Since under this layout bus stops were positioned precisely over roadway network nodes,

many of the stop sites shown in Figure 6 actually gather several stops from several routes and/or several route passes.

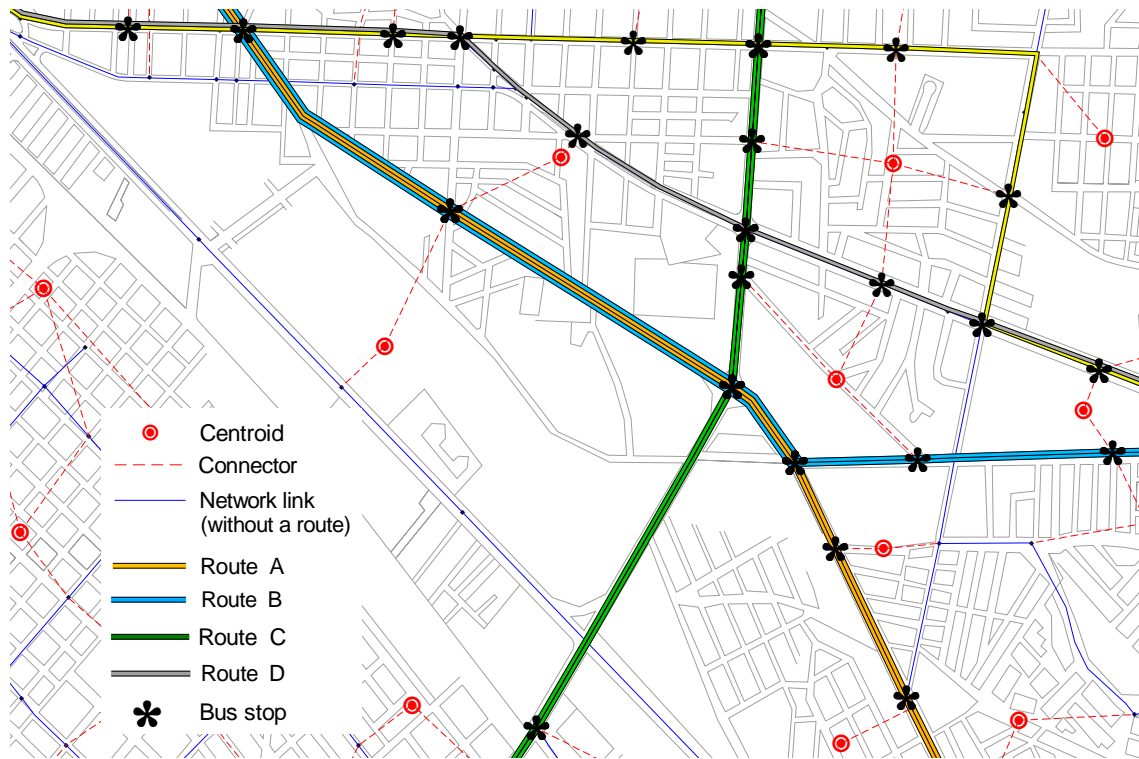


Figure 6. Bus stop layout for transit route system.

3) Link table.

This table lists the links that define each route of the route system. The link table generated for the 1996 base year route system has the following fields:

Field	Description
Route_ID	ID number of the route
Link_ID	ID of link that appears in the route
Direction	"+" if link appears in route in forward direction, "-" if else
Start_MP	Start milepost measurement
End_MP	End milepost measurement

This table is not readably available as a dataview. Nevertheless, special commands are at hand to generate one if required in the future.

Creating the transit network

When all of the attributes on these tables have been filled, a transit network can then be created in TransCAD. This special type of network (identified by the TransCAD file extension *.tnw*) is necessary in order to solve transportation problems in the special environment of transit operation. During this process of creating a transit network, additional attributes depicting general operation characteristics must be provided:

a) Merged stops on single nodes.

To reduce the size of the transit network file, and for better algorithmic performance TransCAD allows the merging of bus stops located within a certain threshold distance of each other (merged stops treshold).

There is no time or distance penalty associated with traveling between these merged stops; thus the stops are coincident for modeling purposes. As previously explained though, the 1996 base year route system for Juarez has all transit stops positioned precisely over a simplified set of roadway network nodes, thus already gathering several stops on single locations. Therefore the merged stops distance has been set to a minimal length of 10 meters just to ensure that these stops are considered on single transit network nodes.

b) Transfer links.

Another powerful tool of TransCAD is one that simplifies the process of coding transfer links through the provision of a transfer threshold distance. This distance indicates the maximum length between adjacent stops for which automatic transfer links are created. These transfers do have a travel time cost associated, which is specified as default for the maximum length; lesser distances between stops would automatically be assigned a proportional smaller travel time cost. In addition to the automatic transfer link tool TransCAD provides a more conventional means of designating transfer links, through the development of a transfer table. This can also be of assistance for particular transfers that do not fall under the automatic transfer link criteria (transfers of longer distance, different/special costs associated, or even transfer prohibition between adjacent stops).

For the 1996 base year route system all transfers were coded through the automatic transfer link tool, specifying a transfer threshold distance of 500 meters with a corresponding travel time cost of 6 minutes, thus implying a travel speed of 5km/hr (walking speed) between transfer stops. No transfer table was required.

c) Access and Egress links.

These links allow the connection of each TAZ to one or more stops in the route system. This is achieved through the use of an access link table. For the 1996 base year route system, the access link table has the following information:

Field	Description
Zone	ID of the TAZ
Stop	ID of the stop
Direction	Link direction (access only = 1 , egress only = -1 , both = 0)
Walk_T	Average travel time of link (in minutes)

Fields in **bold** are required by TransCAD

The Walk_T field provides the cost (in minutes) of getting from each TAZ to the access stops, or from the egress stops to each TAZ. It is intended to account for walking time between the actual trip ends and the bus stops. This information was obtained for each TAZ, from the household survey data and assuming a walking rate of 5km/hr. **In order to be able to use this table to create the transit network, first it needs to be converted into a TransCAD dataview.**

Final remarks

The development of the 1996 transportation network in TransCAD includes both street and transit systems, and provides the required environment to start network analysis and processing.

The 1996 network and corresponding data files developed under this task are fully compatible and consistent with those developed by TxDOT for travel demand modeling in the El Paso, Texas study area. This information in its electronic format will be sent to the project's members together with the present document for further review.