ANALYSIS OF FREIGHT MOVEMENT BETWEEN MAQUILADORA INDUSTRY AND PORTS OF ENTRY

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ABSTRACT

The maquiladora industry in Mexico plays an important role in the economy of both U.S. and Mexico but also border cities of El Paso and Ciudad Juarez. Ciudad Juarez has 29 industrial parks with 350 maquiladoras that ship goods produced in Mexico to warehouses in El Paso, Texas, from where they are transported to retail houses and consumers in other parts of the U.S.

The rapid expansion of Ciudad Juarez as a result of the exploding maquiladora industry could not be supported by plans to manage urban mobility (specially the trucks) within the city. Hence, lack of timely transportation planning resulted in overloaded traffic network. This has resulted in trucks having to use local and often congested inner city streets.

With this in perspective, the researchers developed a large scale traffic simulation model for Ciudad Juarez and analyzed the mobility of commercial vehicles within the city especially between the industrial parks and international border-crossings. The simulation model will prove to be a valuable tool to improve the mobility of commercial vehicles within the city. Using the simulation model, planners and decision makers can improve the flow of trucks by identifying congested roadway segments and develop infrastructure improvement plans.

1 Introduction

The City of El Paso, Texas, together with Ciudad Juarez, Chihuahua, comprises the one of largest metropolitan area on the United States-Mexico border. The approximated combined estimated population of these two cities is 2 million [1] [2].

The El Paso/Ciudad Juarez borderplex economy depends highly on the trade between both cities. This commercial trade is categorized in two groups: industrial and commercial. The commercial is related to the stores and services derived from Mexican visitors from Ciudad Juarez that demand cheaper, up-to-date, and high variety products that are not available in their city. The second group is related with the maquiladoras industry. This group demands supplies and services from companies in United States to be processed in the Ciudad Juarez Maquila industry. This phenomenon has an important impact in El Paso because contributes with direct and indirect jobs, retail sales, companies' providers of services, transportation, warehouses, etc. [3].

1.1 Manufacturing Industry (Maquiladoras)

The maquiladora industry has an important role in the economy of the borderplex. Ciudad Juarez has 29 industrial parks where 350 maquiladoras are located. The industrial parks are located in three main industrial zones in the city: Poniente (Western) with 11 industrial parks, Centro (Downtown) with 6 industrial parks, and Sur-Oriente (southeastern) with 12 industrial parks. Some maquiladoras are located outside of the industrial parks. Figure 1 shows the location of different industrial parks in Ciudad Juarez.

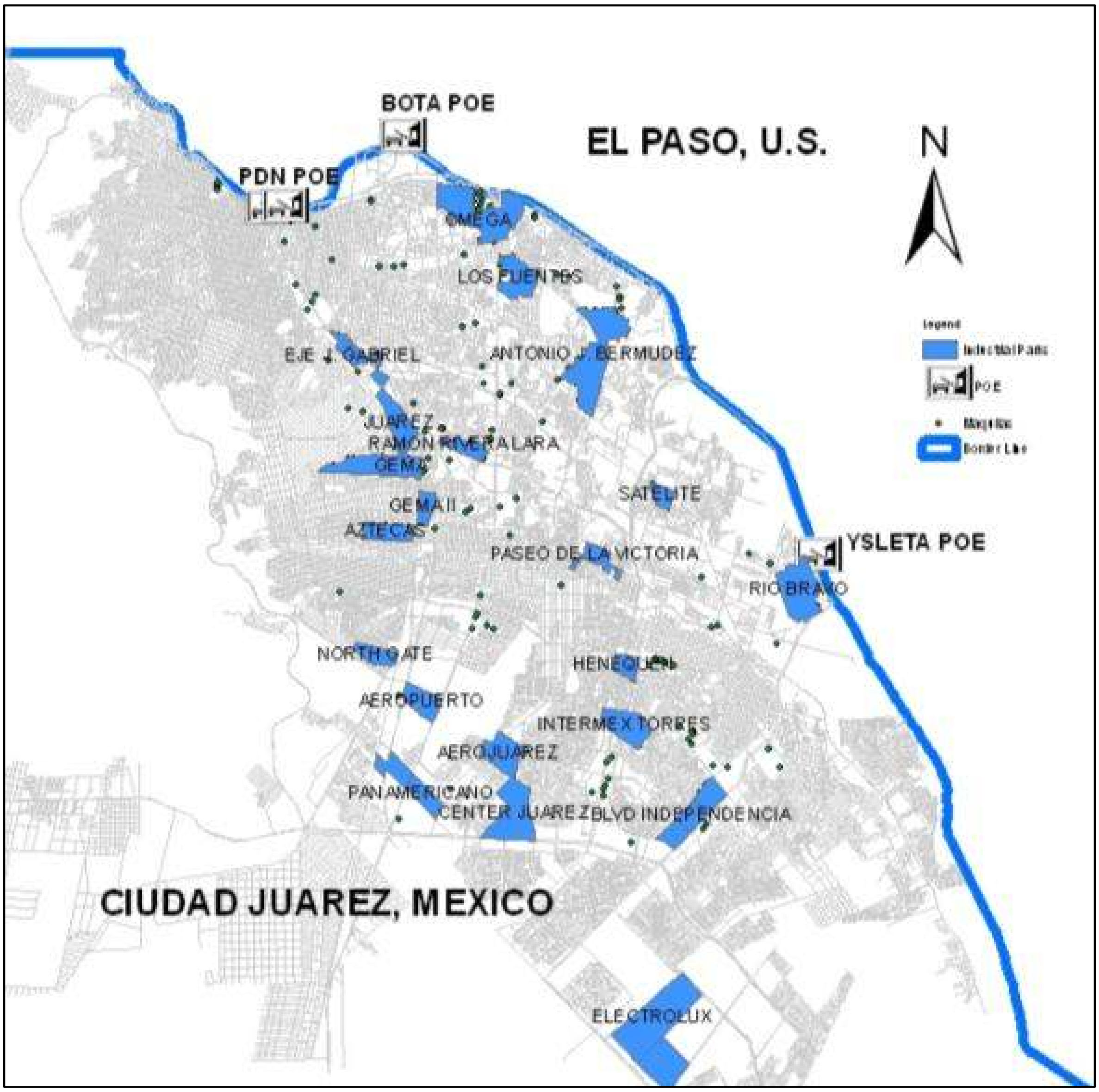

Figure 1 - Location of Industrial Parks in Ciudad Juarez.

1.2 Freight Movement between Ciudad Juarez and El Paso

Because the borderplex is the seventh largest manufacturing center in North America (in terms of workers) [4], the demand of truck transportation is one of the most important factors on the U.S./Mexico border. Trucks cross through the ports of entry in both northbound and southbound directions. In the northbound direction, trucks transport final products to warehouses located in El Paso or directly send their finished products into the U.S. through two ports of entry (Bridge of the Americas and Ysleta). In the southbound direction, through one port (Bridge of the Americas), trucks return empty to Ciudad Juarez or transport supplies stemming from the manufacturing strategy of "production sharing" adopted by companies on both sides of the border. The production sharing consists of sub-assembly on one side of the border and finished products on the other side.

Since 2001, border crossing times of northbound traffic coming from Ciudad Juarez through three ports of entries has increased significantly. Higher delay at the ports of entry has a negative impact on demand for travel, which ultimately affects the economy of both cities. In addition, longer wait times increase lost hours of work, lost productivity, wasted fuel, air pollution, etc.

Freight border crossing delays have a higher significance due to their effect on the maquiladoras industry; a key element of the borderplex economy. Trucks cross the border into the U.S. via two ports of entry in the El Paso area. Unlike private cars, the demand for trucks crossing through the ports of entry in El Paso is high due to the industrial activities between the two countries. Thus, the demand for trucks crossing the border is directly related to high or low production by the maquiladoras. In the last 12 years, the number of trucks crossing the border into El Paso has had a positive increase. This growth has not been affected by the violence in Ciudad Juarez.

1.3 Mobility Issues in Ciudad Juarez

Due to the growth of the maquiladoras industry after 1960, Ciudad Juarez could not keep up with the urban planning process. The lack of planning resulted in an overloaded traffic network with considerable decrease in mobility. More specifically, decrease in mobility is mainly due to inadequate capacity, frequent accidents, etc. In spite of the growing security issues, new companies continue to set up factories in Ciudad Juarez and more people migrate to Ciudad Juarez for jobs. Most likely, the population growth will result in more congestion. Hence, the city needs to evaluate the current traffic network and evaluate how it affects the accessibility of personal and commercial vehicles, especially to industrial parks and to the ports of entry.

1.4 Problem Statement

The growth and expansion of the city of Ciudad Juarez to the south and southeast directions has made it so that the ports of entry are now located far from the newly developed urban areas. On the other hand, the fast expansion of the city, a result of the maquiladoras industry between the 1960s and 1990s, did not provide an ideal environment for planning and managing an urban mobility plan. Consequently, the housing developments located around the ports of entry have avenues and streets that have a limited capacity for connecting traffic from the new housing areas to the ports of entry.

In the same way, the initial location of industrial parks was defined in strategic sites with feasible access to high capacity avenues and distributed around the urban area to provide easier access to and from the ports of entry. However, because of the growth of the urban areas, the industrial parks that were once outside the city are now inside the city core. This has resulted in trucks having to use local and often congested inner city streets to transport products and supplies from/to the maquiladoras. Hence, delays for truck traffic within Ciudad Juarez have increased significantly. The delay for trucks has been exacerbated by the increasing number of accidents, limited roadway capacity, and other traffic controls.

The efficient and reliable transportation of goods is an integral part of the production process of the maquiladoras industry, so this situation affects the whole maquila industry. Worsening mobility within the city imposes a high transportation cost to companies producing and moving goods across the border.

1.5 Objective of the Project

The objective of this particular project is to develop a traffic simulation model for the Ciudad Juarez to analyze and evaluate commercial freight movement between various industrial parks (maquiladoras) in Ciudad Juarez and ports of entry on the U.S.-Mexico border.

The traffic simulation model has numerous short-and long-range benefits, not only for planning but also in operation of transportation infrastructure, including port of entry. This effort will produce such a model to facilitate the planning and construction of roadways to connect with the ports of entry by providing an accurate estimate of traffic movement in the area. This kind of large scale traffic simulation model has never been developed for the Ciudad Juarez.

2 Literature Review

2.1 Microscopic Traffic Simulation

Microscopic traffic simulation (MTS) models simulate the behavior of individual vehicles within a predefined road network. They are used to estimate the likely changes in traffic patterns in the network resulting from changes to traffic flow patterns, physical improvements, etc. Microscopic traffic simulation models represent each vehicle unit (car, bus, train, bicycle, and pedestrian) with their own behavioral characteristics. Majority of MTS models employ Dynamic Traffic Assignment (DTA) to select the route choice of vehicles.

2.2 Large Scale Microscopic Traffic Simulation Models

The MTS programs initially were developed to model small networks due to the software or hardware limitations of processing the numerous events in a detailed model of a large network. MTS models are used to evaluate street networks for a relatively shorter period (e.g., peak hour) when the data can easily be obtained from using field data collection. Nevertheless, increased computer memory and speed has enabled the simulation of relatively large-scale networks. Hence, the models can be used to evaluate performance measures of the roadway network, predict scenarios under different variables such as accidents or traffic demand, optimize traffic signal design, realize accurate transportation projects, and execute evacuation and emergency detour plans. However, developing MTS for larger-scale street networks requires a much larger data set, which is costly and difficult to obtain [5].

The accuracy of MTS models depends on the quality of the model (road geometry and traffic control), calibration process, and the traffic demand input data (e.g., origin-destination matrix). The availability of accurate Origin-Destination (O-D) matrices that represent traffic demand in a MTS model is crucial. The current practice of using large-scale MTS models employs alternatives for importing the O-D into the network. The most frequently used methodology is the combination of a seed O-D matrix and traffic counts. This methodology is called "O-D Estimation" and has the advantage of updating the seed O-D matrix, which is obtained from a prior planning analysis. However, the disadvantage is the need of the seed O-D. [6].

3 Methodology

The methodology used to develop the MTS model of Ciudad Juarez consists of different stages. The flow chart shown in Figure 2 describes the process and the tasks involved. The methodology consisted of data collection from different agencies in Ciudad Juarez, coding the network and inputting traffic characteristics, generating the morning peak-hour O-D based on traffic intersection turn movements and traffic link flows, and finally, evaluating and calibrating the network comparing observed and simulated traffic counts data.

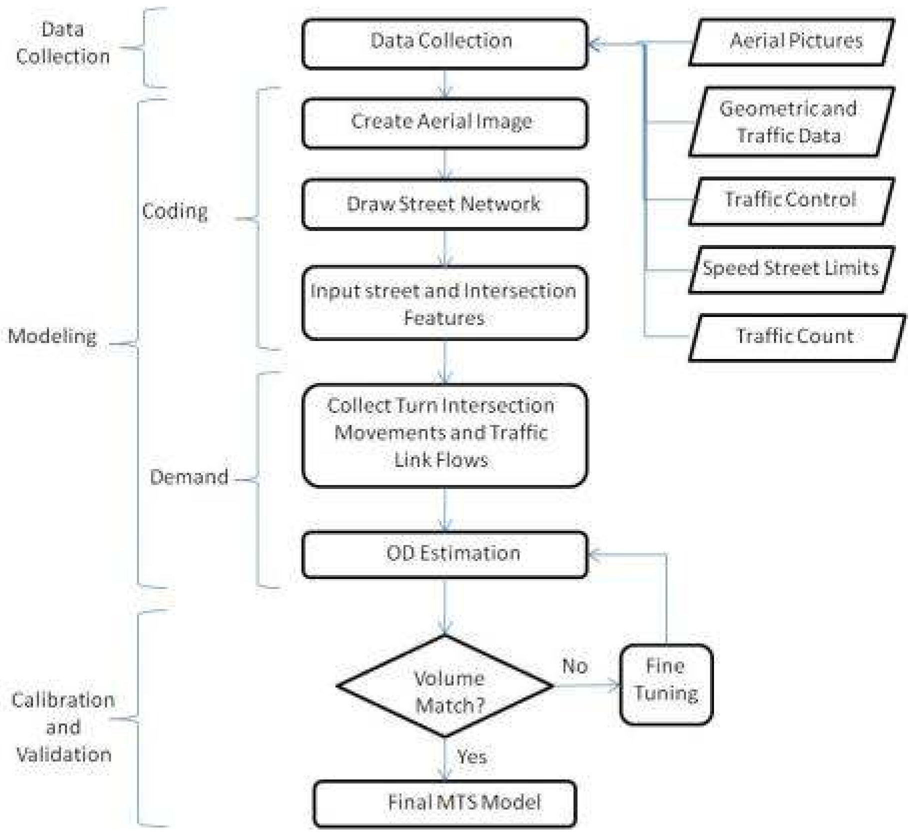

Figure 2 -Flowchart of the Methodology.

3.1 Data Collection

The data needed for developing the traffic simulation were obtained from three different agencies in Ciudad Juarez: Instituto de Investigacion y Planeación de Ciudad Juarez (IMIP) which is a metropolitan planning agency, Centro de Información Geográfica (CIG) of the Universidad Autónoma de Ciudad Juarez, and the traffic control office of the municipality of Ciudad Juarez.

In order to track the flow of trucks traveling between maquiladoras and ports of entry, 19 turning movement data collections were done in main intersections spread in the Ciudad Juarez street network. The intersection selection criterion was based on the locations with truck routes from maquiladoras and ports of entry with access to trucks. The data were obtained during typical days in the morning peak-hour (7:00-8:00). Besides the number of vehicles in each of the legs that comprise each intersection, a classification of them was done including the categories of cars, buses, trucks, and semi-trailer.

A database of traffic counts containing 36 locations throughout the city was provided by IMIP. These data were not sorted by vehicle; therefore they were used on links where trucks are not allowed to travel such as downtown. Finally, traffic from Bridge of the Americas (BOTA) and Ysleta ports of entry were obtained from field studies. The counts were done in both directions and for vehicle and truck access.

3.2 Modelling

The modeling process involved two stages: coding the street network and obtaining the demand (O-D) matrix to assign the traffic flow in the network.

Coding the Network consisted of (1) create an aerial picture mosaic, (2) draw the street and intersection configuration, (3) input signal timing control, (4) input speed information, and (5) input the right-of- way. Figure 3 shows the street network of Ciudad Juarez and a snapshot of the Ciudad Juarez street network modeled. The number of lanes, width, directionality, and horizontal curvature of the streets were based on online maps. Turning movements were obtained from online maps as well as field data collection. The network contains 5,513 links with a total distance of 560 miles (902 km).

Signal timings (204 pre-timed traffic lights) and right of way information was added to traffic lights and other traffic control locations. Finally, as part of the street network configuration, traffic restrictions on certain vehicle types were added.

The traffic demand in the network was obtained as a function of an estimated O-D which employed 126 traffic counts, 19 intersection movement data, ports of entry traffic counts, and 36 traffic count points provided by IMIP. The task involved a visual and traffic flow calibration process. Two O-Ds were obtained to provide a simulation of the traffic flow of vehicles and trucks in the network.

3.3 Calibration and Validation

The calibration process involved the visual calibration and the traffic flow calibration. The visual calibration consisted of evaluating the behavior of the traffic in the network. Figure 4 shows a comparative analysis of visual calibration of one intersection modeled.

The traffic flow calibration step consisted of comparing and fine-tuning traffic flow in the model. The process implied the iterative calculation of an O-D matrix, capable of reproducing a vehicle flow pattern in the network similar to that observed in the field.

The GEH (Geoffrey E. Havers) empirical formula was used to evaluate the differences between the observed and the modeled traffic flow.

Source: Traffic Control Department of Ciudad Juarez

Snapshot of Ciudad Juarez Street Network Model

Figure 3 - Street Network Configuration of Ciudad Juarez.

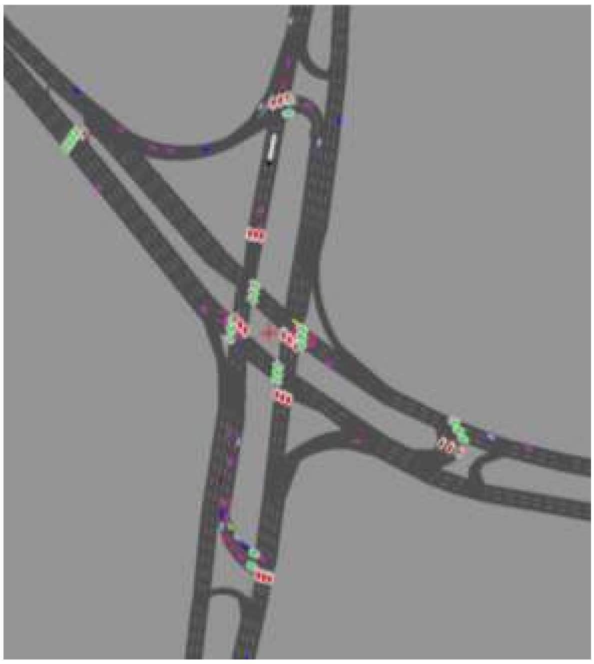

Figure 4 - Snapshot of Bermudez Ave. and Ejercito Nacional Ave. Intersection

4 RESULTS

Measures of effectiveness (MOEs) representing traffic delay and congestion incurred to trucks on pre-defined routes connecting different origins (industrial parks) and destinations (entrances to ports of entry) were obtained and evaluated. These routes represent the shortest path available. The MOEs selected to evaluate the truck movement were simulated travel time and delay. Modeled travel time represents the total truck average travel time from origin to the destination. Delay represents the difference between the modeled travel time and free-flow travel time. Delay includes the average delay due to traffic congestion and traffic control devices.

Results from the analysis allowed identification of how vehicle congestion in the network affects truck movement. Traffic congestion has an especially significant effect on trucks traversing through routes that go through the inner core of the city. Also, MOEs were obtained to analyze the difference in travel time of trucks originating at different industrial parks going to the ports of entry.

A summary of the MOEs obtained from the simulation is presented in Tables 1 and 2. Table 1 includes MOEs obtained between individual industrial parks and the BOTA port of entry. Table 2 includes MOEs between Chihuahua and Casas Grandes highways entries to BOTA port of entry. In the same context, the MOEs between industrial parks and both highway entrances were obtained to Ysleta port of entry.

4.1 Analysis

The analysis of MOEs between different industrial parks and highway entrances from Ciudad Juarez to both ports of entry indicates that the longer the travel distance connecting them, the longer the travel time is as shown in Figure 5. However, from the delay MOE it is possible to detect that the delay for commercial vehicle traffic is not correlated with the travel distance as illustrated in Figure 6.

The delay is caused by the traffic of the network particularly in minor streets. Some trucks with longer trips use freeway corridors where the delay is lower than for shorter trips because trucks travel through urban streets that are usually congested.

Figure 7 shows that the average percentage of delay incurred to trucks traversing between industrial parks and the Ysleta port of entry is approximately 32% of the total travel time. In the case of the BOTA port of entry, delays represent a 35% of the total travel time. Figure 8 shows the proportion of delay for trucks from each industrial park to the BOTA port of entry.

Table 1 - MOEs between Individual Industrial Parks and the BOTA (Americas Bridge) Port of Entry.

Industrial Park	Modeled Travel Time	Free Flow Travel Time	Delay	Length (miles)

Juan Gabriel	0:21:59	0:15:11	0:06:48	8.51
Juarez	0:20:26	0:14:51	0:05:35	7.60
Gema	0:21:59	0:16:35	0:05:24	8.65
Gema II	0:24:47	0:16:53	0:07:54	9.06
Aztecas	0:28:28	0:15:34	0:12:54	8.51
North Gate	0:34:59	0:19:34	0:15:25	11.11
Aeropuerto	0:32:38	0:17:46	0:14:52	9.94
Panamericana	0:32:10	0:20:14	0:11:56	11.51
Industrial Center Juarez	0:35:49	0:22:49	0:13:00	13.01
AeroJuarez	0:33:05	0:23:04	0:10:01	12.44
Electrolux	0:36:59	0:29:20	0:07:39	20.15
Blvd Independencia	0:29:25	0:22:48	0:06:37	16.65
Intermex Blancas	0:28:04	0:19:33	0:08:31	14.42
Intermex torres	0:32:03	0:20:16	0:11:47	11.81
Henequen	0:32:13	0:22:09	0:10:04	15.67
Paseo de la Victoria	0:23:35	0:14:39	0:08:56	8.17
Rio Bravo	0:26:24	0:19:43	0:06:41	13.98
Satelite	0:28:59	0:12:38	0:16:21	8.28
Rivera Lara	0:17:31	0:10:58	0:06:33	5.87
Bermudez	0:11:25	0:09:51	0:01:34	5.94
Los Fuentes	0:06:55	0:05:25	0:01:30	2.84
Omega	0:07:31	0:03:59	0:03:32	1.93

Table 2 - MOEs between Chihuahua and Casas Grandes Highways Entries and BOTA (Americas Bridge) Port of Entry.

Arriving to Juarez from:	**Modeled Travel Time**	**Free Flow Travel Time**	**Delay**	**Length (miles)**
Chihuahua	0:33:36	0:21:40	0:11:56	12.73
Casas Grandes	0:40:21	0:28:24	0:11:57	16.40

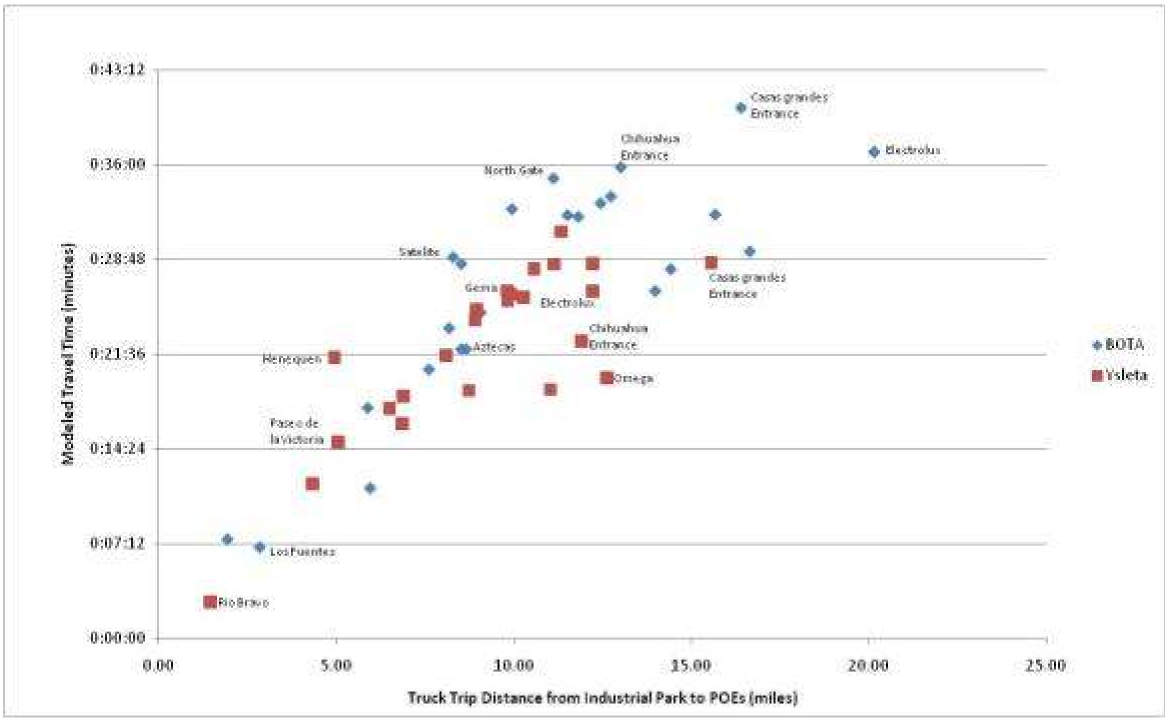

Figure 5 - Comparison of Simulated Travel Time of Commercial Vehicles between Individual Industrial Parks and Both Ports of Entry.

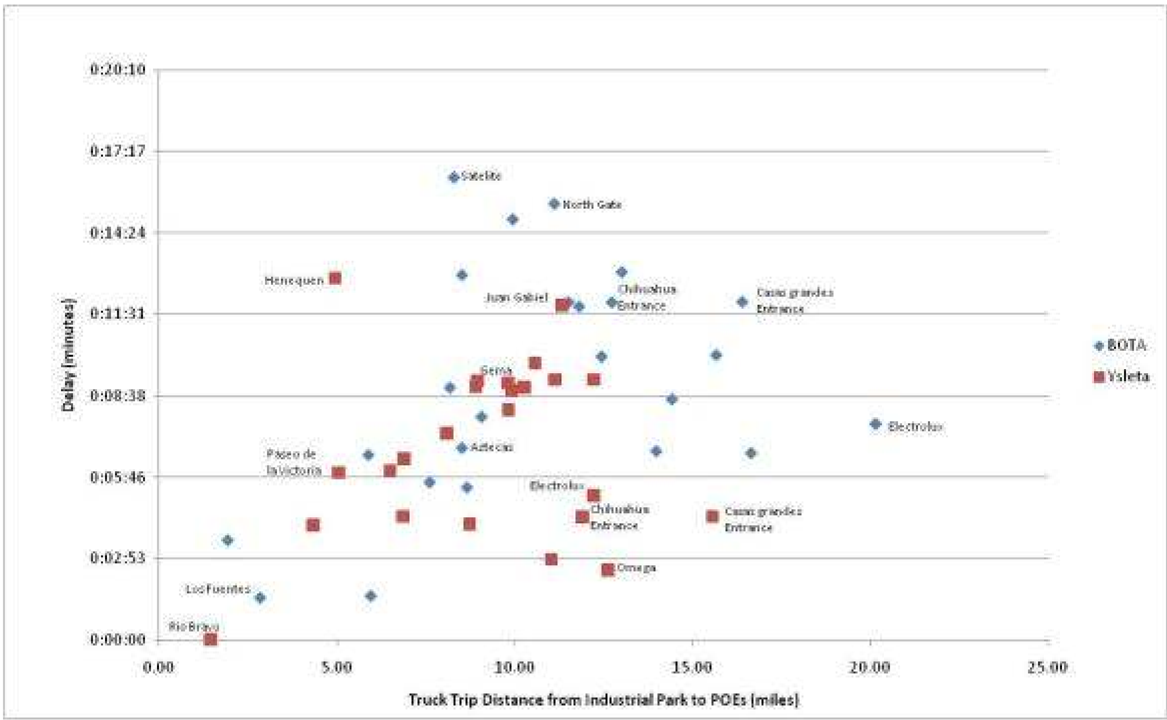

Figure 6 - Comparison of Delay of Commercial Vehicles between Individual Industrial Parks and Both Ports of Entry.

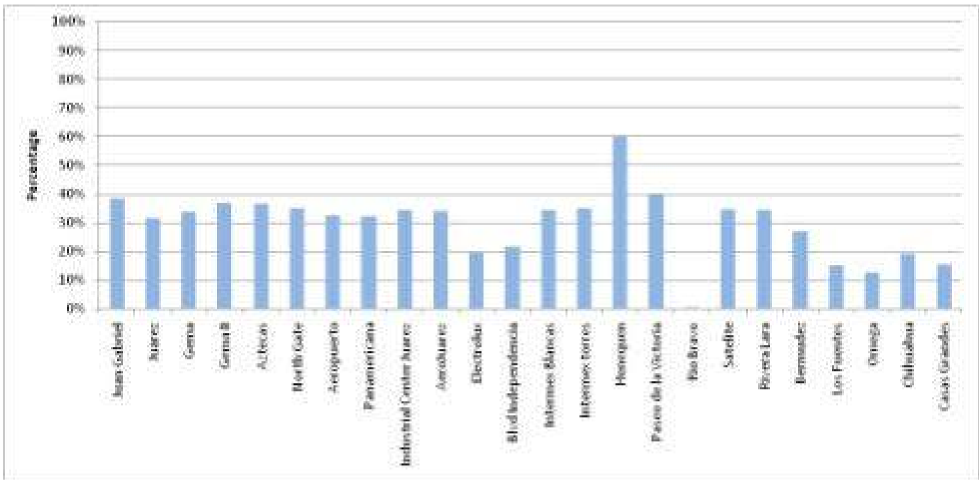

Figure 7 - Percentage of Delay Incurred to Trucks Originating from Different Industrial Parks and Both Highway Entrances to Ysleta (Zaragoza Bridge) Port of Entry.

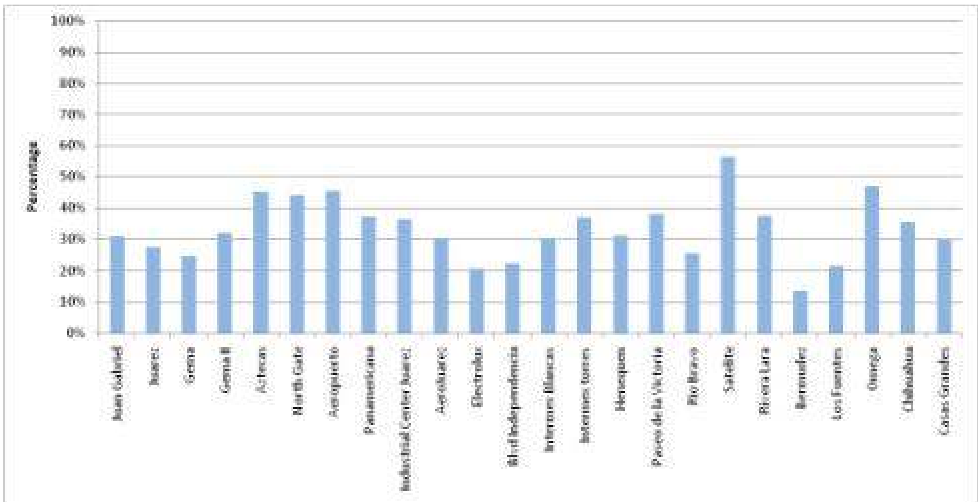

Figure 8 - Percentage Delay Incurred to Trucks Originating from Different Industrial Parks and Both Highway Entrances to BOTA (Americas) Port of Entry.

The simulation model also provides delay incurred by trucks on different segments that form a path of trucks traveling from the industrial parks and highway entrances to both ports of entry. Using the simulation results, segments of the routes with higher delays were identified to target the segment for possible traffic improvements in order to reduce delay over the entire routes (paths).

Figure 9 shows the comparison of two trucks paths traveling from the Chihuahua highway entrance and from the industrial park Gema to the Ysleta port of entry.

The first path shows the longest route. However, it has lower delay. Once trucks leave the freeway and enter surrounding arterials, delays are substantially increased due to intersection impedances caused by congestion, queuing, and pedestrians. The specific delay is a result of the queue at the intersection of Ramon Rayon and Clouthier as shown in Figure 10.

On other hand, the truck route that connects the industrial park Gema with the Ysleta port of entry is affected by the traffic because the trucks travel on different urban streets and have to traverse through several intersections. Figure 11 shows different locations in the city where traffic delays are prevalent.

Path of Trucks Travelling from the Chihuahua Highway Entrance to the Ysleta Port of Entry

Path of Trucks Travelling from. Gema to the Ysleta Port of Entry

Figure 9 - Comparison of Trucks Paths Traveling from Different Origins to the Ysleta Port of Entry.

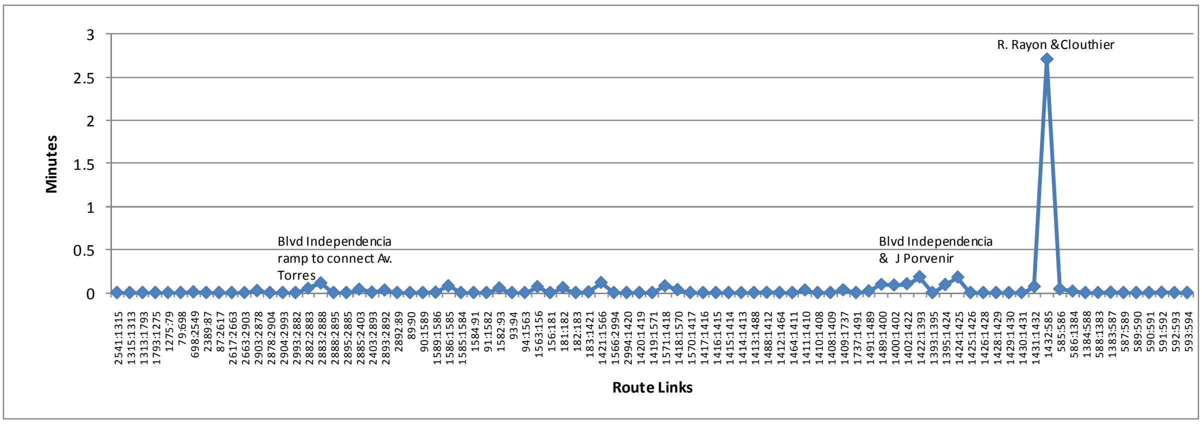

Figure 1 - Delay on Segments of a Path from the Chihuahua Highway Entrance to the Ysleta Port of Entry.

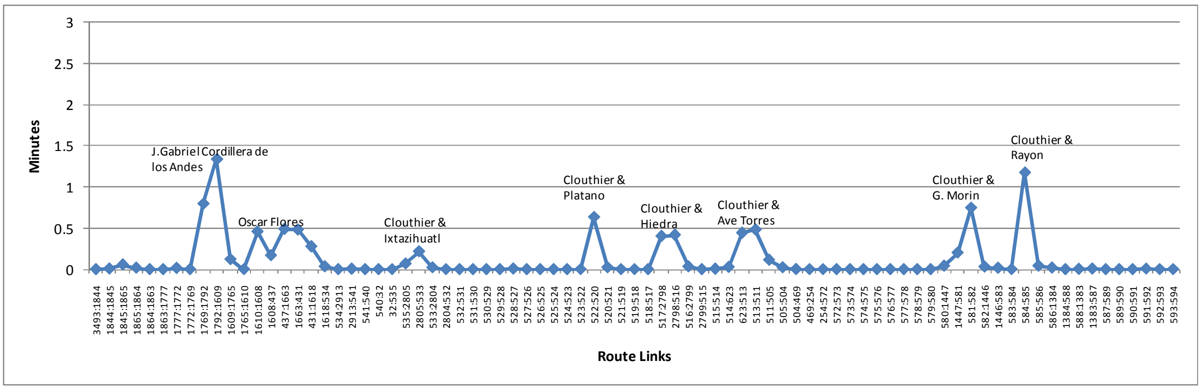

Figure 2 - Delay on Segments of a Path from Gema to the Ysleta Port of Entry.

In the same context, but applied to the BOTA port of entry case, a comparison of two trucks routes from different origins traveling to the BOTA port of entry shows how urban street traffic affects the delay of trucks as they traverse to their destinations. Figure 12 shows the path of the trucks traveling from the industrial park Independencia and industrial park Aztecas to the BOTA port of entry.

Delays on the first path occur on freeway segments and at the intersection of Bermudez Avenue, as illustrated in Figure 13. The second path has a shorter distance and higher delay than the first one, which is mostly due to traffic congestion in the inner core of the city as depicted in Figure 14.

Path of Trucks Traveling from Independencia to the BOTA Port of Entry.

Path of Trucks Traveling from Aztecas to BOTA Port of Entry

Figure 3 - Comparison of Trucks Paths Traveling from Different Industrial Parks to the BOTA Port of Entry.

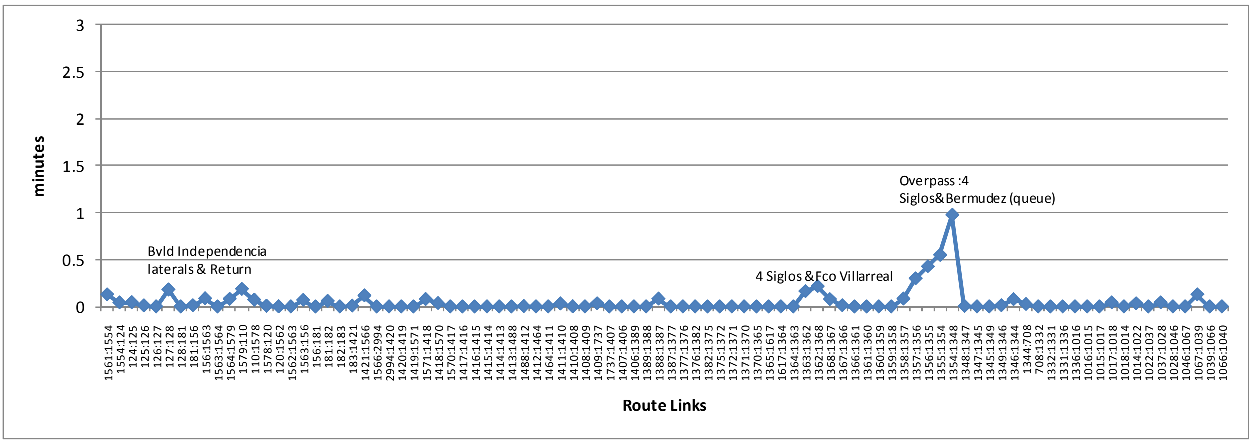

Figure13. Delay on Segments of a Path from Independencia to the BOTA Port of Entry.

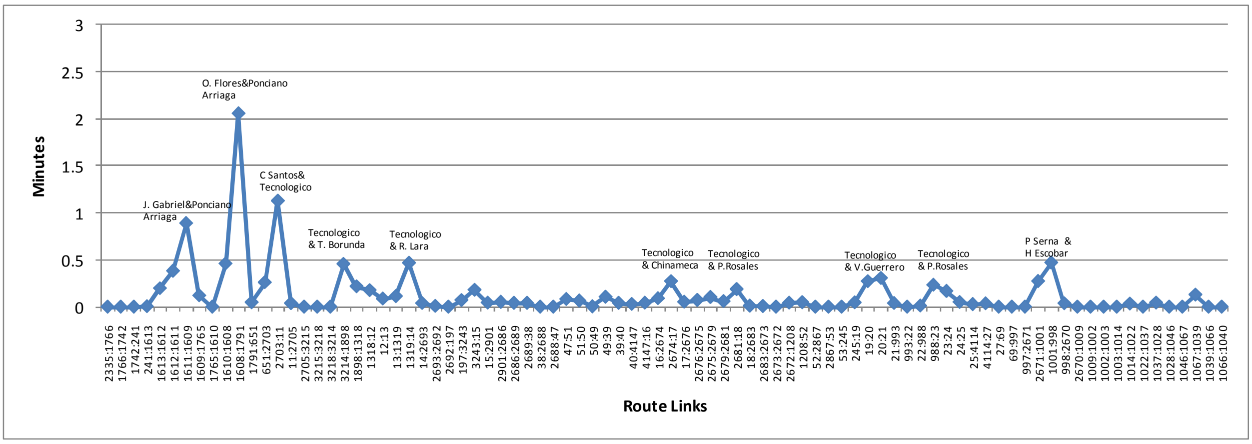

Figure 144. Link Delay of the Path of Trucks Traveling from I.P. Aztecas to BOTA Port of Entry.

5 CONCLUSION

The maquiladoras industry is an important element in the economy of the El Paso/Ciudad Juarez borderplex, and a crucial element in its process for reliable transportation of goods and people. The growth of the urban area and population of Ciudad Juarez has worsened truck mobility within the city due to the delays incurred by accidents, inadequate capacity, and traffic controls. The worsening traffic congestion affects the entire maquiladora industry imposing high transportation costs to companies produce and move goods across the border.

The objective of the research project was to highlight the importance of using a large scale microscopic traffic simulation model to analyze the mobility of commercial vehicles within the city, especially between the industrial parks in Ciudad Juarez and various ports of entry.

This project developed a large-scale traffic simulation model for Ciudad Juarez to analyze commercial freight routes from industrial park areas in Ciudad Juarez to the ports of entry on the U.S-Mexico border. The simulation model included major roadways that connect industrial parks, where the majority of the maquiladoras are established, to ports of entry. Traffic demand of autos and trucks was produced through an O-D estimation process that was based on traffic counts and traffic intersection movement studies in the city. However, for simplicity, the public transportation network was not included in the simulation model.

The simulation model developed in this research demonstrated various scenarios of truck paths connecting industrial parks to ports of entry. The analysis clearly showed that the delay on truck paths is attributed to congestion in the inner urban areas, while freeways surrounding the city provide reliable access to the ports of entry.

The research also showed that the delay contributes to 20–60% of the travel time of trucks moving between industrial parks and the ports of entry. This is unacceptable for carriers and shippers since the burden of delay translates into a higher cost for shipping and moving goods. Hopefully, the traffic simulation model and the results derived from the model will relay a strong need for improved planning and operation of transportation infrastructure in Ciudad Juarez.

As part of the future development of the model, it is highly recommended that several improvements be made, one of which is to include public transportation in the network. Also, calibration of this model was performed with a small number of field traffic counts and the researchers believe that additional counts will definitely improve the reliability of the model.

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