METHOD TO EVALUATING THE ECONOMICAL IMPACT ON TRUCKING BY A CHANGE IN HIGHWAY CLASSIFICATION

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ABSTRACT

Highway planning efforts, in our country, have been focused on infrastructure investment due to the road-damaging caused by the continuous transit of heavy vehicles. In this paper a different paradigm is evaluated changing technical specifications on roads to avoid the transit of heavy vehicles so it is presented a comprehensive methodology that identifies critical links and allows evaluating network performance in terms of cost, traffic and pollution. Using a real network, and a case study it is demonstrated that the approach yields reliable results for planners.

1. INTRODUCTION

In Mexico, the road classification issue is important because it allows the maximization of social and economic benefits to users, however, due it involves a set of opposite criteria and objectives, decision making is very complex between the authorities involved, particularly when it concerns roads with low specifications and high spatial connectivity. For example, for this type of roads, the Department of Conservation will want to ban heavy truck traffic to avoid the rapid deterioration of the pavements; Security authorities, instead, will focuses in reducing accidents due to large vehicles, promoting the shipment of goods with small vehicles. In contrast, Transport operation and Trade areas, will seek to make trucking a highly efficient and economical mode through connectivity offered by this class of roads, between production and consumption centers, without movement restrictions for heavy and large trucks to take advantage of economies of scale. Of course, carriers and cargo owners will agree with this last criterion.

In general, it can be said that road classification is very important for Mexico because in some way may affect the logistics and operational management of private transport networks, but specially, sets the path for economic efficiency of freight transport. In particular, it should not be overlooked that trucking is the mode that most cargo moves in many countries.

This paper presents a systematic methodology for assessing the economic impact on the trucking and the environment as a result of carrying out the upgrading of road sections, especially when going from a higher hierarchy classification to another lower category, highlighting the effect of restricting the movement of heavy and large vehicles for such purpose. Broadly, this methodology includes simulation models for travel assignment supplemented with vehicle operating costs and environmental impact models. In order to involve accessibility and mobility criteria, users origin and destination as well as vehicular volumes and composition were used as main inputs. Results of this approach seek to provide a better perspective for the evaluation of effects of road reclassification.

The paper structure is next: first describes this brief introduction that gives an idea of the theme addressed, then and to come in, we present a real case study of the impact and consequences derived from the unplanned and unevaluated reclassification of a highway from a higher to a lower level (B to C), the road section between Altamira port (Tamps) and San Luis Potosi City (SLP). Thirdly, the methodology used in this paper is described followed by a summary of the results of the methodology applied to the real case; and finally, are included some concluding remarks.

2. FEDERAL HIGHWAY NETWORK (RFC)

There are about 124,000 km federal paved roads in Mexico, according to NOM-012-SCT-2008 its road sections are classified into ET, A, B, C and D, according to their specifications. For roads classified as ET, A and B, all kinds of truck with approved weights and dimensions are allowed; roads type C, only allow the movement of simple articulated trucks but with higher restrictions on weights and dimensions, and doubled jointed truck traffic is restricted instead; finally, in type D roads is prohibited the circulation to all articulated trucks (Figure 1).

Figure 1. Configurations allowed by class of vehicle and roads in Mexico

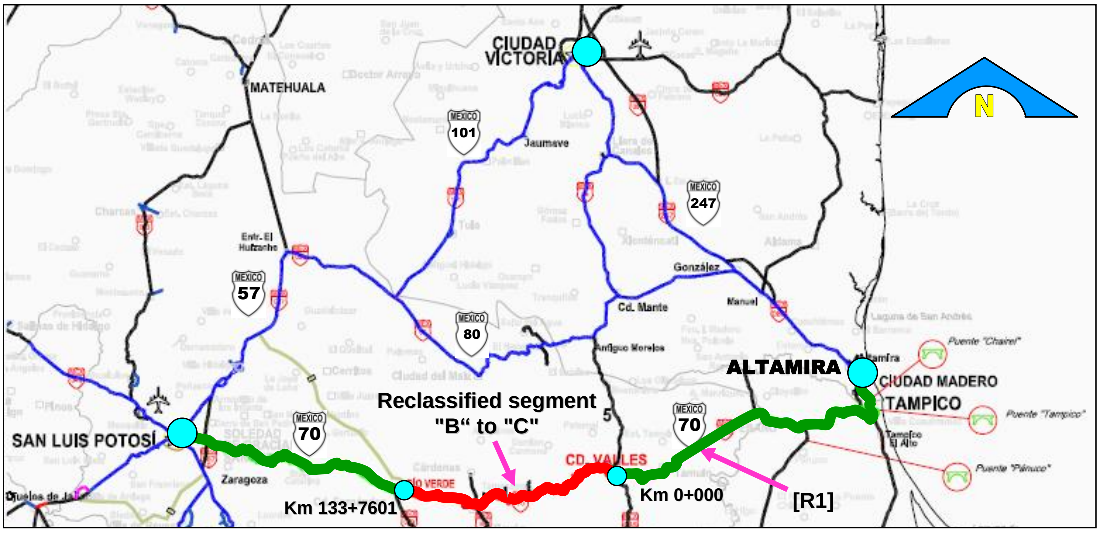
VEHICLE CLASS	NAME	NOMENCLATURE	NUMBER OF AXLES	CLASSIFICATION ROADS			
				ET y A	B	C	D
	Unit or truck (C2 y C3)	C2 or C3	2 ó 3	Yes	Yes	Yes	Yes
	Tractor-trailer combination	T2S1 to T3S3	3, 4, 5 ó 6	Yes	Yes	Yes	No
	Straight truck combination	C2R2 to C3R3	4, 5 ó 6	Yes	Yes	No	No
	Tractor-double trailer combination (*full trailer*)	T3S2 to T3S2R4	5, 6, 7, 8 ó 9	Yes	Yes	No	No

Source: NOM-012-SCT-2008.

3. CASE STUDY

Altamira port is located in the Gulf of Mexico and its operational characteristics and equipment has become an additional option to import or export goods of enterprises located in the Bajio (states: SLP, Guanajuato, Aguascalientes, Queretaro and some other parts of the West). Traditionally, to intern or export containers by that port, trucking companies, use Tractor-trailer combination and Tractor-double trailer combination (full trailer), through the highway MEX-070 Altamira - Ciudad Valles - SLP classified as "B "; however, in December 2005 local authorities decided to reclassify the road segment Rio

Verde-Ciudad Valles (km 0 +000 to 133.76), from a higher hierarchical level "B" to one lower level "C" with the idea of increasing security on this road (see Figure 2).



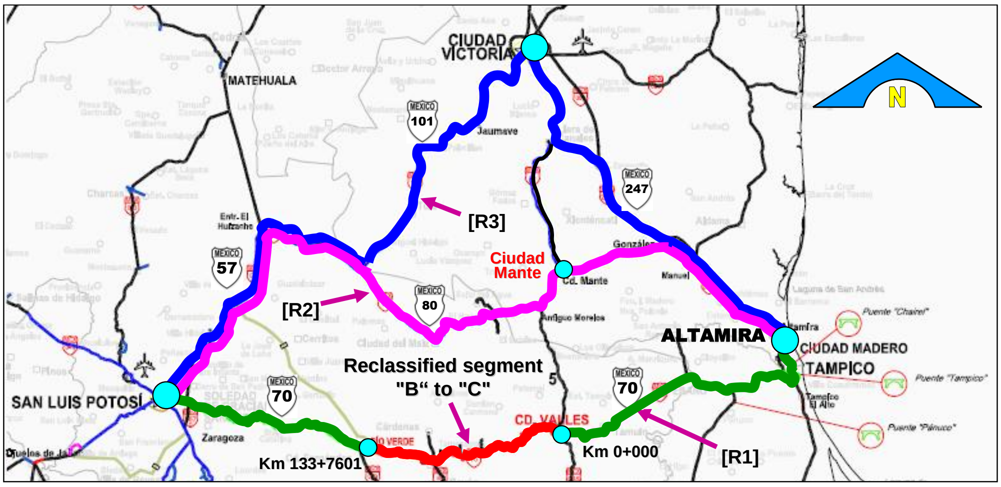
▬ Route 1 Altamira-San Luis Potosí (for Ciudad Valles) [R1]

▬ Segment restricted to transit of tractors or trucks with double trailer

Figure 2

Traditional route until just before December 2005

Following this reclassification, some trucking companies were forced to change its traditional route (R1) for alternative routes (R2 and R3) that were longer and with higher cost and travel time (Figure 3).



▬ Route 1 Altamira-San Luis Potosí (for Ciudad Valles) [R1]

▬ Route 2 Altamira-San Luis Potosí (for Ciudad Mante) [R2]

▬ Route 3 Altamira-San Luis Potosí (for Ciudad Victoria) [R3]

▬ Segment restricted to transit of tractors or trucks with double trailer

Figure 3

Alternate routes between the Altamira port and SLP (to the Bajio), Mexico

Once the circulation for double articulated trucks was restricted on Rio Verde-Ciudad Valles road, carriers were seen a dilemma between using smaller trucks to transport their merchandise or pay a higher freight charges for transporting its products via a longer route with the corresponding increase in time. In theory, one could assume that the reclassification of a road and the sequent restriction in circulation to vehicles with double trailer would encourage the cargo owner to change vehicle configuration to follow the traditional route and keep travel time to avoid affecting the planned logistics. However, in practice, the rate for a single truck (tractor-trailer combination) is similar to a tractor-double trailer combination, in fact in some cases, depending on the route, trucks' performance, the slope of the road as well as other factors; the difference from the single truck freight to the double articulated freight may only represent an increase of 30%. The reason is very simple, diesel consumed to move two trailers is not double of that required to move a single trailer, and also only one operator is paid, with following savings on travel expenses and tolls.

Considering the above factors, it is not surprising that during the interviews with different logistics agents operating in Altamira port was reported that most of its customers located in the Bajio area, opted to seek alternative ports in order to access them with lower cost and time than currently incurred to move their cargo at Altamira port. Table 1 summarizes the data provided by respondents and compares the traditional route with alternative routes connecting the Bajio and Altamira port through SLP

Table 1. Comparison route R1 vs R2 y R3

ROUTE	TIME (h)	LENGTH (km)	DIESEL CONSUMPTION (liters)	COST DIESEL (pesos)	PAYMENT TO OPERATOR	RATE	
						TRACTOR-TRAILER COMBINATION	TRACTOR-DOUBLE TRAILER COMBINATION (*FULL TRAILER*)
R1	9.0	425.00	510.0	$4,651.20	---	$10,500.00	$15,600.00
Base	100%	100%	100%	100%	100%	100%	100%
R2	10.4	470.6	564.7	$5,149.70	---	$11,760.00	$17,472.00
Increase	(1.4 h) 15.0%	(45.6 km) 10.7%	(54.7 lts) 10.7%	10.7%	112%	12.0%	12.0%
R3	11.3	592.00	710.4	$6,478.85	---	$12,550.00	$18,000.00
Increase	(2.3 h) 21.7%	(167 km) 35.5%	(200 lts) 35.5%	35.5%	124.0%	17.4%	13.7%

Source: Interviews to Carriers on 2010.

4. ECONOMIC IMPACT

Under this scenario, the economic impact is significant because it is estimated that about 95,000 articulated trucks are deviated annually from its traditional route (R1) to alternate routes (R2 and R3), resulting in higher travel times, kilometers, fuel consumption, costs and extra charges as tariffs (see table 2). Of course, these concepts do not include extra payment to operators, which carriers say that it increases between 12 to 24%.

Table 2. Increases in time, kilometers, diesel, costs and rates

CONCEPT	T3S2	T3S3	T3S2R4	OTHERS	TOTAL
Deviated trucks to R2	21,170	5,840	16,060	14,496	57,566
Deviated trucks to R3	10,585	2,920	12,045	11,597	37,147
Time (hours)	52,396	14,454	48,782	45,662	161,294
Length (kms)	2,731,989	753,652	2,743,048	2,596,979	8,825,667
Diesel consumption (litres)	3,278,386.20	904,382.40	3,291,657.60	3,116,374.54	10,590,801
Cost Diesel (pesos)	29,898,882.14	8,247,967.49	30,019,917.31	28,421,335.83	96,588,103
Rate	48,373,450.00	13,344,400.00	44,927,850.00	42,038,450.00	148,684,150

Although these results do not represent spectacular figures, we note that economic impact is also evident in the port and business competitivity, due to the alteration of transportation logistics, which is reflected in the time value of goods (costs capital) and the potential pay tolls if using an alternate road toll, affecting the economic development of the region and its environment, mainly due to increased fuel consumption.

In the port sector, Altamira port's authorities, indicated to have lost a significant percentage of cargo from or to the Bajio area, reporting that now represents only 20% of export flows, while in imports, represents only 12%. For carriers, the Bajio zone used to represent 40% of their services both import as export, now indicated that this figure dropped to 12%.

5. METHODOLOGY

For all this, it is important to identify in advance collateral effects that emerge from the road reclassification, especially in the case of changing a road form a hierarchically superior level to another lower. Therefore, this article presents an empirical methodology that aims to support decision-making, and assess the economic impact on freight transport and the environment.

5.1. Focus

To achieve the objectives, study methodology was developed to be applied in the context of the assignment of traffic flow models from the perspective of the user balance, as shown in Figure 4.

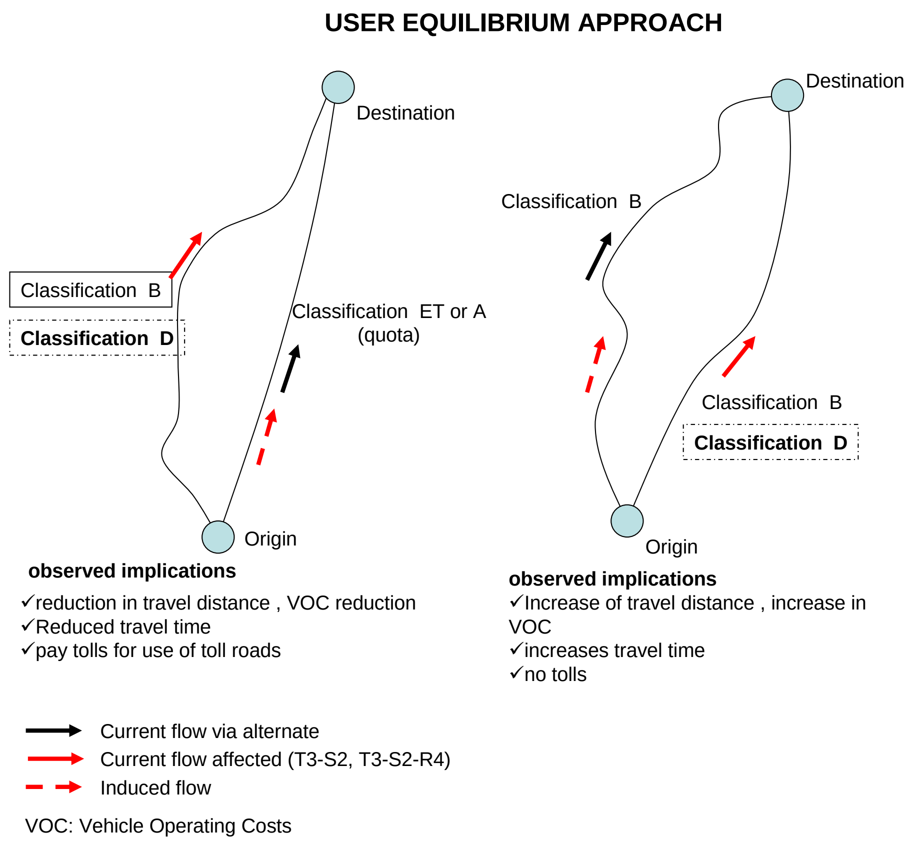


Figure 4
Methodology approaches

To develop the above approaches was used as the main tool TransCAD planning software combined with VOC model (Vehicle Operating Costs). This combination allowed the development of a model (computer software) according to the specific needs of the study, its formation is highly complex due to the high level of programming required and the volumes of information handled.

5.2. Development

Three factors are identified and evaluating in terms of monetary cost, travel time cost and emissions related with rerouting traffic.

The first factor, or the monetary cost of travelling on route *r1*, is given by the following equation:

$$mc_{r1} = \sum_{a} voc_a + p_a \qquad (1)$$

Where:
mc_{r1} is the monetary cost on route 1
r1 is the actual route where heavy vehicles transit
voc_a is the vehicle operating cost on link a
p_a is the tollgate on link a

In the same way the monetary cost of changing from route *r1* to route *r2* is given by the following equation:

$$mc_{r2} = \sum_{a} voc_a + p_a \qquad (2)$$

Where:
mc_{r2} is the monetary cost on the new route
r2 is the new route where heavy vehicles should transit

The Vehicle Operating Cost (VOC) was calculated using the World Bank model (Archondo-Callao, 1994) and it was programmed in an Add-in in TransCAD v4.8. To have a better realistic VOC the network was divided in segments of 0.5 kilometers. The input data, related to the links, were obtained by the Ministry of Communication and Transport. This input data includes: surface type, average roughness (IRI), average positive gradient, average negative gradient, proportion of uphill travel, average horizontal curvature, average superelevation, altitude of terrain and the number of lanes (Leyva et al, 2002). The data related with the vehicle were obtained from real data measured and obtained by freight transport enterprises (Arroyo, et al, 2008). Table 3 shows the results calculated using the VOC model.

The second factor, or the travel time cost of travelling on route *r1*, is given by the following equation:

$$c_{r1} = \sum_a t_a * x_a \qquad (3)$$

Where:
c_{r1} is the travel time cost on route 1
x_a is the flow assigned on arc a
t_a is the travel time on arc a

In the same way the monetary cost of changing from route *r1* to route *r2* is given by the following equation:

$$c_{r2} = \sum_a t_a * x_a \qquad (4)$$

Where:
c_{r2} is the travel time cost on the alternative route

Moreover the V/C ratio provides useful information because it provides the level of congestion on specific highway segments so the V/C ratio is taken into account to decide if a new route should be considered.

Finally the third factor is composed by the emissions of hydrocarbons (HC), oxides of nitrogen (NOx) and carbon monoxide (CO) for the vehicles. The relevance of this factor is related to the relationship between the pollution in the actual and in the proposed scenarios described by the following equations:

$$I_{HC} = \frac{HC_{r2}}{HC_{r1}} \qquad (5)$$

Where:
I_{HC} is the index of hydrocarbon emissions between the first and the second routes.
HC_{r1} is the total hydrocarbon emissions on the first route.
HC_{r2} is the total hydrocarbon emissions on the second route.

$$I_{NOx} = \frac{NOx_{r2}}{NOx_{r1}} \qquad (6)$$

Where:
I_{NOx} is the index of oxides of nitrogen emissions between the first and the second routes.
NOx_{r1} is the total oxides of nitrogen emissions on the first route.
NOx_{r2} is the total oxides of nitrogen emissions on the second route.

$$I_{CO} = \frac{CO_{r2}}{CO_{r1}} \qquad (7)$$

Where:

I_{CO} is the index of carbon monoxide emissions between the first and the second routes.
CO_{r1} is the total carbon monoxide emissions on the first route.
CO_{r2} is the total carbon monoxide emissions on the second route.

5.3. Application

The decision to use TransCAD was based on the fact that the software capability includes the equilibrium assignment model. These three factors were calculated separately. The real network where the methodology was applied is showed in figure 5.

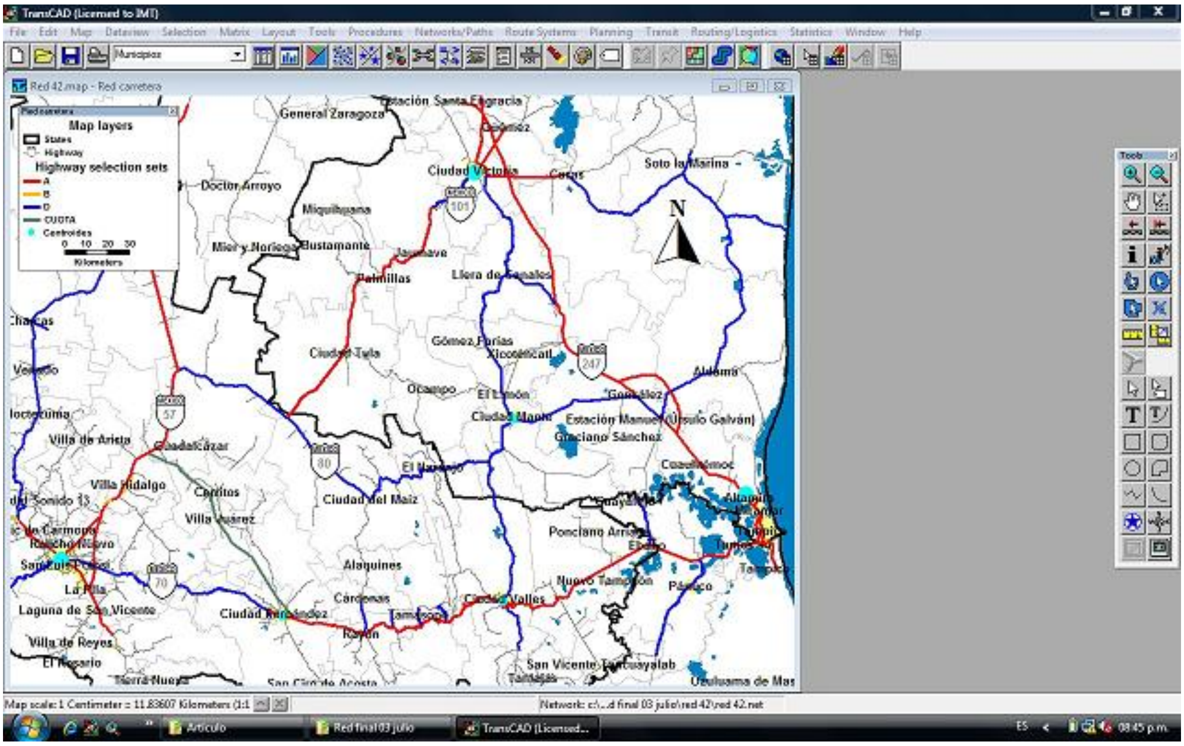


Figure 5. A real network used to evaluate the methodology with only one Origin-Destination (OD) pair from Altamira to San Luis Potosí

Table 3. Comparison between route R1 vs R2 and R3 using VOC

ROUTE	TIME (h)	LENGTH (km)	DIESEL CONSUMPTION (liters)	COST DIESEL (pesos)	PAYMENT TO OPERATOR	RATE	
						TRACTOR-TRAILER COMBINATION	TRACTOR-DOUBLE TRAILER COMBINATION (*FULL TRAILER*)
R1	8.19	426.72	544.25	$4,658.85	644.61		
Base	100%	100%	100%	100%	100%		
R2	8.82	464.7	569.54	$4,875.32	370.93		
Increase	(0.6 h) 7.6%	(37.9 km) 8.9%	(25.28 lts) 4.64%	4.64%	104%		
R3	10.23	562.92	655.4	$5,610.25	773.15		
Increase	(2.0 h) 24.8%	(136 km) 31.9%	(111 lts) 20.42%	20.42%	120.0%		

Source: Own data using the World Bank's Model (VOC).

The average transit of each vehicle was captured on each link to calibrate the traffic assignment model (and the OD matrix). It is assumed that heavy vehicles avoid as much as possible roads with a tollgate so the first route is following the blue path which has not a tollgate. The second route is following the red path and it has a toll gate. In table 4 some results are presented related with the monetary cost on the network for a T3S2R4 vehicle. table 5 presents the average V/C ratio and the flow assigned on each route when there is not restriction of heavy vehicles pass while table 6 presents the average V/C ratio and the flow assigned on each route when there is restriction of pass for heavy vehicles and finally tables 7 and 8 show HC, NOx and CO emissions for a T3S2R4 vehicle, taking into account the parameters showed in table 9, when there is not and there is restriction of pass for a heavy vehicle on each route, respectively.

Table 4. Vehicle operating cost and tollgate on each route for a T3S2R4 heavy vehicle

Route	Origin	Destination	Distance (km)	Time (hr)	Tollgate ($)	AB_VOC ($)	BA_VOC ($)
R1	Altamira	San Luis Potosí	426.72	8.19	78	6.91	10.73
R2	Altamira	San Luis Potosí	464.7	8.81	0	7.64	11.35
R3	Altamira	San Luis Potosí	562.92	10.23	0	9.07	12.98

Table 5. The average V/C ratio and the flow assigned on each route including when there is and when there is not restriction of pass for heavy vehicles by direction A-B

Route	Origin	Destination	Distance (km)	Time (hr)	Tollgate ($)	AB_VOC ($)	BA_VOC ($)
R1	Altamira	San Luis Potosí	426.72	8.19	78	6.91	10.73
R2	Altamira	San Luis Potosí	464.7	8.81	0	7.64	11.35
R3	Altamira	San Luis Potosí	562.92	10.23	0	9.07	12.98

Table 6. The average V/C ratio and the flow assigned on each route when there is restriction of pass for heavy vehicles (Route 1)

Route	Origin	Destination	Distance (km)	Time (hr)	Total Flow	V/C ratio (average)	Vehicle Kilometers Traveled
R1	Altamira	San Luis Potosí	426.72	8.19	84.52	0.77	27758.57
R2	Altamira	San Luis Potosí	464.7	8.81	0	0.9916	0
R3	Altamira	San Luis Potosí	562.92	10.23	0	0.9916	0

Table 7. The average V/C ratio and the flow assigned on each route when there is restriction of pass for heavy vehicles (Route 2)

Route	Origin	Destination	Distance (km)	Time (hr)	Total Flow	V/C ratio (average)	Vehicle Kilometers Traveled
R1	Altamira	San Luis Potosí	426.72	8.19	0	0.6809	24442.21
R2	Altamira	San Luis Potosí	464.7	8.81	83.3	0.0725	4251.12
R3	Altamira	San Luis Potosí	562.92	10.23	0	0	0

Table 8. The average V/C ratio and the flow assigned on each route when there is restriction of pass for heavy vehicles (Route 3)

Route	Origin	Destination	Distance (km)	Time (hr)	Total Flow	V/C ratio (average)	Vehicle Kilometers Traveled
R1	Altamira	San Luis Potosí	426.72	8.19	0	0.6809	24442.21
R2	Altamira	San Luis Potosí	464.7	8.81	0	0	0
R3	Altamira	San Luis Potosí	562.92	10.23	80.5	0.0176	5542.81

Table 9. The average V/C ratio and the flow assigned on each route when there is not restriction of pass for heavy vehicles (Route 1)

Route	Origin	Destination	Distance (km)	Time (hr)	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	Average VOC (g/mi)	Average CO (g/mi)	Average NOx (g/mi)	Vehicle Kilometers distribution (%)
R1	Altamira	San Luis Potosí	426.72	8.19	21.52	101.81	445.81	0.022	0.106	0.4649	0.0856
R2	Altamira	San Luis Potosí	464.7	8.81	21.8	103.56	558.11	0.023	0.108	0.582	0.0856
R3	Altamira	San Luis Potosí	562.92	10.23	25.24	126.25	769.22	0.026	0.132	0.8021	0.0856

Table 10. The average V/C ratio and the flow assigned on each route when there is restriction of pass for heavy vehicles (Route 2)

Route	Origin	Destination	Distance (km)	Time (hr)	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	Average VOC (g/mi)	Average CO (g/mi)	Average NOx (g/mi)	Vehicle Kilometers distribution (%)
R1	Altamira	San Luis Potosí	426.72	8.19	21.48	101.84	447.79	0.022	0.106	0.4669	0.0856
R2	Altamira	San Luis Potosí	464.7	8.81	21.8	103.56	558.11	0.023	0.108	0.582	0.0856
R3	Altamira	San Luis Potosí	562.92	10.23	25.24	126.25	769.22	0.026	0.132	0.8021	0.0856

Table 11. The average V/C ratio and the flow assigned on each route when there is restriction of pass for heavy vehicles (Route 3)

Route	Origin	Destination	Distance (km)	Time (hr)	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	Average VOC (g/mi)	Average CO (g/mi)	Average NOx (g/mi)	Vehicle Kilometers distribution (%)
R1	Altamira	San Luis Potosí	426.72	8.19	21.48	101.84	447.79	0.022	0.106	0.4669	0.0856
R2	Altamira	San Luis Potosí	464.7	8.81	21.8	103.56	558.11	0.023	0.108	0.582	0.0856
R3	Altamira	San Luis Potosí	562.92	10.23	25.24	126.25	769.22	0.026	0.132	0.8021	0.0856

Table 12. Parameters considered to estimate emissions

Calendar Year	2011
Month	Jan
Altitude	Low
Minimum Temperature (F)	60
Maximum Temperature (F)	84
Absolute Humidity (grains/lb)	75
Nominal Fuel RVP (psi)	9
Weathered RVP (psi)	8.8
Fuel Sulfur Content (ppm)	30

6. SUMMARY AND FURTHER RESEARCH

As it can see, when a restriction is applied for heavy vehicles in this network, it can be seen that the operating cost increases in route 2 and route 3 in 10 and 31% respectively to route 1 but not proportionally in spite of this, the tollgate decreases. Talking about congestion of roads, the V/C average ratio decreases on the hole network on the second and third scenarios and finally on the second and third scenarios CO and NOx emissions increase while VOC decreases.

In conclusion this network in economic and operation terms should not be approved because time, length, fuel consumption, lubricant consumption and crew time increases, this increase should be reflected in less enterprises gains. The V/C ratio for route 1 decreases because there will be fewer vehicles and fewer emissions should be reflected.

Finally, we can say that the Method for Evaluating the Economical Impact by Highway Reclassification is a good tool for making decisions, especially to assess the impact on freight transport.

REFERENCES

1. Archondo-Callaro, R. S. and Faiz, A. (1994) Estimating Vehicle Operating Cost. *World Bank Technical Paper number 234*.
2. Arroyo O. A, *et al*. (2008) Costos de Operación Base de los vehículos representativos del transporte interurbano 2008. Instituto Mexicano del Transporte. Publicación Técnica No. 316.

3. Leyva C. J, *et al* (2002) Desarrollo de un SIG para valuar los Costos de Operación Vehicular del Autotransporte de Carga en Carreteras Federales: SIGCOV Mex 1. Instituto Mexicano del Transporte. Publicación Técnica No. 205.

4. Wardrop, J. G. (1952) Some Theoretical Aspects of Road Traffic Research. Proceedings of the Institute of Civil Engineers, Part II, 325-378.

5. TransCad. Transportation GIS Software. Caliper Corportation, 2006.

6. Travel Demand Modeling with TransCad 4.8. Caliper Corportation, 2005.