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Misuse of Speed-Bumps on Two-Lane Main Rural Roads. A Generalized Practice in Venezuela

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SUMMARY

Settlements of uncontrolled population on side of road in Venezuela originate excessive use of speed-bumps to mitigate accidents. Misuse of these speed control devices generate functionality problem in the two-lane main rural roads which requires study to show its effect on level of service (LOS). Although other factors may occur (i.e., environmental problems and health), disproportionate use of speed-bumps worsens circulation quality by increase of travel-time as most sensitive parameter. This effect is difficult reverted in some places, for this reason, it should be made efforts to mitigate impact using another measure. Sub-stretches were selected according to presence of urban settlement with one or more speed-bumps and without speed-bumps, which guarantees contrast. Video cameras to detect travel-time were used in each road section and allowed measure other parameters. The travel-time distribution with or without speed-bumps and probability distribution that characterizes vehicle movement in each sub-stretch allows the simulation and modeling with ARENA software. Speed and percent time-spent following determines level of service according to Highway Capacity Manual (HCM). An analysis of cost was evaluated and may be useful in decision-making by Venezuelan Transport Institutions.

1. INTRODUCTION

Achieve an efficient transportation network includes thinking about infrastructures that supports decisions of public interest, i.e., to improve mobility and security. The goals should be to ensure quality of life, promote productivity and social-economic growth, and actively protect the environment. The problems confronting today derive from town without planning, a growth driven by political decisions and individual interests, financing poorly oriented, disarticulation between urban development and transportation system, and disability for coherent decision-making, what determines serious mobility problems.

Excessive travel-time, congestion and environment deterioration, as effects attributed to transport, requires policies that allows improvements, for this reason, we seek guidelines supported in analyses that could be useful. There is a major road network serving to intercity trips where the operative parameters must be according to its function and hierarchy. Recently, these roads experience a significant descent in transport quality that could be

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qualified by parameters such as: LOS, travel-time and speed, where the rapid population growth adjacent to main roads induces misuse of speed-bumps as only solution to provide security. Consequently, we propose a simulation method to show the effect on travel-time and speed in different scenarios: pre-existing condition, proportional increase of speed-bumps, and without them. A cost analysis of travel-time improvement is added.

2. LITERATURE REVIEW

Duane and Karen (1997) propose studies of traffic engineering for installation of speed-bumps that include: safe sight distance, pedestrian studies, classification of vehicles, traffic count, and mean speed. The speed-bump should be located, designed and installed properly. Kelton et al. (2008) indicates that the computer simulation refers to methods for studying a variety of models of the real world using numerical evaluation using software designed to imitate the operations or features of the system, often in the course of time, that could be useful for measuring the effect. It is not known others studies in Venezuela because application of speed-bumps at principal roads is outrageous; Von Steinberg (2002) found speed reduction up to 40 % for trapezoidal speed-bump where a variable influence length between 53 and 130 m, measured from the speed-bump at urban area. Ribbon and Ceballos (2012) measured the effect of isolated speed-bump at road with slope of 3 % and, Pérez and Valero (2012) did the same at section to level. Both thesis describe speed reduction up to vehicle stop and length of speed-bump influence in local environment, key aspect, for sections delimitation where were captured the partial times.

3. SIMULATION METHOD

Studied stretch was divided in 25 sub-stretches identified by kilometric point (kp), with urban settlements and speed-bumps (of 12-18 cm high and 60-80 cm long) placed individually, in series, and without them, for measuring the impact. The sections have similar geometry (terrain at level) and video cameras were placed to capture travel-time of vehicles through defined sections, i.e., at limits of influence zone (before and after of speed-bumps). Field data allows travel-time probability distribution that best characterizes the transit in each sub-stretch in function to speed-bumps number and its influence length.

The travel-time distribution was coded in each sub-stretch with 0, 1, 2, 3 or 4 speed-bumps chosen according to statistical analysis of significant differences for 6 scenarios. The travel-time per scenario was determined with ARENA software based on analysis of pre-existing condition; the results allow calculate mean speed that in conjunction with transit volume defines the level of service. The stretch has length of 33.9 km between “La Blanca” and “Santa Elena de Arenales” represents part of the main road T001 that connects “Caracas” with “Táchira” in Venezuela. To find travel-time distribution without speed-bumps were processed data of sub-stretches 4 and 20; the video cameras were placed at sections 11+500 and 13+500 with influence length of 2000 m, and 29+500 to 30+700 with 1200 m.

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Observation relates video of 30 min and 60 travel-times were randomly selected.

Class	Sub-stretch 4 (length 2000 m)				Sub-stretch 20 (length 1200 m)			
	Mean time	Frequency			Mean time	Frequency		
		Absolute	Relative	Accumulated		Absolute	Relative	Accumulated
1	65	3	0.0429	0.0429	41	3	0.0429	0.0429
2	78	8	0.1143	0.1571	48	8	0.1143	0.1571
3	92	13	0.1857	0.3429	55	14	0.2000	0.3571
4	101	20	0.2857	0.6286	62	19	0.2714	0.6286
5	119	12	0.1714	0.8000	69	10	0.1429	0.7714
6	132	5	0.0714	0.8714	76	7	0.1000	0.8714
7	145	4	0.0571	0.9286	83	4	0.0571	0.9286
8	157	2	0.0286	0.9571	90	3	0.0429	0.9714
9	172	3	0.0429	1.0000	97	2	0.0286	1.0000
Mean time = 108.8 ± 25.0 s Mean speed = 66.2 ± 15.2 km/h					Mean time = 63.9 ± 13.1 s Mean speed = 67.6 ± 13.8 km/h			

Table 1 – Travel-time distribution in sub-stretch with 0 speed-bumps

The mean speed not had significant difference in case without speed-bumps, see sub-stretches 4 and 20 in Table 1. The distribution of sub-stretch 20 was selected to 0 speed-bumps simulation, and so on; it will have an accumulated frequency distribution to 0, 1, 2, 3 or 4 speed-bumps, see Figure 1. As is a discrete event simulation, statistical parameters come from of accumulated distribution, encoded DISC00 to 0 speed-bumps.

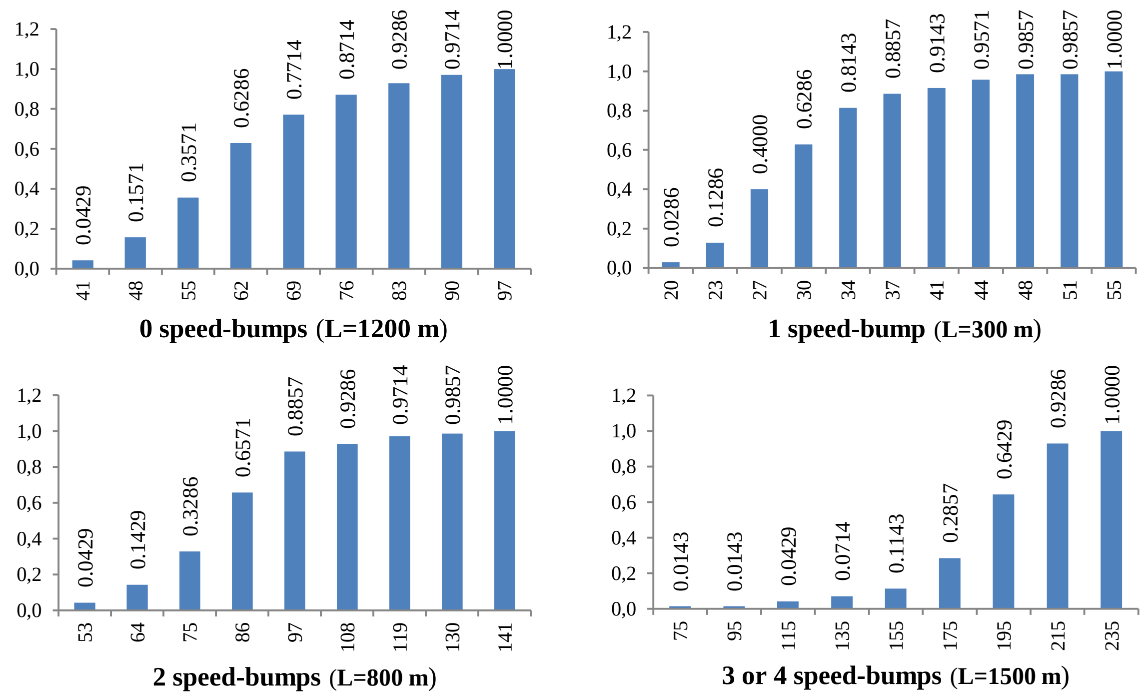

Fig. 1 – Travel-time accumulated distribution for 0, 1, 2 and 3 or 4 speed-bumps

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Similarly to 1 speed-bump simulation was chosen distribution of sub-stretch 11 with influence length of 300 m, encoded as DISC01. The sub-stretch 21 was selected to 2 speed-bumps simulation with 800 m length, encoded DISC02. For 3 and 4 speed-bumps there is not major difference in speed according to sub-stretches 17 and 1. Consequently, to both cases we decide to use distribution of sub-stretch 1 with 1500 m length (DISC34).

4. SIMULATION RESULTS

Spent time in each sub-stretch allows modeling total delay per entity (vehicle) that access by mean of Poisson distribution. When first vehicle access to the stretch, delay is captured by the system clock, the vehicle is retained using a randomly time generated by probability distribution of each sub-stretch, and then, it releases to the next delay process, i.e., starts the trip through following sub-stretch. Table 2 shows pre-existing condition or scenario 1.

Sub-stretch	Length (m)	S-bumps	Distribution	Adj. Factor	Expected time
1	1,500	4	DISC34	1.00	192.70
2	4,100	0	DISC00	3.42	218.30
3	500	2	DISC02	0.63	54.10
4	9,100	0	DISC00	7.58	484.60
5	700	3	DISC34	0.47	89.90
6	100	0	DISC00	0.08	5.30
7	400	3	DISC34	0.27	51.40
8	2,600	0	DISC00	2.17	138.50
9	900	4	DISC34	0.60	115.60
10	2600	0	DISC00	2.17	138.50
11	300	1	DISC01	1.00	31.00
12	300	0	DISC00	0.25	16.00
13	1,100	3	DISC34	0.73	141.30
14	300	0	DISC00	0.25	16.00
15	300	1	DISC01	1.00	31.00
16	1,400	0	DISC00	1.17	74.60
17	1,400	3	DISC34	0.93	179.90
18	100	0	DISC00	0.08	5.30
19	400	2	DISC02	0.50	43.30
20	3,200	0	DISC00	2.67	170.40
21	350	2	DISC02	1.00	86.60
22	350	0	DISC00	0.33	21.30
23	300	1	DISC01	1.00	31.00
24	500	0	DISC00	0.25	16.00
25	600	2	DISC02	1.00	86.60

Table 2 – Adjustment factors for length and expected time in scenario 1

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When vehicle circulates for the last sub-stretch the time is registered and by subtraction of initial time the total travel-time is determined. If a sub-stretch length does not coincide with a pattern (influence length), the distribution must be adjusted by a factor, i.e. divides the length between the patterns. The simulation is performed with 100 replications per scenario; with these values it gets mean travel-time and speed. In scenarios 2 to 5 (10, 20, 30, and 40 percent of increase) three speed-bumps were added progressively. Scenario 6 corresponds to not speed-bumps to check impact without urban settlements, see Table 3.

Scenario	Sub-stretch	Length (m)	S-bumps	Distribution	Adj. Factor	Expected time
2	4_2	1,500	3	DISC34	1.00	192.70
3	16_2	300	1	DISC01	1.00	31.00
	20_2	800	2	DISC02	1.00	86.60
4	4_3_2	1,500	3	DISC34	1.00	192.70
5	8_2	800	2	DISC02	1.00	86.60
	10_2	300	1	DISC01	1.00	31.00

Table 3 – Sub-stretches added in scenarios 2, 3, 4 and 5

The Table 4 shows travel-time, speed and the level of service obtained for each scenario. And Figure 2 shows the travel-time and speed according to number of speed-bumps. These results are useful to quantify the effect of multiple speed-bumps in key parameters of class I highways.

N	Scenario	S-bumps	Mean Travel-time (s)	Mean Speed (km/h)	LOS
1	Pre-existent	31	2,422.40	50.40	E
2	+ 10 %	34	2,537.00	48.10	E
3	+ 20 %	37	2,597.10	47.00	E
4	+ 30 %	40	2,710.20	45.00	E
5	+ 40 %	43	2,769.60	44.00	E
6	Not S-bumps	0	1,780.50	68.50	D

Table 4 – Simulation results and level of service. Class I Highways (HCM-2010)

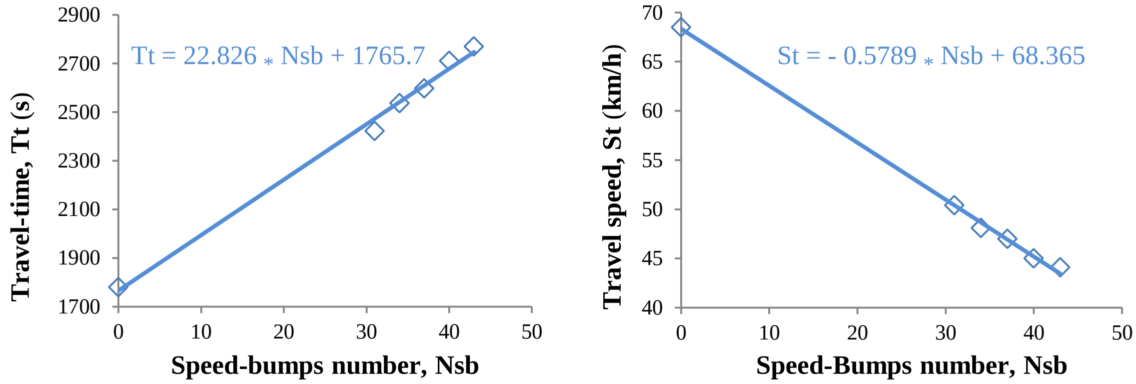

Fig. 2 – Linear fit. Values by simulation with software ARENA

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5. COST OF IMPROVEMENT AND TRAVEL-TIME

The mode distribution of Road Transport National Institute in Venezuela (RTNI) is used, based on 100 % of registered vehicles up January 31, 2013, see Figure 3. The Table 5 shows operating costs by transportation mode that come from data of Venezuelan Logistics Association (VLA) and sources as built infrastructure too. Of data weighted daily fixed cost of $27.43 was obtained. Eight useful hours per day has a fixed cost per second of $0.00096, for 12 useful hours $0.00064 and for 24 hours $0.00032. Daily intensity was 6,000 vehicles for simulation. The cost of specific measures are showed in Table 6.

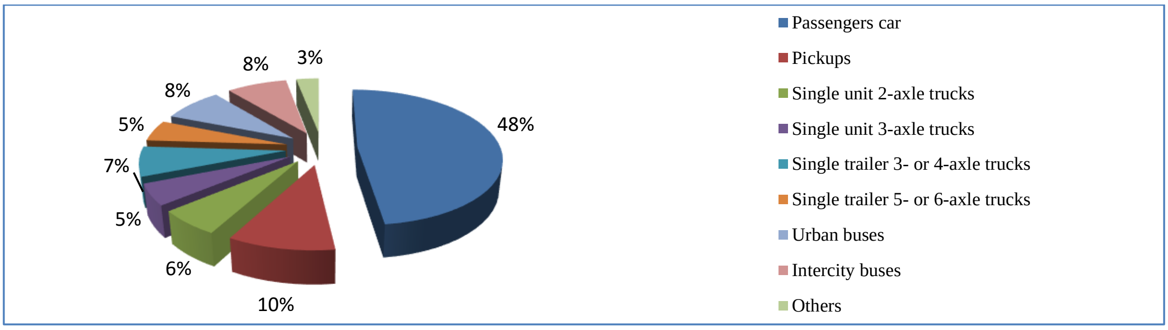

Fig. 3 – Mode distribution in Venezuela. Source: RTNI

	Up January, 2013		
Mode	Investment (Bs)	Fixed cost (Bs/day)	Cost (Bs/km)
Passenger car	350,000,000.00	693.00	9.95
Pickup	450,000,000.00	769.00	10.33
Single unit 2- axle truck	420,000,000.00	797.00	10.42
Single unit 3- axle truck	480,000,000.00	872.00	10.52
Single trailer 3- or 4- axle truck	680,000,000.00	1,226.00	12.65
Single trailer 5- or 6- axle truck	1,950,000,000.00	3,635.00	13.91
Urban bus	2,300,000,000.00	4,236.00	27.76
Intercity bus	1,350,000,000.00	3,298.00	25.59

Table 5 – Operation cost by transport mode. Local money. Source: VLA

N	S-Bump	Time (s)	Difference (s)	Additional cost (US$/day)			L	Cost
				8 h	12 h	24 h	(km)	(US$)*
6	0	1,780.5	0.0	0.0	0.00	0.00	0.0	0.0
1	31	2,422.4	641.9	3,697.3	2,464.9	1,232.4	9.4	1,880,000
2	34	2,537.0	756.5	4,357.4	2,905.0	1,452.5	10.9	2,180,000
3	37	2,597.1	816.6	4,703.6	3,135.7	1,567.9	12.0	2,400,000
4	40	2,710.2	929.7	5,355.1	3,570.0	1,785.0	13.5	2,700,000
5	43	2,769.6	989.1	5,697.2	3,798.1	1,899.1	14.6	2,920,000

(*) Cost in dollars of specific measures (improvement)

Table 6 – Cost vs travel-time and additional cost by different useful hours per day

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The specific measures are: roadway expansion to segregate traffic passing through town, protect pedestrians by mean of sidewalk, overpasses and fences. The overall estimated cost of this set of measures is US $200,000.00 per kilometer. Scenarios determine the increase in the time measured in seconds from the basic condition without speed-bumps, condition that allows to estimate an appropriate service level. The improvement costs versus travel time is obtained.

6. CONCLUSSIONS AND POLICIES

The low speed condition cannot be reversed easily in some places due to the magnitude of occupied space by urban settlements little planned to side of road. Policies that allow reducing accidents without alteration of basic transit parameters should be a better idea. It should provide the consensus among involved parties for to taking measures in the future. The results show the effect of multiple speed-bumps applied to reduce accidents at uncontrolled urban settlements located near of main road and represent a diminution rate of **-0.6 km/h** per speed-bump in mean speed and increase of the mean travel-time in **24 s** per speed-bump. This report must help to decision-making in Venezuela. The planning and management of the transport systems and land use must facilitate mobility by people and goods, efficient circulation and safe; avoiding extensive travel-time and negative effects on the environment and health. Like this, the proposed policies are:

- Operation of the transport system should be considered in conjunction with the planning of land-use, housing locator, services, and productive centers. Protect spaces for transport functioning, including regulation of land-use in side of main roads and appropriate infrastructure to guarantee its functionality, economic activity and services, to avoid congestion, accidents and consequent emissions;
- Rationalize the investment for balancing an efficient movement of vehicles with safe transit of people and goods. Apply specialized infrastructures to get spatial continuity; safety and quality of transit, which promotes interaction of motorized and non-motorized transport at places with uncontrolled urban settlements to side of main roads;
- Establish mechanism that requires the new urban development to internalize effects in the transport system. It must be achieved a constant evaluation of costs to prevent negative externalities caused;
- Priority to public transport as efficient and sustainable option should be applied to suburban trips. Towns and small settlements, which grow and develop as functional units that invigorate economic growth, must also manage and control exit and entrance of traffic passing through town, to ensure adequate interaction between principal flow and side access. The planning should incorporate a design based on a strategic plan (national and local), providing space for growth and better connectivity of the suburban public transport;
- Traditional sidewalks are adopted in main roads. This is not appropriate, since users need to know, without misunderstandings, what kind of road they walk. If is express road, it

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must be segregated so that pedestrians not enter, and it must be permeable (different level), for can cross comfortably and safely;

- Authorities should ensure provision of accessible services, safe, comfortable and with quality, both if they are caused by State as if they come from private initiatives, always assuming his role as planner of the whole system. However, the good operation of transportation is hampered by a not adequate institutionalism, administrations that evade their responsibility and dependent on decisions at central level of government;
- Is important to locate them at roads with low speed, where the traffic calming policies are required. Each speed-bump must be painted with a pattern to make them visible to drivers and provide a safe and reasonable sight distance, the speed-bump must have accompanying of warning signs and a better sizing according international specifications.

The policies scope should not be only to generate conditions for provision of land-uses; it should lead to develop of soil quality for perfect interaction of vehicles, pedestrians and cyclists. The integrated modeling of land-uses and transport as a strategy, should to include an operational analysis and traffic simulation, application of new methodologies that incorporate economical-social assessment for impact quantification.

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REFERENCES

- KELTON, W.D., SADOWSKI, R.P. and STURROCK, D.T. (2008). Simulación con Software ARENA. *McGraw-Hill Interamericana*. México.
- DUANE, E.S and KAREN, L.G. (1997). A study on speed-humps. *Center for Transportation Research and Education*. Iowa State University.
- PEREZ, L. and VALERO, G. (2012). Influencia por reductores de velocidad tipo resalto en operación de carretera dos canales en tramo a nivel. *Unpublished thesis*. ULA. Venezuela.
- RIBBON, M. and CEBALLOS, Y. (2012). Influencia causada por los reductores de velocidad tipo resalto en la operación de una carretera dos canales en pendiente específica. *Unpublished thesis*. ULA. Venezuela.
- VON STEINBERG, M. (2002). Atenuantes de tráfico: Aplicación de un modelo de reductor de velocidad en una vía urbana de la ciudad de Mérida. *ULA-SERBIULA*. Venezuela.