University of Puerto Rico, Mayagüez Campus
Department of Civil Engineering and Surveying

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EVALUATION OF REGULATIONS AND TRAFFIC CALMING TREATMENTS FOR PEDESTRIAN FACILITIES IN TREN URBANO

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LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
DTPW	Department of Transportation and Public Works
ITE	Institute of Transportation Engineers
HTA	Highway and Transportation Authority
MBA	Metropolitan Bus Authority
MUTCD	Manual on Uniform Traffic Control Devices
PB	Planning Board
TU	*Tren Urbano*

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I. ABSTRACT

A professional in the field of transportation engineering that is required to design a street and all the elements and components of its right-of-way will need to follow certain regulations in order to comply with the laws of the state and the agencies that have proposed these regulations. When the majority of the existing roadways where designed, pedestrians were taken little into consideration, or none at all. They suffered from being ignored or given less importance than they deserve, and thus we ended up with roads that are not safe, or inviting at all, to pedestrians.

The problem lies in the fact that not everyone is familiar with the regulations that exist that *do* consider our walking citizens. Contemporary highway design offers alternatives that favor pedestrians and sometimes even give *them* the priority, namely by using *traffic calming* techniques. Now we can find bumps on the road that reduce the velocity of motorized vehicles, lanes reserved solely for pedestrian use, and even streets that are fully closed to let pedestrians walk in a safe and secure way. With all these techniques, the question arises: are the regulations not minding the pedestrians, or is it the professionals that are not? Can the focus of the system prioritize pedestrians?

The purpose of this investigation is to evaluate the actual regulations, and traffic calming techniques, on behalf of the pedestrians. Because the regulations exist, and some are very useful, this work will also serve as a guide to follow when searching for tools to design a pedestrian-friendly environment, which begins by designing pedestrian-friendly roadways.

II. INTRODUCTION

Frequently in Puerto Rico pedestrians are forgotten when designing new roadways, when remodeling existing highway structures, and even when constructing facilities *for pedestrians*. This is no contradiction, since we may very well *forget* pedestrians while building the most beautiful and cost-efficient pedestrian access that doesn't satisfy their needs for security. This research is, in a way, a call for attention to those that have chosen walking over riding. These people have taken a very important and significant decision, as we live in a country that although is only 35 miles wide by 100 miles long has a population reaching 3.8 million. These numbers send us into the top 5 of the most densely populated countries, and also, distressing to say, with the highest density of motorized vehicles per square mile.

It is the purpose of this research to partly investigate the reasons of these statistics that are directly associated with the design of pedestrian facilities. This will be done by evaluating the actual regulations that consider such matters, following the vision of a committee representing local communities, special interest groups, schools, environmental agencies, state and county agencies, and neighborhoods. Their vision is a transportation system which meets the needs of all walkers; supports, encourages and accommodates pedestrian travel; provides access to other modes of transportation, destination-oriented facilities, and existing linkages within areas. Also ensures the development of pedestrian facilities, reduces the dependence on single-occupant motorized vehicles, supports pedestrian-friendly land-use and ensures a *safe and secure* pedestrian environment[1].

Tren Urbano is the name of Puerto Rico's new heavy rail system, which is currently under construction and expected to begin services in September of 2003. To understand the concepts presented in this work, a critical station in Tren Urbano has been chosen to evaluate its surrounding pedestrian facilities.

[1] Pedestrian Facilities: Best Practices 1999. http://209.57.154.225/trans/pedistrian/Introduction.PDF

III. OBJECTIVES AND SCOPE

- Get acquainted with the regulations applicable to pedestrian space and treatments in urbanized areas.
- Understand the primary treatments applicable to pedestrian facilities and their application to Tren Urbano.
- Provide guidelines on how to implement these treatments and regulations in the Tren Urbano open space.
- Analyze the pedestrian facilities at an existing intersection at a *Tren Urbano* location based on its present conditions.

The scope of this work is limited to pedestrian facilities and traffic calming treatments applicable to urban settings, with an emphasis on *Tren Urbano* stations.

IV. METHODOLOGY

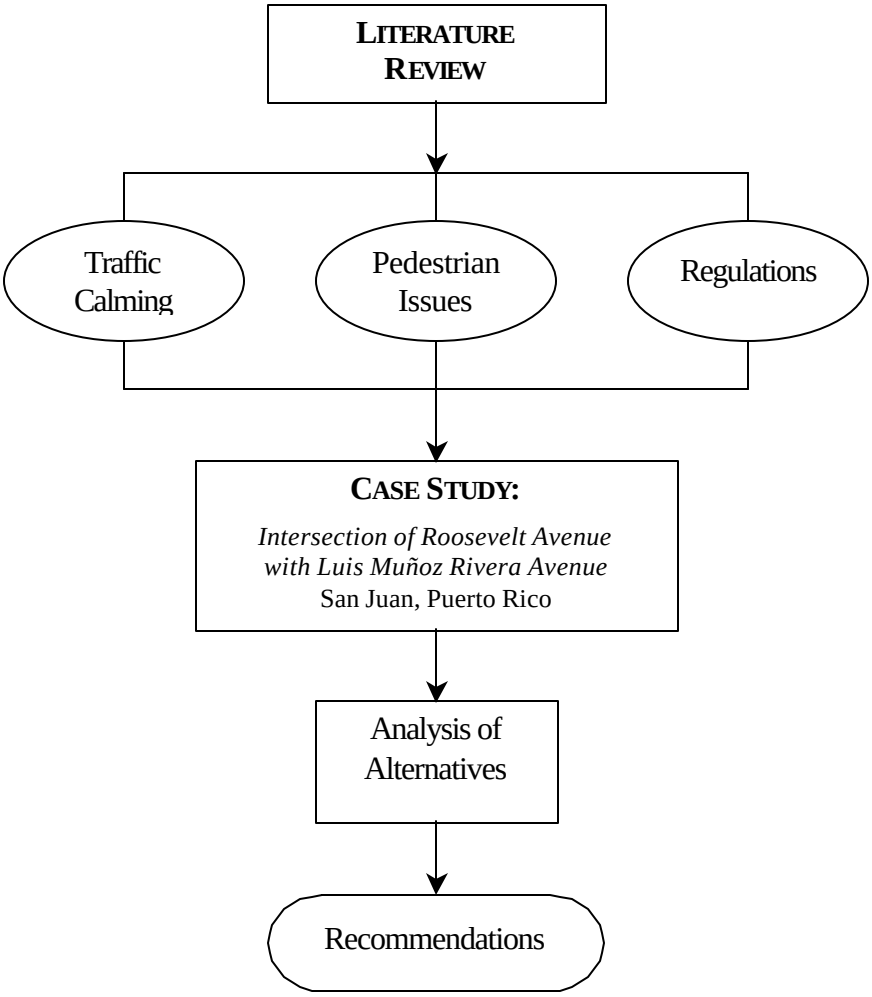

Fig. 1 Methodology flowchart

V. RESEARCH PLAN

The methodology followed throughout this research project is shown in Figure 1 and described in an overview below.

A. Literature Review

1. **Pedestrian Issues** – For the analysis of pedestrian facilities and for the purpose of this investigation, such parameters as description, problem approach, variables involved and some existing treatments are established; stating of the pedestrian problem in Puerto Rico as perceived from state statistics.

2. **Regulations** – An insight into various documents that regulate pedestrian facilities and the use of open space in the urban areas of Puerto Rico; interview to Tren Urbano Office architect.

3. **Traffic Calming Techniques** – Definition and categorization of diverse traffic calming techniques.

4. **Engineering and Aesthetic Issues in Traffic Calming** – Engineering design principles behind the use of traffic calming techniques; landscaping as a tool for the improvement of both the aesthetics and effectiveness of treatments; and MUTCD principles applicable to traffic calming measures.

5. **Traffic Calming in Puerto Rico** – Results of interviews made to actual design firms in Puerto Rico about their use of traffic calming when designing.

6. **Literature Lessons Learned –** Processing of gathered information and its value to this investigation.

B. Case Study

For the application of the work encompassed in this investigation, an intersection in Hato Rey of San Juan, Puerto Rico, is analyzed. This is the intersection nearest to *Tren Urbano* Roosevelt Station, where Roosevelt Avenue meets Luis Muñoz Rivera Avenue. The work breakdown structure is described as follows:

1. **Case description** – Description of the study site; overview; intersection plan.

2. **Problem Statement and Case Analysis** – Actual conditions in the studied case hazardous to the walking public; analysis of the dangers involved for the pedestrians.

3. **Evaluation of Alternatives –** Proposal of alternatives as possible solutions to the stated problem; evaluation of alternatives proposed.

4. **Conclusions and Recommendations –** Regarding the analyzed *Tren Urbano* station's pedestrian facilities at the intersection, recommendations for improvement based on the evaluation of alternatives are stated.

VI. PEDESTRIAN ISSUES

Statistics

The fatalities reported in the highway network of the Commonwealth of Puerto Rico for years 1995 and 1996 are summarized in figures 2 and 3. In a black and white picture, pedestrian deaths would easily be mistaken for the uppermost slice, that in 1995 (fig.1) has 21.98%. Regrettably, this is not so. Pedestrians encompassed 32.21% of all deaths for that year, making their category the second highest in amount of fatalities, following only to drivers. Third in this distribution are passengers. This means that for this year, 1995, there were more pedestrians being killed on the streets than passengers in vehicles. Figure 2 shows that the same tendency is repeated the next year, 1996, and this year the percentage of pedestrian fatalities increased, decreasing the percentage of drivers.

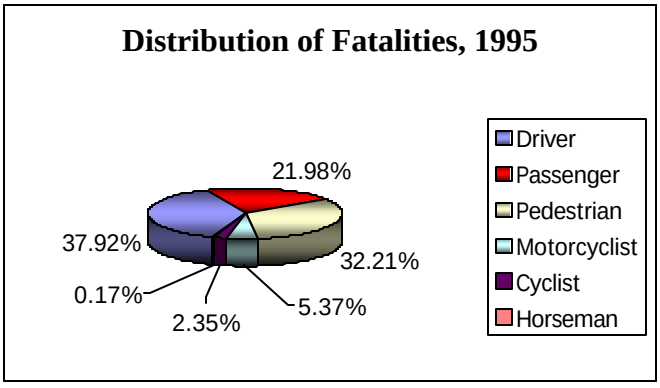

Fig. 2 Distribution of Fatalities for 1995

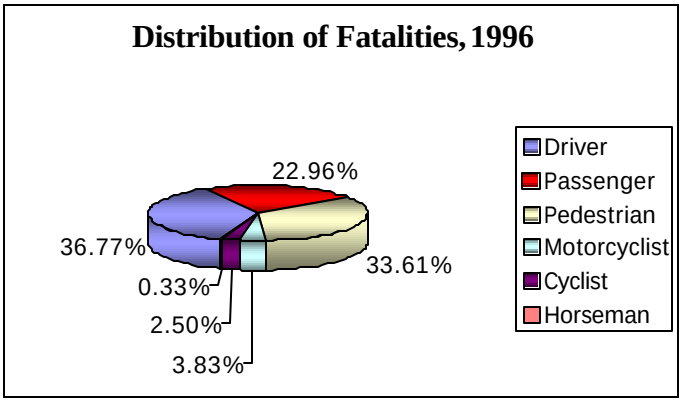

Fig. 3 Distribution of Fatalities for 1996

These shocking statistics reveal that there are almost as many pedestrians being killed on the streets of Puerto Rico as drivers. The tragedy lies in the fact that the majority of the times, drivers will be responsible for their own accidents, but this is not mostly the case of pedestrians; these are simply people transiting the streets without the protection of the metal provided by a motorized vehicle.

Approach

There are Pedestrian Speed-Flow-Density relations that convert the pedestrian problem into an analysis problem. This is an analytical method to be used in the design of pedestrian facilities, but its downside is that it treats pedestrians as small mobile units that possess variables such as volume, speed, flow and density, and whose walkways may be evaluated for performance using Level of Service criteria. However, there are a certain *performance measures* that are very useful to grade the effectiveness of a system. In our case, we may apply the concept using the following indicators[2]:

- Attractiveness
- Comfort
- Convenience
- Safety
- Security
- System Coherence
- System Continuity

There are several other that apply and many more to consider but these seven can be used to provide a research of this type with an effective evaluation of pedestrian facilities.

Treatments

This investigation will focus the treatments for pedestrian facilities to traffic calming techniques, by which the solution to the pedestrian problem is the reduction of speed or volume of motorized vehicles. However, recent studies provide us with new treatments in different situations. For example, motorists exiting their garages can check there are no pedestrians in the way using *animated "eyes"*; effective *Signal Coordination*

[2] Transportation Research Record 1438, pages 45-50

for pedestrians crossing streets may significantly reduce accidents, and minimize delays. Also, for the prediction of travel time, an *estimate of the demand* of non-motorized trails will yield basically how much time the average pedestrian needs to complete the trip; and lastly take in consideration *Sidewalk Bicycling Safety Issues* because the safety of cyclists is as essential as the safety of pedestrians.

VII. REGULATIONS

There are various regulations a transportation engineer would study to develop, for example, the design for a new road. The Department of Transportation and Public Works (DTPW) in Puerto Rico is a key in this process; they hold rules and laws in Transportation Design. Also the *Junta de Planificación Ambiental* or Planning Board (PB) is really important in these matters, because they have basically developed the planning guide for urban development. Following are the important aspects in concern of pedestrians in the studied regulations.

Access Control

Presently the DTPW is working with the draft of the Access Control Regulation, and we have been given a copy of this draft, which is in the rough still. This is an important reference holds all the necessary aspects for the design of accesses to the roadway system. Access control is the tool that the DTPW has to regulate intersections: the volume of the flow and the speed of the vehicles, because it regulates the widths and the lengths of the right-of-way of roads that serve as accesses. And for the benefits of pedestrians, the regulation states such aspects as that under no circumstance the pedestrian way shall be obstructed, and as that planting the sidewalk is encouraged to protect pedestrians from the dangers of the road.

Still, this regulation is intended for the control of accesses, which are basically any entrance or exit including streets of adjacent lands, residence, commerce, industry or any other similar development adjacent to the public roads, to be used by any vehicle and/or pedestrians from and into these. And as access control, not everything applies to urbanized areas, because the avenues at an intersection are, depending on their use, not considered accesses, but main roads.

A briefing in Spanish on this regulation and some of its aspects that are helpful to this investigation are provided in the appendix.

Law 22

On January 2000, Law 22 in Puerto Rico was revised and signed. This law includes, for example, the penalizing of pedestrians that cross streets anyplace, refusing to use the facilities built for them. We have the manual for the study of Law 22 and it is a magnificent piece of information, because this is the law that everyone is commenting about as it is relatively new and aggressive in the penalization. The most relevant aspects of Law 22 to this investigation are:

- *Pedestrian Right of Way*: "Any driver that approaches an intersection where the traffic lights are NOT working and notes that a pedestrian is about to cross, is obliged to yield the way to the pedestrian, reducing speed and stopping if necessary."

- *Applicable rules to pedestrians*:
    - In a street without sidewalks the pedestrian will walk by the edge or by the left emergency lane of the road, face to traffic.

    - When crossing in an intersection the pedestrian is obliged to use the pedestrian pass, tunnels or elevated structures and cross only with the green light at his/her favor, or in indications of "Crossing."

    - The pedestrian must wait for the vehicle to stop and for the driver to yield the way.

    - The pedestrian must look at both sides before crossing.

    - Every pedestrian that walks across the public lanes in a rash and careless way will be fined; the cost of such fine is fifty dollars ($50).

    - Every pedestrian that causes an accident when using carelessly the public lane will be fined; the cost of such fine is five hundred dollars ($500).

    - If a driver notes that a pedestrian will cross, the driver must yield the way, especially in streets where there are no traffic lights.

- Any conductor that does not yield the way to a pedestrian, even when the pedestrian is using carelessly the public lane, will pay a fine of fifty dollars ($50).

However, these are aspects, stated as available to the public in the manual for the study of this law found in the site of the public agency. The articles comprehended in the law are sometimes too technical for the average citizen to some understand. For example, Article 9.02(a) states that “outside any intersection or pedestrian walkway, the pedestrian will yield the way to any vehicle in the roadway.” Article 9.02(b) states that “between consecutive intersections any of which is controlled by traffic lights, the pedestrian will only cross through the pedestrian walkways marked on the pavement.” These are not only a little bit difficult to understand, they are also hard to follow, as there are many roads missing the walkways, and sometimes the pedestrian would have to walk a few blocks to find one and cross.

Regulation 22

This is the regulation of arrangement of the infrastructure in the public space, last revised in 1992 by *The Planning Board* (PB), and was adopted by the diverse agencies in Puerto Rico. It contains the necessary norms to adequate the form and placing of the infrastructure in the public environment in a functional, organized, and aesthetic way, thus contributing to the improvement of our natural surroundings and preventing the loss of the visual attractiveness essential for a pleasant atmosphere.

Some of the many topics it covers are classification of the different areas of the public space, classification of the different types of lanes, norms for the organization of the infrastructure, applicable norms to the installation of sewers, lighting, electric utility, traffic lights, traffic signals, telephone and communication lines, applicable norms to the design of lanes, and more. This is a complete regulation and a good one to follow when designing and evaluating facilities.

The fact that it covers basically all aspects of urban organization does not mean that our streets are meticulously well organized and our streets are pedestrian friendly as the regulation encourages. The main problem is that the aspects established in this regulation are being taken little into consideration by the developing municipalities, and in most places where the developed land is not in compliance with what the regulation establishes, no action is taken by the municipality to fix the problems.

To generalize the idea, Chapter 6 states that the minimum width of the sidewalk shall be 1.5 meters, for the flow of pedestrians, and this must not be interrupted according to this regulation and also the access control regulation. Still we find the sidewalks being

used as parking by the commerce, all day, everyday. Is this a contradiction? No, this is simply not taking seriously the regulation.

The majority of the highway designers focus their concept in the vehicle, and forget pedestrians. Sometimes this is because professionals are not aware of the existence of these regulations that were established for this purpose. In the case of this particular regulation, of 1998, it must be unawareness, because it is really thorough in its demands for a better and more organized infrastructure surrounding the public space. For better examples, a briefing in Spanish of this regulation is also provided in the appendix, including examples of some of the articles that show that pedestrians have been taken into consideration in this regulation, however neglected they are in the real world.

Regulation 25

This regulates the planting, cut and forestation for Puerto Rico, last revised in November 1998, and is a complement to Regulation 22 when designing sidewalks, as these may include flora, such as trees. It includes dispositions for tree replacement, planting areas, planting standards, protection measurements, security measurements, erosion control, and such important aspects. This investigation strongly favors the use of landscaping to improve conditions in the roadway, therefore this regulation is very important, and its existence is a gift in the process.

The preferable situation in this research project would be to actually have surveys that reveal the feelings of the pedestrians towards these regulations, the new law, and the system. However, it is not in the scope of this project to carry out a survey amongst pedestrians, even though this could be very helpful to the investigation.

VIII. TRAFFIC CALMING TECHNIQUES

Definition

Traffic Calming is, as defined by a subcommittee of ITE, the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users[3]. Also, in contrast to traffic *control* devices, such as stop signs and speed limit signs which require enforcement, traffic calming measures are intended to be *self-enforcing*. It is also defined that traffic calming measures rely on the laws of physics rather than human psychology. For example, street lighting, furniture, trees and such streetscape elements may in part calm traffic, but will not compel drivers to slow down.

The following definitions and illustrations are taken from ITE's *Traffic Calming: State of the Practice.*

Volume control measures

- *full street closures*: will close the street completely to traffic, but sidewalks or bicycle paths are left open (see fig.1).

- *half closures*: block travel in one direction, for a short distance, which are often used in sets to make travel through neighborhoods with griddled streets more circuitous rather than direct (see fig.2).

- *semi-diverter*: formed when two half closures are placed across from one another at an intersection

[3] I.M. Lockwood, "ITE Traffic Calming Definition," *ITE Journal*, Vol. 67, July 1997, pp 22-24.

- *diagonal diverters*: barriers placed diagonally across an intersection, blocking through movement, forcing circuitous routes through neighborhoods like the half closures

- *median barriers*: raised islands located along the centerline of a street and continuing through an intersection so as to block through movement at a cross street (see fig.3).

- *forced turn islands*: islands positioned not in the centerline but in such a way that they block certain movements on approaches to an intersection. These measures are used to reduce volume by discouraging or eliminating through traffic.

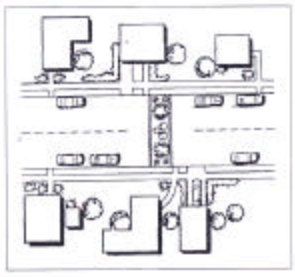

Fig. 4 Full Closures

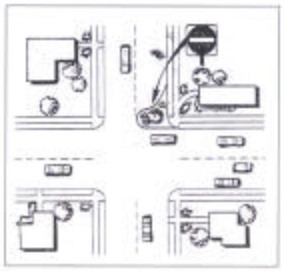

Fig. 5 Half Closures

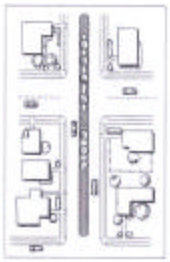

Fig. 6 Median

Speed control measures

Their function is to discourage speeding, be it physically, which is the case of the **vertical** and **horizontal** measures, or psychologically, as it is the case of **narrowings**. These use a psycho-perspective sense of enclosure that mentally pushes the driver to reduce speed, but because this measure deals most with human psychology it is often not counted as a speed control measure.

- *vertical measures:*
    - speed humps - *or speed humps;* rounded raised areas across the road
    - speed tables - basically flat-topped humps, to use the forces of vertical acceleration to discourage speeding
    - tiling - use of tiles as speed reducers

- *horizontal measures:* Horizontal measures achieve speed reduction by forcing drivers around horizontal curves and by blocking the view of the road ahead.
    - *traffic circles*: raised islands placed in intersections around which traffic circulates, mainly in neighborhoods
    - *Round-abouts*: basically traffic circles designed for higher capacity roads, found primarily on arterial and collector streets. These may substitute traffic signals or four-way stops.

Fig. 7 Speed Tables

Fig. 8 Roundabouts

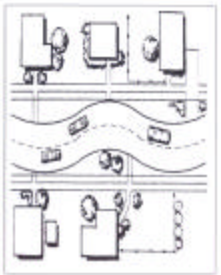

Fig. 9 Chicanes

- *Chicanes*: curb extensions that form S-shaped curves, that will reduce speed depending on the radii of the curves and their degrees of curvature.

- *Lateral shifts:* will bend an otherwise straight road one way, then back the other way to the original direction of travel.

- *Realigned intersections*: changes in alignment that convert straight T-intersections with straight approaches into curving streets that meet at right angles.

- *Narrowings*: Narrowings include measures that will narrow the streets, mainly described by their names.

  - *Neckdowns:* these are curb extensions at intersections that reduce roadway width curb to curb

  - *center island narrowings*: raised islands located along the centerline of a street that narrow the travel lanes

  - *chokers*: curb extensions at midblock that narrow a street by widening the sidewalk or planting strip.

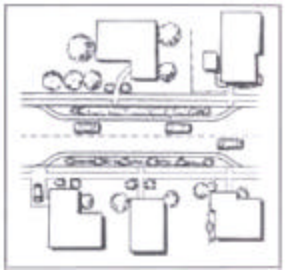

Fig. 10 Chokers

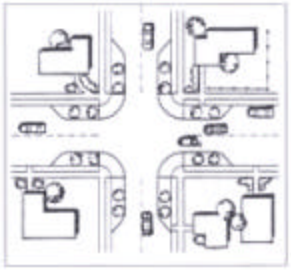

Fig. 11 Narrowings

The impact of these diverse measures on traffic calming depends not just on the measures used, but on the way that they are used, the magnitude of the problem and the behavior of the community. Every one of the measures mentioned above has been applied in the United States throughout the country, although not necessarily all in a single community. The selection of one over the other depends on the conditions of the streets, the volume and density of flow, and the available funds of the project, because they all have different cost estimates.

IX. AESTHETIC ISSUES

Sometimes the importance of aesthetics is made clear by the contracting agency in the project. This was the case in Caguas, PR, where Eng. José A. Batlle has served the municipality with projects that include traffic calming techniques, such as the construction of median barriers. In his example, the medians were planted with ornamental bushes, and fancy street lamps were used for lighting.

In a case study of the community of Bellevue, Washington[4], the city found that by combining speed humps with landscaped curb extensions, it could not only improve the appearance of humps but also draw attention to them for added safety and speed reduction; any vertical element such as a tree of shrub is more visible from the driver's angle of vision than is a *horizontal* element such as a speed hump. And while the new enhanced hump did cost considerably more ($5,000 versus $1,500 in their particular case), the potential speed reduction and neighborhood approval for the community is also greater with this design. This application demonstrates how aesthetics, safety and control may be complementary.

Use of Landscaping

In visual preference surveys, scenes containing landscapes and other natural elements tend to be rated highest[5]. Landscaped street edges soften the appearance of speed humps and other vertical traffic calming measures. Landscaped chicanes, center islands, and traffic circles may create distinctive and pleasing streetscapes, whereas the same measures in plain concrete may appear cold and uncomfortable to the driver. It has happened in the studied cases of United States, as well as in Puerto Rico[6], that the public will react strongly against a new traffic calming technique because it is basically interfering with the street and annoying the drivers, and thus ask the municipality to remove the measure without analyzing the benefits of a reduction in speed and accidents.

---

[4] *Traffic Calming, State of the Practice*. US Department of Transportation, FHWA. *ITE Publications*, 1999

[5] T.R. Herzog, S. Kaplan, and R. Kaplan, "The Prediction of Preference for Familiar Urban Places," *Environment and Behavior*, Vol. 8, 1976

[6] Installing of street humps in PR 67 project, by *CSA Group* designing company.

Landscaping is an option to increase favorable public response towards the new measures, if the result is appealing enough to the community.

Besides enhancing appearance, landscaping a measure might also improve the effectiveness and safety of the circles by drawing attention to them. Any vertical element – trees, shrubs, planters, signage and even man-made elements such as a monument, as is the case of the Monument to the *India Taína* in Caguas, PR – should draw attention to traffic calming measures.

MUTCD Principles Applicable to Traffic Calming Measures

While only addressing traffic islands specifically, the *Manual of Uniform Traffic Control Devices for Streets and Highways* (MUTCD) establishes principles that may be relevant to other traffic calming measures as well. First, the MUTCD offers a degree of flexibility in the application of signs and markings. For example, it states:

> Engineering judgment is essential to the proper use of signs, the same as with other traffic control devices. Traffic engineering studies may indicate that signs would be unnecessary at certain locations.[7]

Added flexibility is provided by the MUTCD's frequent use of the term "should" rather than "shall". The first denotes a *recommended* practice, while the latter denotes a *mandatory* practice.

Second, the MUTCD urges conservative use of signage, which is consistent with an aesthetic orientation:

> Care should be taken not to install too many signs. A conservative use of regulatory and warning signs is recommended as these signs, if used to excess, tend to lose their effectiveness.[8]

More than one surveyed traffic calming program has learned though experience that excessive signage detracts from sign comprehension and street aesthetics.

Third, the MUTCD provides general guidance for warning signs, object markers, curb markers, lane lines, pedestrian crossings, and other traffic control devices that in some communities have been applied to traffic calming measures as well as to other geometric features. Examples include:

> Warning signs are rectangular of diamond-shaped with a yellow background and black messages.

[7] Federal Highway Administration (FHWA), *Manual on Uniform Traffic Control Devices for Streets and Highways*, Millennium Edition. Washington, DC, p. 2A-2

[8] FHWA, op. Cit., p. 2A-3

> White lines mark the right edge of the pavement; yellow lines always separate opposing traffic and mark the left edge of the pavement on divided highways.
>
> Legibility is the basic requirement of street signs. *"This means high visibility, lettering or symbols of adequate size, and short legends for quick comprehension…"* [9]
>
> Use of symbols is favored over word messages[10]. Symbol signs should be evaluated for motorist comprehension before they are approved for installation. New symbol signs not readily recognizable should be accompanied by educational plaques.
>
> Advance warning signs are to be placed upstream of measures wherever *"high driver judgment"* or *"deceleration to a specified speed"* is required. A one-lane choker is an example of a situation that requires high driver judgment. A 12-foot hump in a 30-mph zone is an example of a situation that requires deceleration to a specific speed of 20 mph. The MUTCD establishes advance warning placement.

Fourth, the MUTCD allows State and local highway agencies to develop word message signs for conditions not addressed in the MUTCD, provided the appropriate shape and color sign is used:

> In situations where messages are required other than those herein provided for, the signs shall be the same shape and color as standard signs of the same functional type.[11]

[9] FHWA, op. Cit., p. 2A-4
[10] FHWA, op. Cit., p. 2A-6
[11] FHWA, op. Cit., p. 2A-4

X. TRAFFIC CALMING IN PUERTO RICO

For the purpose of investigating in a general manner the tendencies in Puerto Rico of engaging in projects that make use of traffic calming techniques, a few design companies were interviewed about their projects and their use of traffic calming.

Five design companies were called and asked to answer simple questions regarding their company, the position of the interviewed person, kind of projects that the company has had, and if they have used traffic calming techniques in their projects. The information gathered via these interviews is what follows.

CMA Architects and Engineers LLP (Limited Liability Partnership)

Eng. Fernando Morales was interviewed. The company mostly engages in public (the client is the government) projects. For the Puerto Rico Highway and Transit Authority, they have constructed highways such as the PR-9, and have the contract for the design of the West Connector, which is the conversion of PR-2 to highway, the parcel from Mayagüez to Hormigueros. Because their projects are most of the time high speed roads, where traffic calming is not liable, this company does not use traffic calming techniques in their designs. They do, however, use signing and pavement marking, as instructed by the MUTCD.

CSA Group

Eng. Pedro Moreno, highway and bridge engineer of the company, was interviewed. This company's projects are something like 65% public, 35% private. Although they have used traffic calming, this is not very often, as they had problems with one installment of traffic humps in PR-67, where the community reacted against the

measures, and then were asked to remove the humps. As is the case of CMA Architects and Engineers, CSA Group designs mostly state roads, and very little rural or urban.

Guillermety, Ortiz & Associates

Eng. Carlos Daniels was interviewed. This is a design company, and they too work mostly with public projects. For HTA, their projects are mostly high speed, new roads, such as the conversion of PR-2 to highway, the parcel from San Germán and forward. However they have sometimes designed the reconstruction or rehabilitation of an existing road, like is the case of a project in Mayagüez in front of PR-102 between the Yavat ravine and the Yagüez River, a stretch that will be redesigned. The mayor of this municipality and his Historical Planning director have personally asked this firm to use tiles in a short distance as a traffic calming technique because the place is located in a historic zone. This way tiles serve as a speed reducing tool and also as decorative pavement.

José A. Batlle & Associates

Eng. José A. Batlle was interviewed. His firm's projects include the conversion of PR-2 to highway, the parcel from Hormigueros to San Germán. The majority of their work is in Caguas, which the engineer calls "the city of the future". Caguas has many traffic calming examples already built, even some by his company. They make aesthetic improvements, geometric improvements, improve the pluvial channels, planting and lighting.

The factors affecting the selection of these techniques are how much money they have been assigned, the existing space, the available space, the attendance or servitude of the road, etc.

Rodolfo López & Associates

This is another kind of firm, with respect to the previous, because their projects are mostly private, and they have hardly any public projects. They mostly design buildings and big houses.

Table 1. Summary of interviews made to five design firms in relation to *traffic calming* techniques

	TRAFFIC CALMING TECHNIQUES					
Firm	**Speed Bumps**	**Tiling**	**Median barriers**	**Islands**	**Roundabouts**	**Does not use T.C.**
CMA Architects & Engineers						X
José A. Batlle & Associates			X	X	X	
Guillermety, Ortiz & Asociados		X				
CSA Group	X					
Rodolfo López & Asociados						X

XI. LITERATURE LESSONS LEARNED

When examining the pedestrian issues in Puerto Rico, the statistics that reveal the appalling truth, one cannot help but wonder why is nothing being done, why does the pedestrian death rate keeps increasing. An insight into the regulations reveals that they *are* minded, or at least supposed to be. The organization of the infrastructure is regulated to encourage pedestrian safety, but the public space is sometimes found to do the opposite and favor the vehicles, either because new designs do not follow the regulations or because nothing has been done to fix an existing problem.

If the public space does not harbor reliable pedestrian facilities, then, to promote the safety of our walking citizens, different alternatives must be found. If the main cause of pedestrian deaths is by impact of vehicles, then the logical deduction is that vehicles must be restricted somehow to reduce the probability of loss of control and thus reduce the impacting of pedestrians. Reducing this probability can be achieved by reducing the speed of travel, because at lower speeds the drivers have more control over their vehicles, and in the event of encountering a pedestrian in their way, they will be able to react and decelerate more rapidly, not harming the pedestrian in any way.

The way we have learned to reduce speed throughout this investigation is to use traffic calming techniques, and the different techniques have been studied. If we are able to attack the pedestrian issues by using traffic calming and abiding by the regulations, then we can build a safer environment for pedestrians, and in the long term, a better community.

XII. TREN URBANO CASE STUDY:

INTERSECTION OF ROOSEVELT AVENUE WITH LUIS MUÑOZ RIVERA AVENUE

A. Case Description

Traffic flow in this intersection is currently disturbed by *Tren Urbano* Roosevelt Station construction (fig. 13), on both sides of Roosevelt Avenue. The sketch of the study site is presented in the following figure.

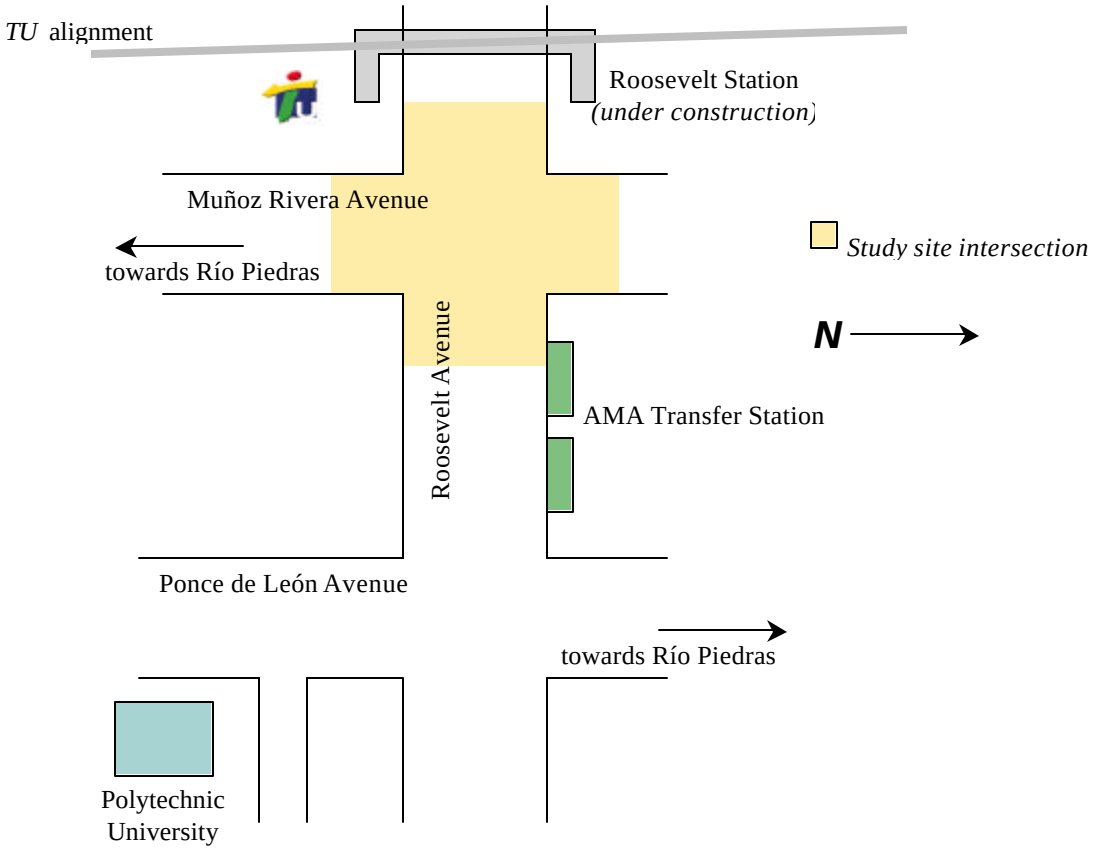

Fig. 12 Study site

Fig. 13 Station construction view

Fig. 14 "*Chuleta*" island

Roosevelt is the principal avenue and it has three lanes per direction. In the east direction, it has two additional lanes to accommodate the incoming flow from Luis Muñoz Rivera Avenue to the east. These lanes have free right turns when entering Muñoz Rivera Avenue because an island type "*chuleta*" (*chop*, from its shape) permits it, as figure 14 shows.

Once the vehicle is inside the turn, merging into Muñoz Rivera Avenue is relatively easy because after the curve there is an accelerating lane. This lane will accommodate any queue created in the turn when traffic is high, but it has the negative effect of allowing the vehicles to achieve the turn without reducing their speed when traffic is low. The very same island is on all four corners of the intersection.

B. Problem Statement and Case Analysis

The major problem with these volume-accommodating measures is that while they serve the motorized vehicle a comfortable merge into the desired lane, they neglect altogether the pedestrians traversing across the avenue. It is important to discern from figure 9 that this intersection will have a high volume of pedestrians walking across it, because there is a transfer station of the *Metropolitan Bus Authority* (MBA) in Roosevelt Avenue, and very close by is the Polytechnic University.

When *Tren Urbano* is in full operation of Phase 1, many pedestrians will be crossing the streets at this intersection to reach Roosevelt Station: people transferring from MBA buses to *Tren Urbano* and vice versa. Students from the Polytechnic University will most likely walk to the station (a less than 5 minutes' walk). The actual conditions of the intersection are compromising their safety in exchange of accommodating traffic as smoothly as possible.

Fig. 15 Low island

Fig. 16 Unsafe turning

Let us now consider a vehicle in the right lane of Roosevelt Avenue that is about to turn right into Muñoz Rivera Avenue, and a student arriving from Roosevelt Station about to *cross* Muñoz Rivera Avenue. The student has all the attention devoted to the upcoming vehicle, but the driver has his attention to the *left* at Roosevelt Avenue, making sure it is safe for *him* to turn right into the lane. After making sure no vehicle is crossing Roosevelt Avenue, the vehicle will *accelerate* to exit the turn as quickly as possible, and this is achievable because of the accelerating lane. After the vehicle leaves, the student crosses the turn and enters the island, where he or she will wait for the pedestrian signal to change to *Walk* mode, cross the avenue, and enter the second island where the process is repeated.

Sometimes, though, a pedestrian will be engaged in some other thought rather than his or her safety, and not pay the necessary attention to the vehicles turning. If this happens, this pedestrian is in danger because the vehicles entering the turn are not paying attention to the turn as much as to the avenue in the incoming direction, with the mind focused on exiting the turn as quickly as possible.

Fig. 17 Pedestrians entering island

Fig. 18 Uninviting island

Besides this dangerous situation, another problem most likely to be faced by pedestrians is that the islands themselves are unsafe. They are low in height; this is for the protection of vehicles against a possible collision (see figure 15). While protecting vehicles, they are unsafe for pedestrians as well as unfriendly and uninviting (figure 18).

For the separation of lanes, at the intersection, the avenues use median barriers. This is very useful for pedestrians because the right-of-way of the avenue is very long. Median barriers protect vehicles from entering the opposing direction, and they also serve as a break for walking pedestrians. The problem with the median in Roosevelt Avenue is that it is too narrow (approximately 2 feet), making it unsafe and also impractical for the handicapped.

Fig. 19 Median barriers

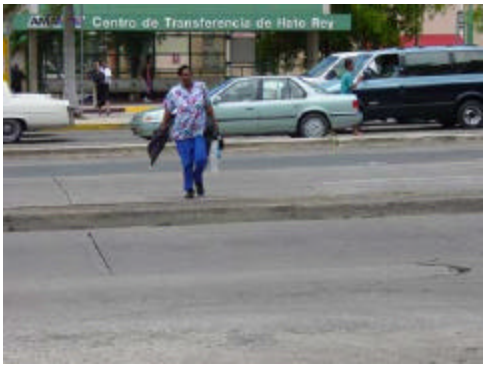

Fig. 20 Pedestrian crossing carelessly

Fig. 21 Planted medians

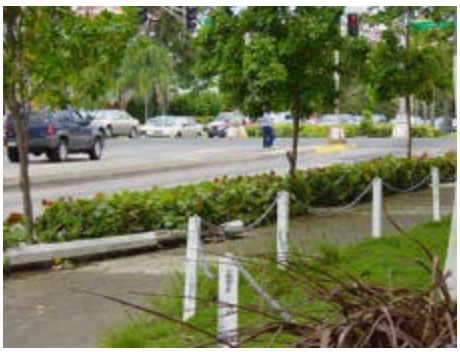

Fig. 22 Planted sidewalk

The median in Muñoz Rivera Avenue is wider, and has been planted. It is much more appealing to pedestrians and could serve as an example for improving the median in Roosevelt Avenue. Moreover, such landscaped traffic calming techniques have more positive public response, and embellish the city (see section IX on the use of landscaping).

The sidewalk presented in figure 22 is along the eastbound lanes of Roosevelt Avenue, after the intersection with Muñoz Rivera Avenue. Although the picture shows damage, this is a very inviting sidewalk because of the planting. The shrubs serve both aesthetically and functionally, because they separate the motorized vehicles and the pedestrians. While they could not hold vehicle gone astray out of the walkway, they do hold pedestrians *inside* the sidewalk. On the other side of Roosevelt Avenue *(westbound)*, no such planted sidewalk exists, and let us remember that this is the side that yields the MBA Transfer Station. Planting the westbound sidewalks as the eastbound already are would be ideal for the MBA users, to further protect them form traffic during rush hours. And, at the same time, if both sides are planted, this will improve aesthetically the part of Roosevelt Avenue that will receive *Tren Urbano* riders.

C. Evaluation of Alternatives

The main problem with this intersection is the constant neglect of pedestrians. It was designed giving priority to the motorized vehicle. From a traffic management point of view the intersection is a success; but a failure in a pedestrian-oriented vision. However, the imminent presence of *Tren Urbano* is expected to improve life quality in the city, and this change must start before *Tren Urbano* begins operations in 2003. The use of traffic calming techniques has been associated with life quality improvements as the community welcomes the changes.

The first logical step would be to protect pedestrians walking the avenue, with the purpose of increasing the amount of people that will leave their vehicles parked and choose to walk to their destinations, at least for lunch or such other short trips. To protect pedestrians, the speed of the vehicles that *interact* with them must be reduced, meaning the vehicles in the turns, which can encounter a pedestrian in the same space and time as they are turning. Pedestrians crossing the main avenue are not considered to interact directly with vehicles because they have their own crossing time assigned by the pedestrian signal.

Achieving speed reduction is no simple task. Following are some options:

1. *Lowering of speed limit*. This is not an option of high liability, but will be most likely rejected by the public, for the conditions at the intersection will worsen as longer queues appear and driver incommodity intensifies.

2. *Traffic calming speed control treatments at the intersection*. Such may include intersection raising by tiling. This could reduce significantly the speed for the studied stretch of avenue, and although driver rejection is always a possibility, these raised intersections are not that uncomfortable as, say, speed humps,

because the vehicle encounters the raise *once*, then traverses a short length before reaching the drop. Moreover, adequate tiling in conjunction to landscaping sidewalks can embellish a once unattractive intersection. The only problem with this treatment is that it does not target speed reduction where the problem lies, which is at the turns. If raising the intersection includes raising the turn, then vehicles *turning* will not encounter a differential of vertical acceleration because *they are already raised as they enter the turn*, and thus will not be encouraged to reduce speed.

3. *Speed humps at the beginning and end of the turn*. This treatment will definitely reduce speed at the turn, where the problem is because vehicles interact with pedestrians. However, speed humps are highly uncomfortable because the vehicle the vehicle rises as it encounters the hump, followed immediately by a drop that increases the downward acceleration. This incommodity is liable to public rejection.

4. *Tiling of the turn*. Since speed reduction at the turn is the goal, but speed humps may be openly rejected, tiling as described to raise the intersection could be applied *only* at the turn. It is less uncomfortable to the driver than speed humps because the rise is not immediately followed by the drop. The vehicles will not accelerate while they are inside the turn because as the speed increases, so does the vibration or rumbling of the vehicle, discouraging any king of speed increase before the vehicle exits the turn. Another advantage of tiling is that pretty tiles will improve the aesthetics at the turn, but the turn is part of the avenue; thus the avenue is further embellished.

D. **Conclusions and Recommendations**

The most favorable way of achieving the needed speed reduction is the proper use of traffic calming techniques. The problem is that these treatments annoy the driving public, and thus are frequently exposed to rejection. Because of this, the treatment to be used must be the one that serves its purpose but at the same time minimizes liability. That is why I favor the use of tiles at the intersection more than any other alternative. Proper use of this treatment will reduce speed and thus protect pedestrians crossing the turn and improve the quality of the intersection without excessively annoying drivers.

However, the success behind traffic calming techniques is not only success in speed reduction, but also the longer-term benefits of improving the avenue, which is expected to be greatly aided by the inauguration of *Tren Urbano* in 2003. The community has to strongly express this need and stand by this statement, to reduce the liability associated with traffic calming.

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