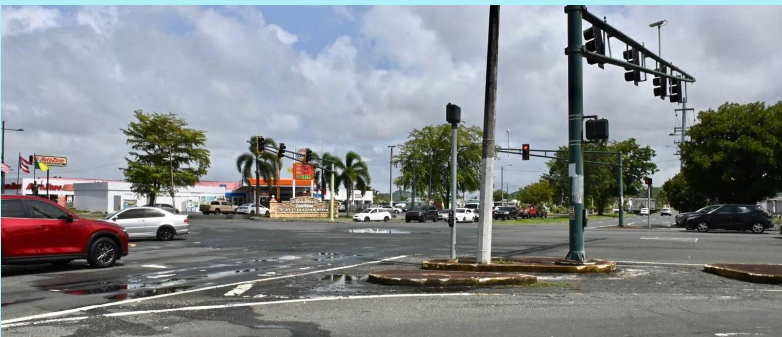


# PHASE 2 REPORT: COMPREHENSIVE SAFETY ACTION PLAN MUNICIPALITY OF TOA BAJA MANAGEMENT AND TECHNICAL CONSULTING GROUP



The Second Phase of the Comprehensive Safety Action Plan for the Municipality of Toa Baja is characterized by the technical and engineering aspects of the safety plan. In this document, the reader can understand the current roadway safety problems and hazards faced by motorists, pedestrians, cyclists and other types of road users on the municipal roads. The reader can also understand to a great extent how some areas of the municipality are defined by higher risks. The report highlights four major activities that comprise this phase of the project:

- the definition of the high injury network of Toa Baja, where most of the severe collisions occur
- the targeted safety investigations that quantify the severity of incidents according to exposure, road conditions and user behavior
- the equity analysis conducted which associate road safety hazards with underserved communities, and
- the analysis of safety countermeasures considered for the roadways of Toa Baja.

The information presented in this report is the result of a multidisciplinary approach undertaken by transportation engineers, planners, architects, and statisticians.

This report is divided into four chapters:

1. Network Screening
2. Safety Investigations
3. Equity Analysis
4. Safety Evaluations

## Network Screening

As long as there are users on the road, there is the potential for a safety-related incident. A core fundamental of the Safe Systems Approach rests on the inevitability of collisions on the road. Therefore, the goal of traffic safety engineers and planners is to mitigate the severity of incidents.

From 2020 to 2024, there were 853,202 traffic-related collisions across Puerto Rico<sup>1</sup>. During the same period, there were 17,869 collisions in Toa Baja, Puerto Rico, accounting for 2.1 percent of all collisions.

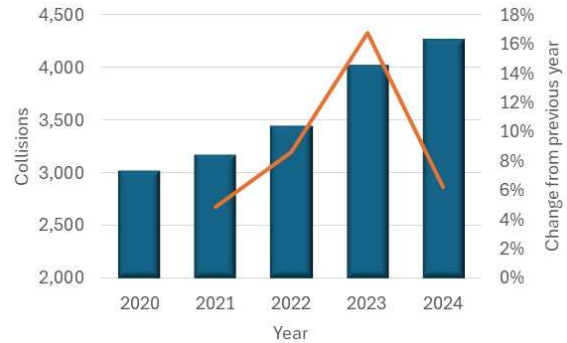
When compared annually, there is clearly an increasing trend in roadway collisions from the lows from 2020. Since 2020, each year there are between 150 and 580 more collisions than the previous year, which has resulted in an overall increase of 41.3 percent in collisions.

Figure 1 shows the number of collisions in Toa Baja by year and the rate of change from one year to the next.

Many have resulted in fatalities or severe injuries to individuals. In fact, there were 31 fatal collisions and 117 severe-injury collisions during the 2020 to 2024 five-year period. The rate of fatal collisions per 1,000 collisions was estimated at 1.73. Meanwhile, there were 6.55 severe

collisions for every 1,000 collisions in the municipality.

Figure 1 Traffic collisions per year and rate of change



The rates of collisions and severe collisions are found to be higher in Toa Baja compared to the rest of Puerto Rico. The rate of severe injury collisions is two times higher compared to the rest of Puerto Rico (6.55 versus 3.28), and the rate of fatal collisions is a tenth higher, as Table 1 shows.

Table 1 Severe collisions in Toa Baja and Puerto Rico

	Toa Baja	Puerto Rico
Collisions	17,869	853,202
Fatal Collisions	31	1,345
Rate of Fatal Collisions (per 1,000 crashes)	1.73	1.58
Severe Injury Collisions	117	2,801
Rate of Severe Injury Collisions (per 1,000 crashes)	6.55	3.28

As the number of collisions have increased on an annual basis since 2020, so has the number of severe collisions.

<sup>1</sup> Source: Observatorio Vial. <https://observatoriovial.net>

The three-year average number of severe collisions in the municipality has climbed from:

- 26 per year (2020 to 2022);
- 30 per year (2021 to 2023);
- 33 per year (2022 to 2024).

A map of the 148 severe collisions that occurred in Toa Baja during the 2020-2024 period is shown in Figure 2. Severe collisions have occurred across all areas of the municipality. Sites with a higher number of severe collisions require an in-depth analysis to identify hazards, common causes and contributing circumstances.

### Roadways

Severe collisions have occurred along the major highways, primary arterials, minor arterials, and collectors across Toa Baja. In all, 32 roads of Toa Baja had a severe collision during the 2020 to 2024 period. The five roads with the highest number of severe collisions during this period were:

- State route PR-2: 28
- State route PR-867: 22
- State route PR-165: 20
- State route PR-865: 11
- State route PR-866: 11

State routes PR-2, PR-867 and PR-165 stand out as roads with the most occurrences of severe collisions. The three roads accounted for 70 of the 148 severe collisions in Toa Baja – almost half of all severe collisions. State routes PR-865 and PR-866 also have a high number

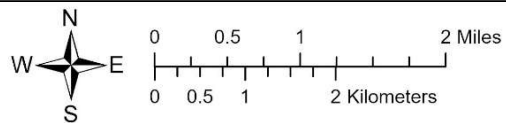
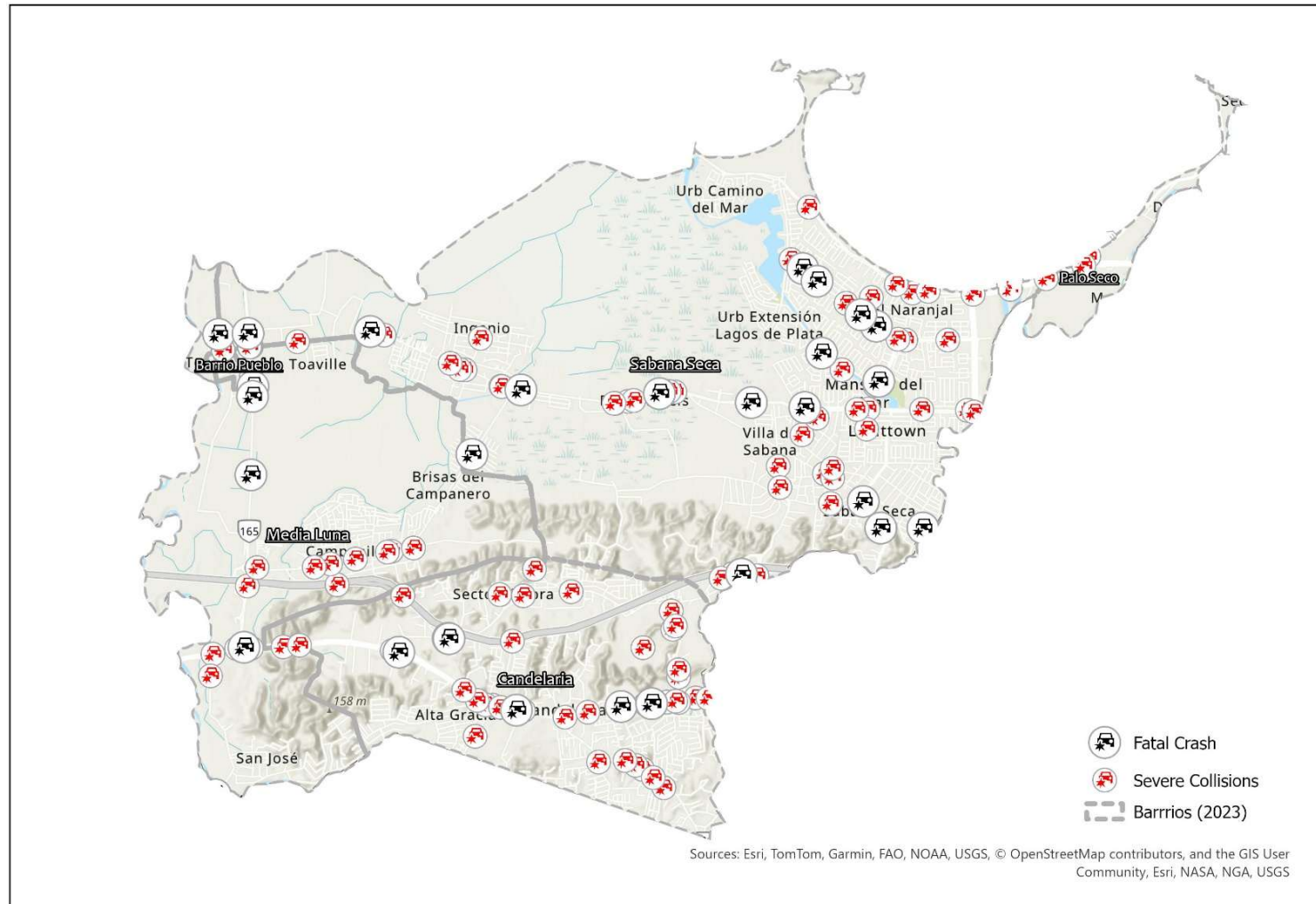
of severe collisions, with 11 severe collisions each.

Municipal roads Avenida Boulevard (9) and Avenida Juan “Picolino” Hernández Ferrer (7) had the highest number of severe collisions among local roads. Both roads are multilane minor arterials located in the Levittown sector.

*Table 2 Severe Collisions by Road*

Road	Severe Collisions
PR-2	28
PR-867	22
PR-165	20
PR-865	11
PR-866	11
Avenida Boulevard	9
Avenida Juan “Picolino” Hernández Ferrer	7
PR-863	5
PR-22	3
Avenida Dr Alvarez Chanca	3
Avenida Ramón Ríos Román	3
Avenida Olga Tañón (Los Dominicos)	2
PR-872	2
PR-8865	2
PR-865R	2
Avenida El Plantio	2
Avenida Campanilla	1
Avenida Dos Palmas	1
Avenida La Fuente	1
Calle Aleli	1
Calle Bellísima	1
Calle Jazmín	1
Calle Parcelas Nuevas	1
PR-167	1
PR-819	1
PR-854	1
PR-870	1
Calle Marginal	1
Calle Progreso	1
Boulevard Bruno Cruz	1
Calle Crispe Interior Callejon	1
Paseo Dilma	1
<b>Total</b>	<b>148</b>

Figure 2 Location of Severe Collisions Between 2020 and 2024



### Functional Classification

Minor arterials have the highest number of severe collisions, followed by principal arterials. Minor arterials distribute local traffic, while principal arterials serve local and regional traffic. The number of severe collisions in these two roadway types can tell us that residents of Toa Baja carry a higher burden from severe collisions occurring within the municipality.

*Table 3 Severe Collisions by Functional Classification, 2020 to 2024*

Functional Classification	Severe Collisions	Fatal	Serious Injury
<b>Interstate</b> PR-22	3	0	3
<b>Principal Arterials</b> PR-2 PR-165 PR-167	48	10	38
<b>Minor Arterials</b> PR-865 PR-867 PR-866: PR-865 to PR-167 Ave Olga Tañón Ave Boulevard Ave Juan “Picolino” Hernández Ferrer: PR-866 to PR-867 Ave Ramón Ríos Román: PR-867 to PR-866	66	13	53
<b>Collectors</b> Ave Dos Palmas PR-8865 PR-866: PR-2 to PR-865 PR-872 Ave Juan “Picolino” Hernández Ferrer: PR-167 to PR-866 Ave Campanilla PR-865R Ave Dr Álvarez Chanca	21	7	14
<b>Local</b> PR-854 PR-870 Several others	10	1	9
<b>Total</b>	<b>148</b>	<b>31</b>	<b>117</b>

Figure 3 shows a map of roads in Toa Baja by functional classification and the location of severe collisions.

### Average Daily Traffic

Location data from severe collisions was also paired with Average Annual Daily Traffic (AADT) data from the Highway Performance Monitoring System (HPMS) to identify the rates of severe collisions per 1,000,000 vehicles. AADT data from the HPMS is segmented along a roadway, so the data is presented by section of roadway.

The roadway segments that have the highest rates of severe collisions relative to the volumes of the roadways are shown in Table 4.

The most dangerous roadway segment in Toa Baja is route PR-854, which connects the city center of Toa Baja to route PR-6165 in Mameyal, Dorado. Despite the low traffic volumes on this road, the rate of severe collisions is 1.564 per million vehicles.

The segment with the most severe collisions is route PR-867 between route PR-165 and Avenida Campanilla that includes the communities of Toaville, La Monserrate and Ingenio.

Figure 4 highlights the severe collision rates on a map of Toa Baja.

Figure 3 Severe Collisions and Functional Classification of Roads

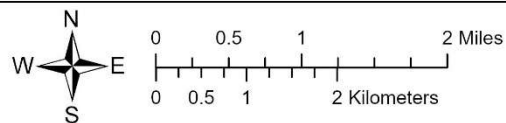
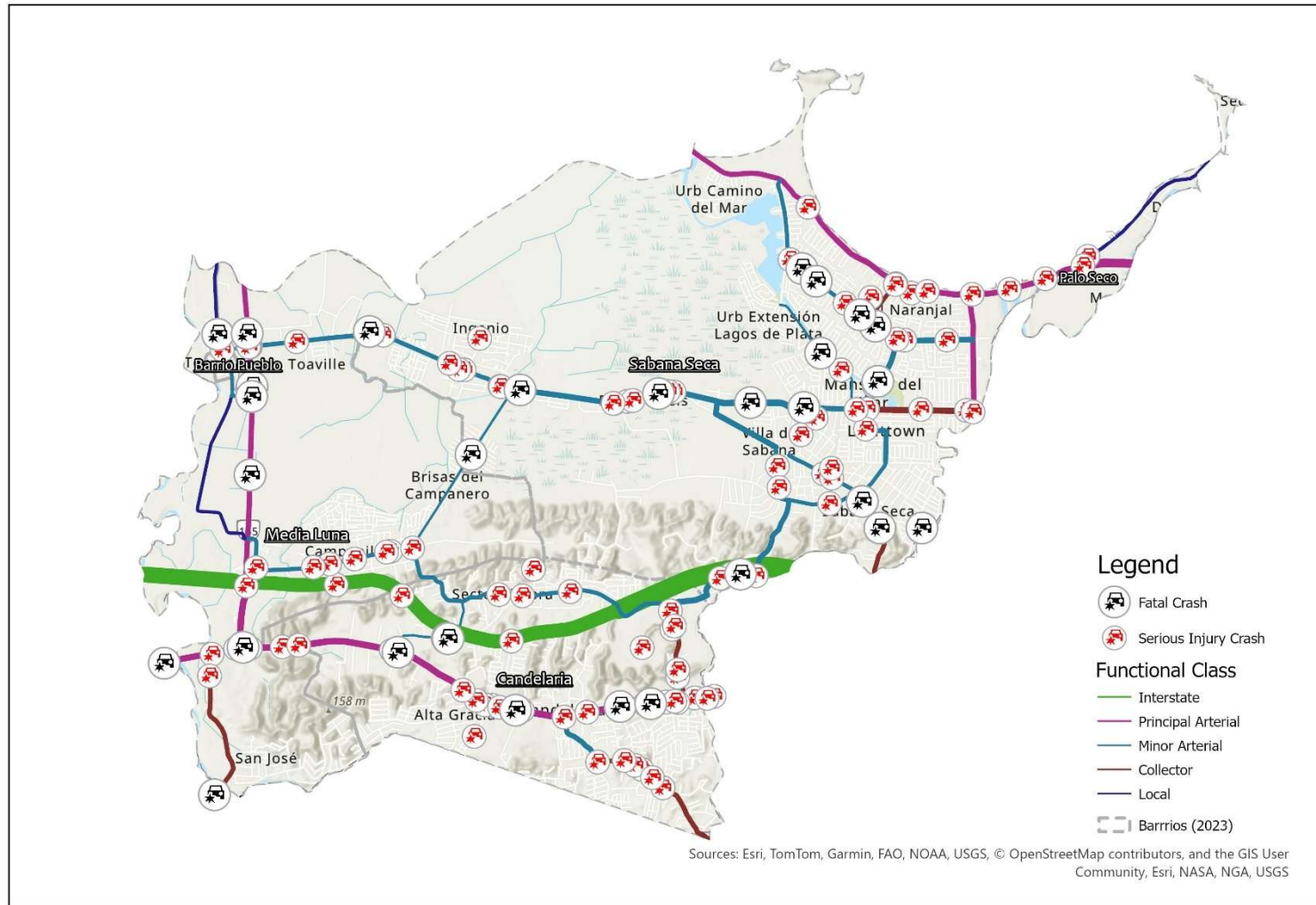
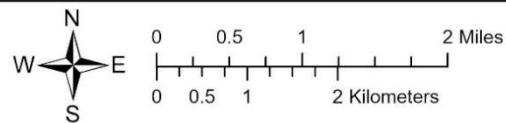
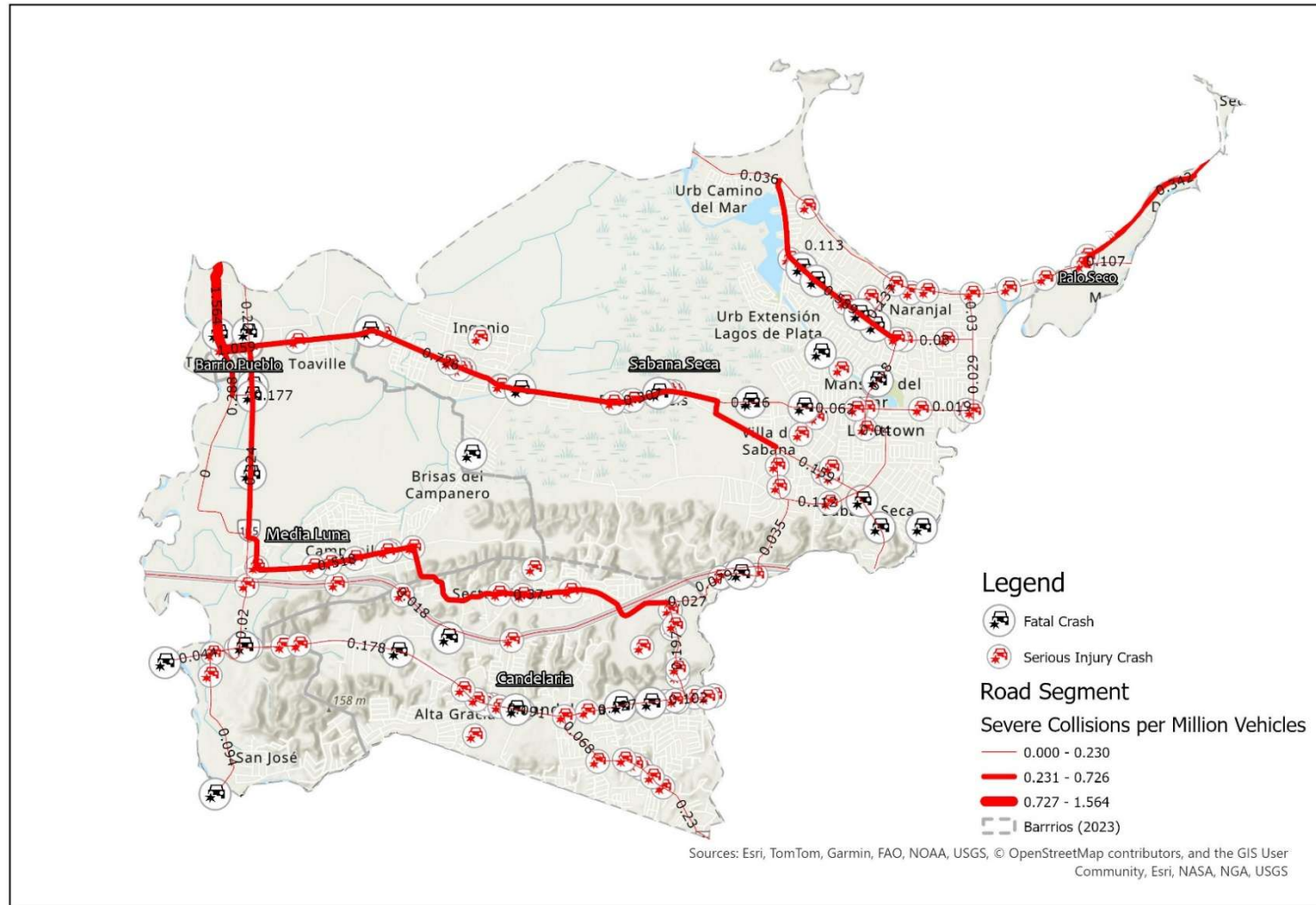


Table 4 Road segments with the highest severe collision rates

ID	Road	Segment	Functional Class	AADT	Severe Collisions	Collisions per Million Vehicles
1	PR-854	Boulevard Bruno Cruz to Rio Cocal	Local	700	2	1.564
2	PR-867	PR-165 to PR-854	Minor Arterial	3,100	6	1.059
3	PR-867	Avenida Campanilla to PR-165	Minor Arterial	9,800	13	0.726
4	Avenida Boulevard	Avenida Olga Tañón to PR-165	Minor Arterial	6,500	7	0.589
5	PR-865	PR-165 to Avenida Campanilla	Minor Arterial	7,400	7	0.518
6	PR-865	Avenida Campanilla to PR-866	Minor Arterial	7,400	5	0.370
7	PR-870	PR-165 to Parque Nacional Isla de Cabras	Local	1,600	1	0.342
8	PR-165	PR-865 to PR-867	Principal Arterial	16,842	10	0.324
9	PR-867	Avenida Ramón Ríos Román to Avenida Campanilla	Minor Arterial	19,600	11	0.307
10	PR-854	Calle Jaime Fonalleda to Boulevard Bruno Cruz	Minor Arterial	1,900	1	0.288
11	PR-165	PR-867 to Rio Cocal	Principal Arterial	14,900	6	0.220
12	PR-866	PR-2 to PR-865	Collector	11,100	4	0.197

Figure 4 Severe Collision Rates per Million Vehicles



## Safety Investigations

Safety investigations help municipal officers organize their safety-related work around geographic or temporal shifts that are characterized by higher collision rates. Similarly, efforts can target specific population groups or specific types of road users at times when these are most likely to be involved in severe collisions.

Collisions take place across all times of days, every day of the week and every month. But taking a closer look at the collision data can reveal patterns that reveal periods of higher risk of collisions across the day, the week, or the year. Similarly, several patterns emerge when sorting the collision data through a demographic scope, or across modes.

For instance, December is the calendar month with the most collisions (1,599) and with the most severe collisions (18).

Across a 24-hour period, the time of day with the most collisions is between 12 PM and 8 PM, which includes afternoon and early evening trips. The deadliest hours are from 7 PM to 8 PM, and from 2 PM to 3 PM.

Figure 5 shows the time periods with the highest number of severe collisions for each calendar month.

Figure 5 Deadliest Time of Day by Month

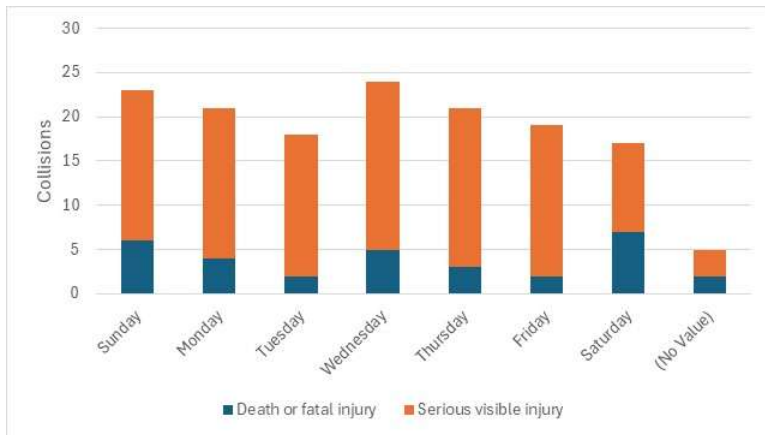


The 2 PM to 3 PM period is among the times of day with the most severe collisions on 4 of the 12 months of the calendar. This period of the day is characterized by school-related trips generated by the end of the school day.

Collisions can occur any day of the week. Wednesdays and Sundays had the most severe collision events, as shown in Figure 6. Tuesdays had the least number of severe collisions (18).

When considering only for fatal collisions, weekends are characterized as being more deadly. Saturdays (7) and Sundays (6) have the highest number of fatal collisions in Toa Baja. On weekdays, the deadliest day is Wednesday (5), while Tuesdays (2) and Fridays (2) have the fewest fatal collisions.

Figure 6 Severe Collisions by Day of the Week



### Collision Type

The most common type of collision is the rear-ending of another vehicle. This type of collision happens when there is not enough distance between vehicles, causing the trailing motorist to crash against the vehicle in front of them. There were 4,768 rear-end collisions between 2020 and 2024, accounting for 26.7 percent of all collisions during this period.

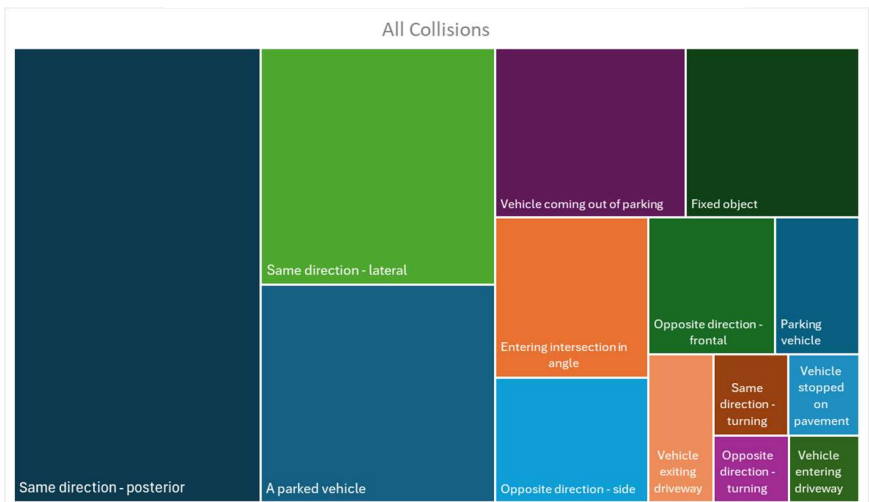
On Wednesdays, the day of the week with the highest number of severe collisions, the period with the highest incidence is between 7 PM and 8 PM.

On Sundays, the time periods with the most severe collisions are between 6 AM and 7 AM, and between 7 PM and 11 PM.

On Saturdays, the day of the week with the highest number of fatal collisions, the periods with the most incidents are between 3 AM and 4 AM, between 5 PM and 6 PM, and between 7 PM and 8 PM.

Other common types of collisions in Toa Baja are: same direction lateral collisions, collisions with parked vehicles, collisions with vehicles coming out of a parking space, collisions with fixed objects and collisions entering an intersection, as seen in the treemap on Figure 7.

Figure 7 Distribution of All Collisions by Type



### Collision Attributes

Safety investigations looked at the composition of collisions across an array of temporal, physical, behavioral, and modal characteristics. This section of the report provides an analysis of these characteristics and their interrelationships.

Same direction lateral collisions occur when a trailing vehicle tries to overtake the vehicle in front. These types of collisions are usually associated with aggressive driving behavior. There were 2,361 collisions of this type between 2020 and

2024, accounting for 13.2 percent of all collisions.

Collisions with parked vehicles can happen when a motorist does not take into consideration the available width of the travel lane and crashes against a parked vehicle on the side of the road. Oftentimes the roads are not wide enough to accommodate parked vehicles, leading to the parked vehicles partially occupying a travel lane. There were 2,170 collisions of this type between 2020 and 2024, accounting for 12.2 percent of all collisions.

Collisions with fixed objects are defined as interactions with non-roadway elements. Collisions with fixed objects include collisions between vehicles and pedestrians, cyclists, and animals. These also include fixed elements on the side of the road such as trees, utility poles, fire hydrants, bus stops, fences, gates, mailboxes, culverts, guardrails, etc. There were 1,252 collisions with fixed objects between 2020 and 2024, accounting for 7.0 percent of all collisions.

Collisions entering an intersection at an angle can occur at any crossing of two roads. These types of collisions are also common in Toa Baja, with 1,038 taking place between 2020 and 2024 and accounting for 5.8 percent of all collisions.

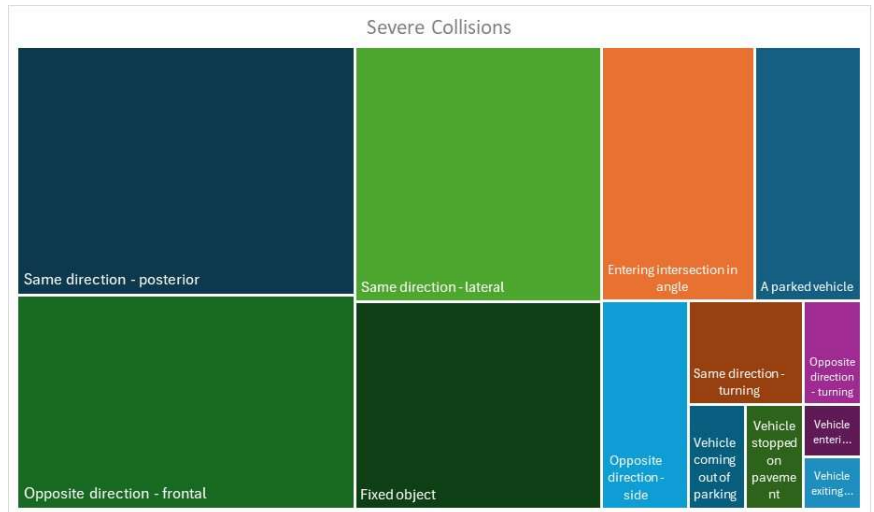
*Severe collisions by type*

Severe collisions are more common for specific types of collisions. The most common collision types among severe collisions are:

- Same direction posterior (28)
- Opposite direction frontal (24)
- Same direction lateral (21)
- Collision with fixed object (17)
- Entering intersection in angle (13)

Figure 8 shows a treemap of the distribution of collision types for severe collisions.

*Figure 8 Distribution of Severe Collisions by Type*



The types of collisions that are most likely to be severe are:

- Front-end collisions: 4.1 times more likely to be severe
- Same direction turning: 2.0 times more likely to be severe
- Collision with fixed objects: 1.7 times more likely to be severe.

### Severe rear-end collisions

The most common cause for the rear-end collisions was following too closely the vehicle ahead, which was the case on 19 of the 28 collisions (67.8 percent). Another common denominator in severe rear-end collisions was aggressive drivers. Of the 28 rear-end collisions, 20 involved aggressive drivers. Male drivers were driving the trailing vehicle in 23 of the 28 collisions, or 82 percent of these collisions.

Afternoons were the most common time for rear-end collisions, with 16 of the 28 severe collisions occurring during this time of day. Daytime conditions were also prevalent for this type of collision, with 20 of the 28 severe collisions taking place in daylight.

Of the 28 collisions, 25 occurred in clear weather conditions.

Severe rear-end collisions were most common on route PR-2, where 12 of the 28 collisions took place. Other areas of concern were routes PR-866, Avenida Juan “Picolino” Hernández Ferrer, and Avenida Olga Tañón (Los Dominicos).

### Severe opposite direction frontal collisions

Opposite direction frontal collisions is one of the deadliest types of collision because the energy exerted in the collision is magnified by the speeds of the vehicles

involved. Opposite direction frontal collisions are four times more likely to be severe compared to all other collision types.

Severe opposite direction frontal collisions took place repeatedly on these roads:

*Figure 9 Head-on collision on route PR-867 Toa Baja<sup>2</sup>*



- PR-867: 5
- PR-865: 4
- PR-866: 3
- PR-2: 5
- PR-863: 3

Most of these collisions – 16 of 24 – occurred on roadway segments where opposing traffic was separated by a single line. This was the case for collisions on routes PR-867, PR-866, PR-865, and PR-863.

<sup>2</sup> Photo source: <https://www.telemundopr.com/noticias/puerto-rico/conductor-muere-en-aparatoso-choque->

[con-otro-vehiculo-en-la-pr-867-en-toa-baja/2484488/](https://www.telemundopr.com/noticias/puerto-rico/conductor-muere-en-aparatoso-choque-con-otro-vehiculo-en-la-pr-867-en-toa-baja/2484488/)

Opposite direction frontal collisions are more common during afternoon hours, but these types of collisions are 40 percent more likely to be severe in the morning hours between 6 AM and 12 PM. Daylight conditions were also present on 14 of the 24 severe collisions. Severe collisions were more likely during daylight conditions, dark conditions with street lighting and during sunrise conditions.

Clear weather conditions were prevalent on 22 of the 24 collisions.

While most of the severe collisions of this type occurred on straight flat road segments (15 of 24), collisions on flat curves and straight downhill segments were 2 and 3 times more likely to be severe collisions, respectively.

#### Severe same direction lateral collisions

Severe collisions involving lateral impacts for two or more vehicles traveling in the same direction were the third most common type of collision. There were 21 severe collisions of this type, which accounted for 16.2 percent of the severe collisions.

Of the 21 severe collisions, 14 resulted in serious injuries and seven (7) were fatal.

The most common contributing factors relating to same direction lateral collisions were improper lane changes and improper passing. Other elements mentioned were avoiding a person/object, disobeying a traffic signal, disregarding traffic control, and driver condition.

Males were also most responsible for these types of collisions; 17 collisions were caused by male drivers (80 percent).

Most of the same direction lateral collisions occurred in clear weather conditions (71 percent) and during daylight conditions (12 of 21). However, these types of collisions were 70 percent more likely to be severe during dark visibility conditions.

This type of severe collision occurred most on the following roads:

- PR-867: 5 collisions (23 percent)
- PR-165: 4 collisions (19 percent)
- Avenida Boulevard: 3 collisions (14 percent)
- PR-2: 3 collisions (14 percent)

#### Severe collisions with fixed objects

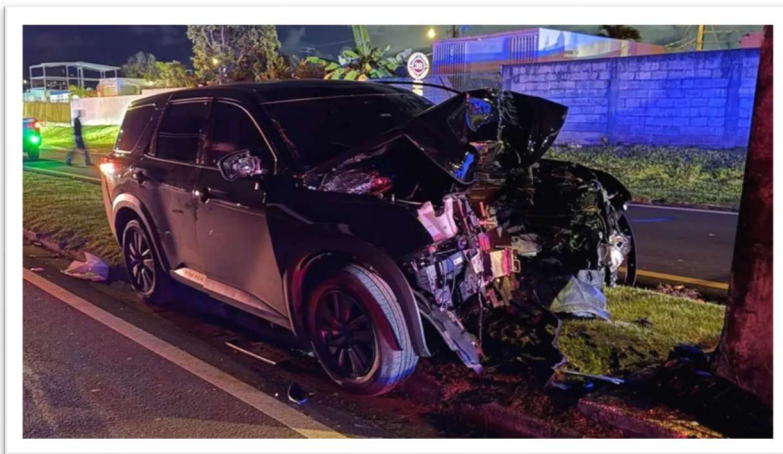
Collisions with fixed objects accounted for 17 of the 148 severe collisions, or 11.5 percent of these. Six (6) of the collisions were fatal and the other 11 collisions involved serious injuries.

The 17 collisions with fixed objects included several types of objects, as shown in Table 5.

Table 5 Severe collisions with fixed object by object type

Collision with	Fatal	Serious Injuries	Total
Concrete barrier	1	0	1
Another vehicle	0	2	2
Barrel	1	0	1
Hit and run	1	0	1
Motorcyclist	2	0	2
Unspecified fixed object	1	0	1
Pedestrian	0	2	2
Pole	0	2	2
Three or more vehicles	0	1	1
Hole	0	1	1
Not specified	0	3	3
<b>Total</b>	<b>6</b>	<b>11</b>	<b>17</b>

Figure 10 Collision with fixed object, Avenida Campanilla<sup>3</sup>



Of the 17 incidents,

- 16 occurred on straight roadway segments,
- 16 occurred in midsegments (not at intersections),
- 12 of these occurred in clear weather conditions,

- 11 did not have any visual obstructions, and
- 6 involved vulnerable users.

#### Entering intersection at an angle

Collisions caused by vehicles entering an intersection at an angle are usually the result of judgement decisions by the motorist entering the intersection. These types of collisions can be severe because the passengers and drivers' sides of the vehicles entering the intersection are more exposed to the impact of the collision.

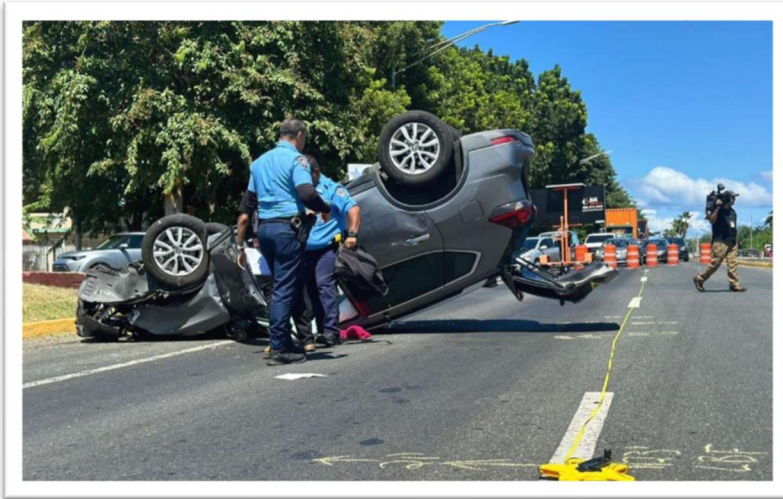
Severe collisions entering the intersection occurred on four-legged intersections and at three-legged intersections. Collisions of this type are more common at three-legged intersections, accounting for 42 percent of all collisions and 67 percent of severe collisions.

At four-legged intersections, all the severe collisions occurred at signalized intersections.

<sup>3</sup> Photo source: <https://www.elvocero.com/ley-y-orden/policiacas/muere-conductor-tras-chocar->

[contra-un-poste-en-toa-baja/article\\_32aa36e7-980d-43ae-a95e-2b0458927906.html](https://www.elvocero.com/ley-y-orden/policiacas/muere-conductor-tras-chocar-)

Figure 11 Angle collision at unsignalized intersection of PR-165 and Calle Jaime Fonalleda<sup>4</sup>



At three-legged, however, severe collisions were most likely to occur where there were unspecified traffic control features or at signalized intersections. This means that the intersections were missing signage or control features to guide motorists. At signalized intersections, collisions of this type were 54 percent more likely to be severe.

While there are many contributing circumstances to a collision at an intersection, the most common was failing to yield to the motorist with the right of way.

But other factors at play resulted in a greater likelihood of a severe collision. Disobeying the traffic light is eight (8) times more likely to result in a severe collision. Improper lane changes are four (4) times more likely to result in a severe

collision. Failing to obey the traffic signal – at unsignalized intersections – made severe collisions two (2) times more likely.

Severe collisions occur in the morning, afternoon, and evening time periods. Morning collisions were 80 percent more likely to be severe when compared to other periods of the day.

Eleven of the 13 severe collisions occurred during clear weather conditions.

#### *Run Off the Road Collisions (ROTR)*

Vehicles running off the road can pose significantly hazardous conditions for both the occupants of the vehicle and for other road users like pedestrians and cyclists. A vehicle that departs from the road can strike a fixed object, potentially causing death or serious injuries to the occupants of the vehicle.

During the 2020 to 2024 period, there were 2,677 collisions that involved vehicles running off the road. Among the 148 severe collisions with documented information, there were 26 incidents when the vehicles ran off the road. These account for 18.1 percent of all severe collisions, compared to 15.2 percent of run-off-the-road collisions during the five-year period.

<sup>4</sup> Photo source: <https://wapa.tv/noticias/locales/reportan-dos-accidentes-fatales-en-toa-baja-con-menos-de->

[dos-horas-de-diferencia/article\\_0778a620-80d4-11ef-9268-6fed646fc387.html](https://wapa.tv/noticias/locales/reportan-dos-accidentes-fatales-en-toa-baja-con-menos-de-dos-horas-de-diferencia/article_0778a620-80d4-11ef-9268-6fed646fc387.html)

Figure 12 Run-off-the-road collision with fixed object, route PR-867<sup>55</sup>



Severe run-off-the-road collisions are concentrated along 13 roads. These are shown in Table 6.

Table 6 Run-off-the-road severe collisions

Road	Death or fatal injury	Serious visible injury	Total
PR-165	4	3	7
PR-866	1	2	3
PR-867	1	2	3
PR-865R	2		2
PR-2	1	1	2
Ave Juan “Picolino” Hernández Ferrer	1	1	2
Paseo Dilma		1	1
PR-22		1	1
Ave La Fuente		1	1
PR-854	1		1
PR-872	1		1
PR-863		1	1
Ave El Plantío		1	1
<b>Total</b>	<b>12</b>	<b>14</b>	<b>26</b>

Severe collisions caused by vehicle departures from the road tend to involve fixed objects (including pedestrians and

cyclists). Nine (9) of the 26 collisions involved fixed objects, making it the most common collision type. Other common severe collision types were opposite direction frontal (4) and same direction lateral (4).

#### Environmental Conditions

Environmental conditions are factored into roadway collisions, and the effects of these conditions are not as important as motorist behavior.

Environmental conditions include the following components:

- Weather
- Visibility
- Road condition

#### Weather

Weather conditions can create hazardous conditions on roadways. The data for the 2020 to 2024 period reveals that four of every five severe collisions occur in clear weather conditions. Therefore, the majority of severe collisions occur in clear weather conditions. However, collisions are two times more likely to be severe in cloudy conditions.

Severe collisions in clear weather conditions were more common in corridors with a greater concentration of intersections (see Figure 13). A higher concentration of clear weather conditions was found on route PR-2 between routes

<sup>55</sup> Photo source: [https://www.telemundopr.com/noticias/puerto-](https://www.telemundopr.com/noticias/puerto-rico/conductor-choca-con-poste-de-luma-energy-en-toa-baja/2400182/)

[rico/conductor-choca-con-poste-de-luma-energy-en-toa-baja/2400182/](https://www.telemundopr.com/noticias/puerto-rico/conductor-choca-con-poste-de-luma-energy-en-toa-baja/2400182/)

PR-866 and PR-863, PR-863 between PR-819 and Calle Nárceas, PR-865 in Campanilla and route PR-165 between PR-870 and Avenida Dos Palmas.

A closer look at severe collisions in cloudy conditions reveals that:

- Half of the severe collisions were caused by aggressive drivers,
- Nine of the severe collisions involved male drivers,
- Nine of the eleven collisions occurred on straight flat roads,
- Seven of the eleven collisions occurred during evening hours
- Dark conditions were present on eight (8) of the eleven collisions. Dark conditions with no street lighting were found on four of these collisions, while dark conditions with street lighting were found on the other four
  - Dark conditions with no street lighting were found on severe collisions on PR-867 (2), PR-865 near Avenida Campanilla (1), and at route PR-2 near the PR-165 off ramp.
  - Dark conditions with street lighting were found on Avenida Boulevard (2), Avenida Juan “Picolino” Hernández (1), and route PR-165.
- Wet pavement conditions were present on seven of the eleven collisions, which means that rain had fallen prior to the incident.

### *Visibility*

Dark roads create poor visibility conditions for drivers and is one of the prevailing concerns among communities across the municipality. Of the 17,862 traffic collisions during the 2020 – 2024 period, 3,370 occurred in nighttime conditions. These 3,370 collisions account for 18.9 percent of all collisions during the five-year period. When considering for severe collisions, 53 of the 148 incidents occurred during nighttime conditions, accounting for 35.8 percent of all severe collisions. That means that nighttime collisions are two times more likely to be severe (serious injuries or fatal).

The routes with the highest number of severe collisions under dark conditions are:

- PR-2,
- PR-165,
- PR-867, and
- Avenida Boulevard.

Geographic concentration was observed at the following road segments:

- PR-165 between Calle Jaime Fonalleda and route PR-867.
- PR-2 between Calle El Acto and Carretera Candelaria (Calle 13).
- PR-863 between Calle Los Plas and Calle José Campeche.
- PR-867 Sector El Veintiséis between km 2.2 and 2.4.
- Avenida Boulevard between Calle Mariano Abril Costalo and Calle Luisa.

Figure 14 shows the location of severe collisions occurring during nighttime visibility conditions.

#### *Road Conditions*

Most of the severe collisions occurred on dry roads. Of the 148 severe collisions, 124 occurred on dry roads, accounting for 85 percent of all severe collisions. There are no notable differences with respect to the road conditions affecting the severity of the collision.

Route PR-867 had the most severe collisions on wet roads, and accounted for three of the 16 collisions. The severe collisions in route PR-867 took place on the 1.25-mile stretch of road between Ingenio and Sector El Veintiséis between kilometer markers 2.2 and 2.4.

Figure 15 shows the location of severe collisions categorized by the condition of the road.

Figure 13 Severe Collisions by Weather Conditions

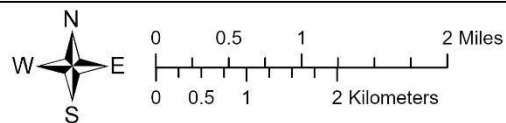
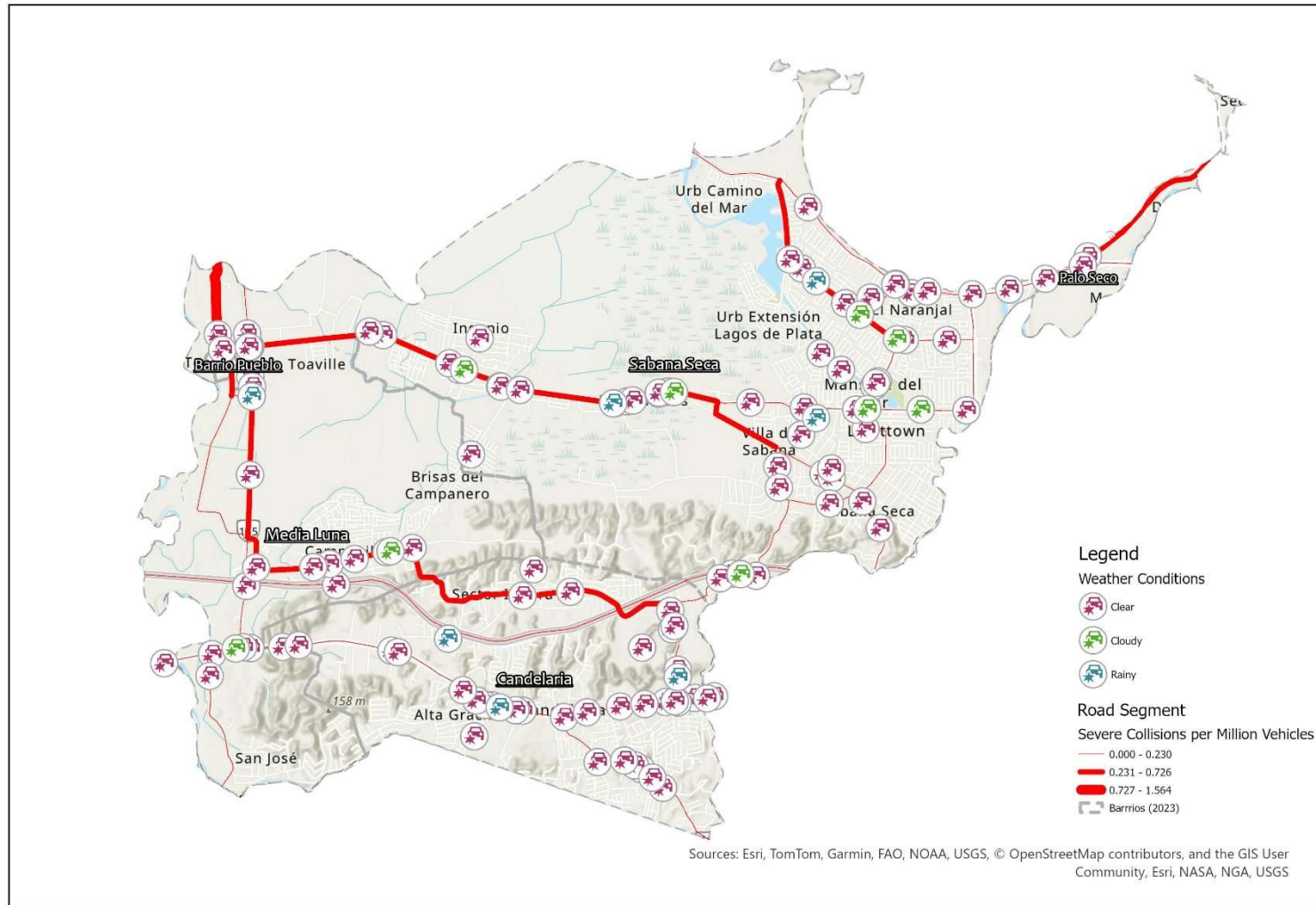


Figure 14 Severe Collisions during Nighttime Visibility Conditions

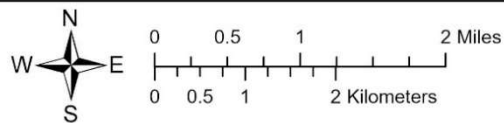
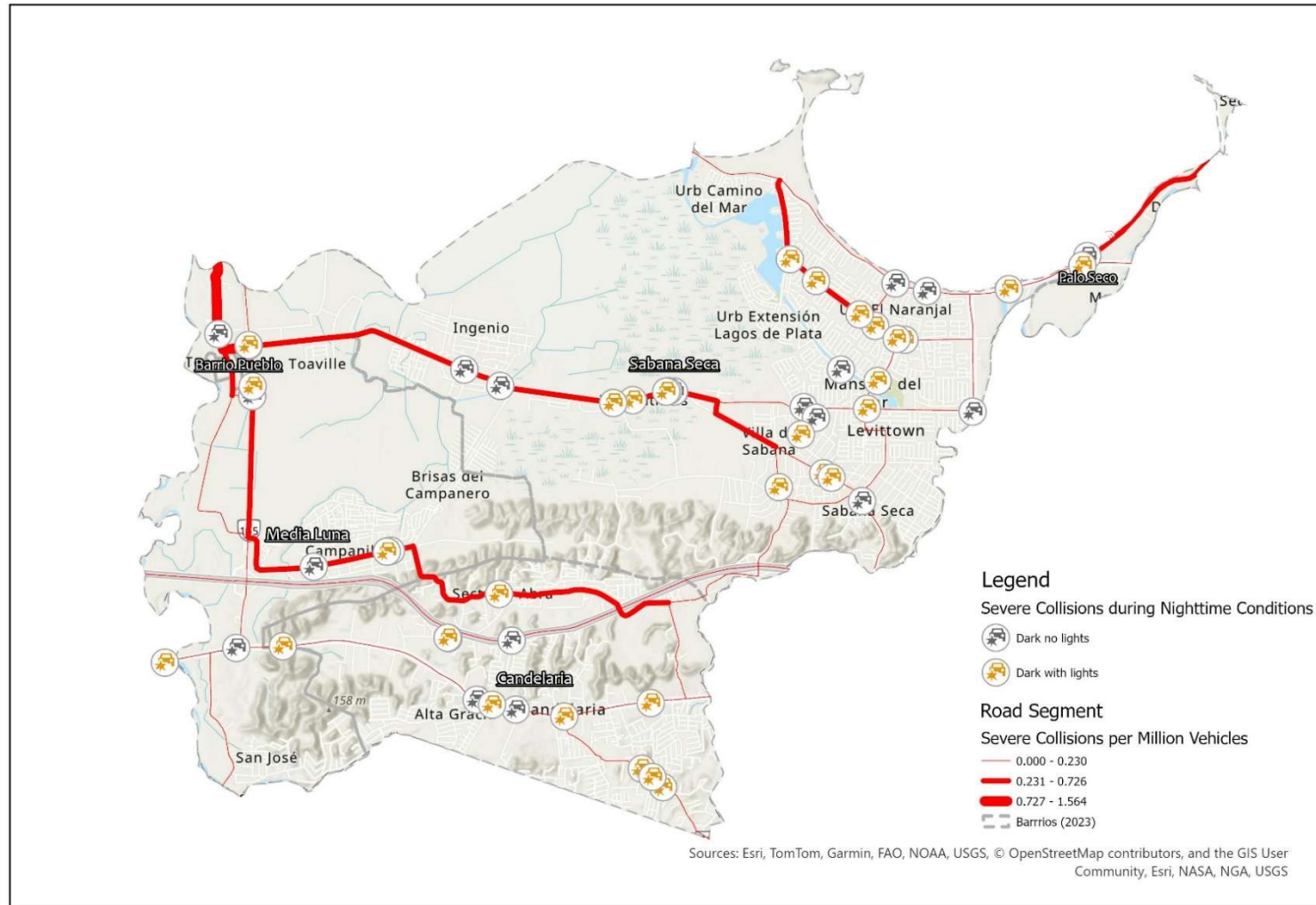
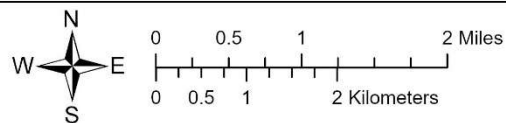
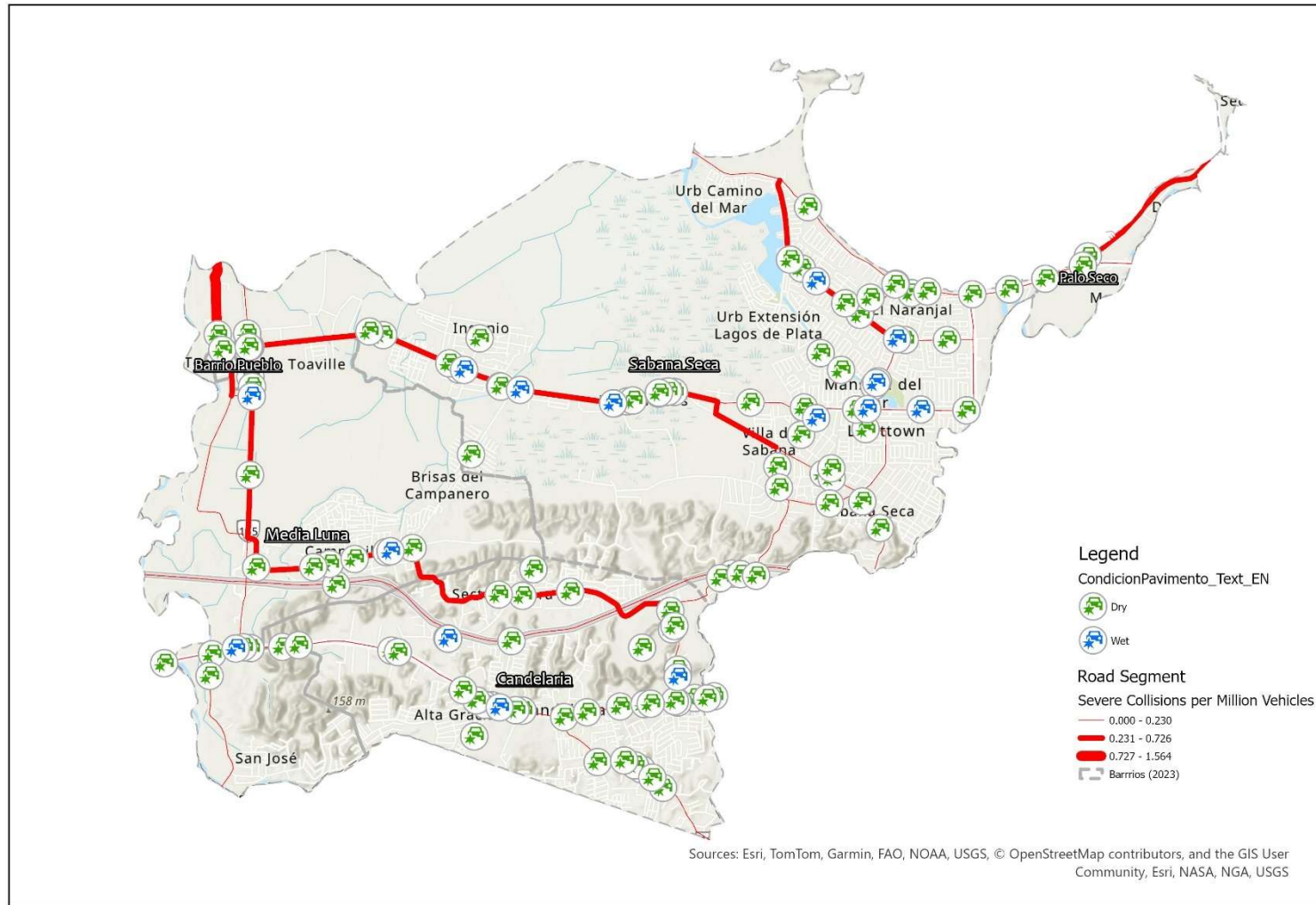


Figure 15 Severe Collisions by Pavement Condition



### Road Geometry

Road geometry conditions include location of the collision (intersection, ramp, intermediate segment), and terrain conditions (straight, level, horizontal curve, downhill, etc.).

#### *Location*

Collisions in Toa Baja are largely concentrated along intermediate road segments, not at intersections.

Four out of every five collisions occur at intermediate road segments, and there is no statistical difference between severe and non severe collisions.

Severe collisions occurring at intermediate road segments are more common among the following collision types:

- Opposite direction – sideswipe
- Opposite direction – turning
- In same direction – posterior (rear-end)

#### *Three-legged intersections*

Collisions at three-legged intersections are more common than at four-legged intersections. Between 2020 and 2024, there were 1,519 collisions at three-legged intersections, compared to 1,201 collisions at four-legged intersections.

The most common *severe* collisions at three-legged intersections are angle collisions and opposite direction frontal collisions. In particular, angle collisions at three-legged intersections are 60 percent more likely to be severe than other collision types.

#### *Four-legged intersections*

At four legged intersections, the most common types of collisions are entering intersection in angle and opposite direction turning movements.

In terms of severity, collisions with fixed objects, such as pedestrians or utility poles, are 3.1 times more likely to be severe at four-legged intersections. Collisions with turning vehicles in the same direction are 2.7 times more likely to be severe than other collision types, and same direction lateral collisions are 1.8 times more likely to be severe.

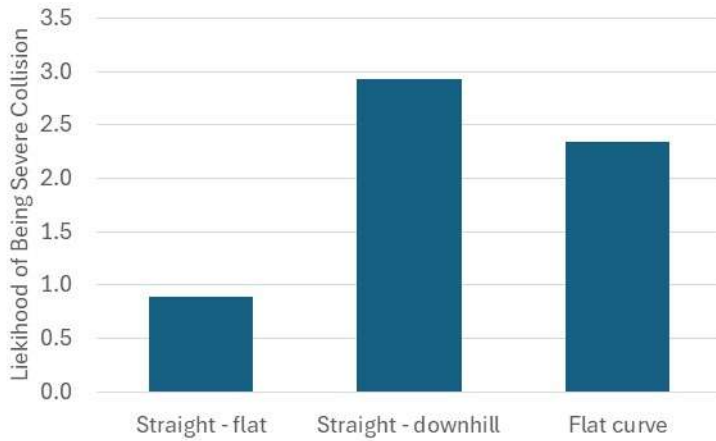
#### *Road Terrain*

Most collisions occur on a straight flat road segment in the municipality. Of the 17,862 collisions between 2020 and 2024, 86.2 percent occurred on straight flat roads.

Of the 148 severe collisions in Toa Baja, 114 occurred on straight flat roads, account for 79.2 percent of all severe collisions. This means that severe collisions are less likely to occur on straight flat roads, despite their high incidence.

Collisions on straight downhill roads are 2.8 times more likely to be severe collisions, and collisions on flat curves are 2.3 times more likely to be severe when compared to all collisions, as Figure 16 shows.

Figure 16 Likelihood of Severe Collisions by Road Geometry



**Modal Attributes**

Aside from cars and trucks, road users also include pedestrians, bicyclists, motorcycles, and other modalities of transportation such as electric scooters.

Travelers in cars and trucks have greater protection from collisions because the impact of a collision is absorbed in part by the vehicle. Safety systems in vehicles – seatbelts, airbags, rearview cameras and sensors – provide additional protection to motorists. In addition, vehicle technologies in newer vehicles are including safety technologies such as advanced collision warning systems, collision avoidance systems and automatic braking which can protect passengers inside the vehicle and individuals outside the vehicle. However, these nascent technologies are not wide spread across the car and truck industry, and interactions between motor vehicles and other roadway users are leading to

disproportionate impacts on the other roadway users.

This section presents a summary of the state of roadway safety for pedestrians, bicyclists, motorcyclists and other road users.

*Pedestrians*

Pedestrians are an especially vulnerable group with respect to the probability of survival in the event of a collision with a motor vehicle. When pedestrians are involved in a collision, they have no protection to their bodies, so the energy exerted from impact is not mitigated. To make matters worse, the impact of the pedestrian with the pavement is an added force applied to the overall collision impact.

Of the 17,862 collisions in Toa Baja between 2020 and 2024, there were 117 collisions involving pedestrians. These collisions accounted for 0.66 percent of all collisions during the five-year period.

These collisions include one (1) fatal collision and 13 severe injury collisions, totaling 14 severe collisions. This means that of the 148 severe collisions in Toa Baja, 9.5 percent involved pedestrians.

Severe collisions involving pedestrians were more likely than with any other road user group. The rate of severe collisions in pedestrian-related collisions was approximately one out of every eight *Collisions involving pedestrians are therefore 19.7 times more likely to be*

severe collisions compared to all other types of collisions.

Pedestrian collisions have occurred across all parts of the municipality. The ten roads with the most incidents are:

- Route PR-2 (12)
- Avenida Boulevard (10)
- Route PR-867 (10)
- Route PR-865 (7)
- Route PR-165 (5)
- Route PR-866 (5)
- Route PR-863 (4)
- Avenida Juan “Picolino” Hernández Ferrer (3)
- Avenida Ramón Ríos Román (3)

Avenida Boulevard – a local road – is among the top roads with the most pedestrian related collisions. Figure 18 shows a map of the pedestrian collisions across the municipality for the 2020 – 2024 period.

### *Bicyclists*

Bicyclists are also vulnerable road users who are disproportionately represented among severe collisions. Like pedestrians, bicyclists do not have body protection from the force exerted in a collision. The only protection that bicyclists wear is the helmet, however all other body parts are exposed to a collision. Also, like pedestrians, bicyclists are also subjected to additional impact forces when they hit the pavement.

Between 2020 and 2024 there were 82 collisions involving bicycles, accounting

for 0.47 percent of all collisions. Of the 82 collisions, four (4) were severe, which means that 2.8 percent of severe collisions involved bicyclists. *Bicyclists are therefore 6.0 times more likely to be involved in a severe collision*, compared to collisions in other modes.

Bicyclist collisions also occur across all parts of the municipality. However, the roads with the most bicycle-related collisions are:

- Route PR-165 (10)
- Route PR-2 (9)
- Route PR-866 (8)
- Route PR-865 (5)
- Route PR-867 (5)
- Avenida Boulevard (2)
- Avenida Olga Tañón (2)
- Avenida Juan “Picolino” Hernández Ferrer (2)
- Route PR-863

There are 41 other roads where bicycle collisions have occurred. Figure 19 shows a map of the bicycle collisions occurred during the 2020 – 2024 period.

### *Motorcycles*

Motorcyclists are another vulnerable user group who is disproportionately affected when involved in a collision. This is also because motorcyclists do not have sufficient protection from the force of an impact from a collision, so their body absorbs the energy of impact.

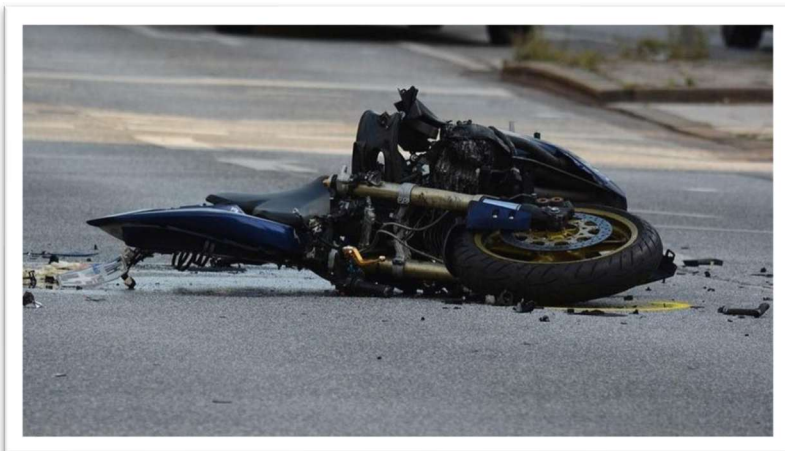
Between 2020 and 2024, there were 89 collisions involving motorcyclists,

including three (3) fatalities and six (6) severe injury collisions. Severe collisions involving motorcyclists accounted for 6.3 percent of all severe collisions. However, *collisions involving motorcyclists were 12.5 times more likely to be severe collisions*, compared to all other modes.

Collisions with motorcyclists were more common on the following roads:

- Route PR-2 (15)
- Route PR-165 (14)
- Route PR-865 (8)
- Route PR-867 (8)
- Rote PR-866 (5)
- Route PR-863 (4)
- Avenida Boulevard (3)
- Route PR-167 (3)
- Avenida Campanilla (2)
- Avenida Ramón Ríos Román (2)

Figure 17 Motorcycle collision in Toa Baja<sup>6</sup>



Collisions also occurred on 25 other roads within the municipality. Figure 17 shows the location of collisions involving motorcyclists.

#### Other modes

There were 104 collisions with other types of road users, but none were severe in terms of injuries or fatalities. Only three (3) of these collisions had minor injuries for which there was no immediate hospitalization required.

#### Behavioral Attributes

Behavioral attributes to severe collisions include temporal behavior of individuals who caused the collisions.

The most common behavioral attributes associated with severe collisions in Toa Baja were:

1. Following too closely (27)
2. Driver out of control (17)
3. Other circumstances (not previously defined) (11)
4. Improper lane change (8)
5. Improper turn (7)
6. Improper passing (5)
7. Failure to yield (4)
8. Disregarding traffic control (4)

These behavioral attitudes were responsible for 70 percent of severe collisions.

<sup>6</sup> Source: <https://m.facebook.com/islanewspr/photos/toa-baja-motociclista-pierde-la-vida-en-accidente->

[fatal-contra-objeto-fijo-agent/1879950549401808/](https://m.facebook.com/islanewspr/photos/toa-baja-motociclista-pierde-la-vida-en-accidente-fatal-contra-objeto-fijo-agent/1879950549401808/)

Figure 18 Pedestrian-related collisions by severity

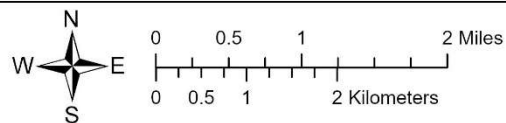
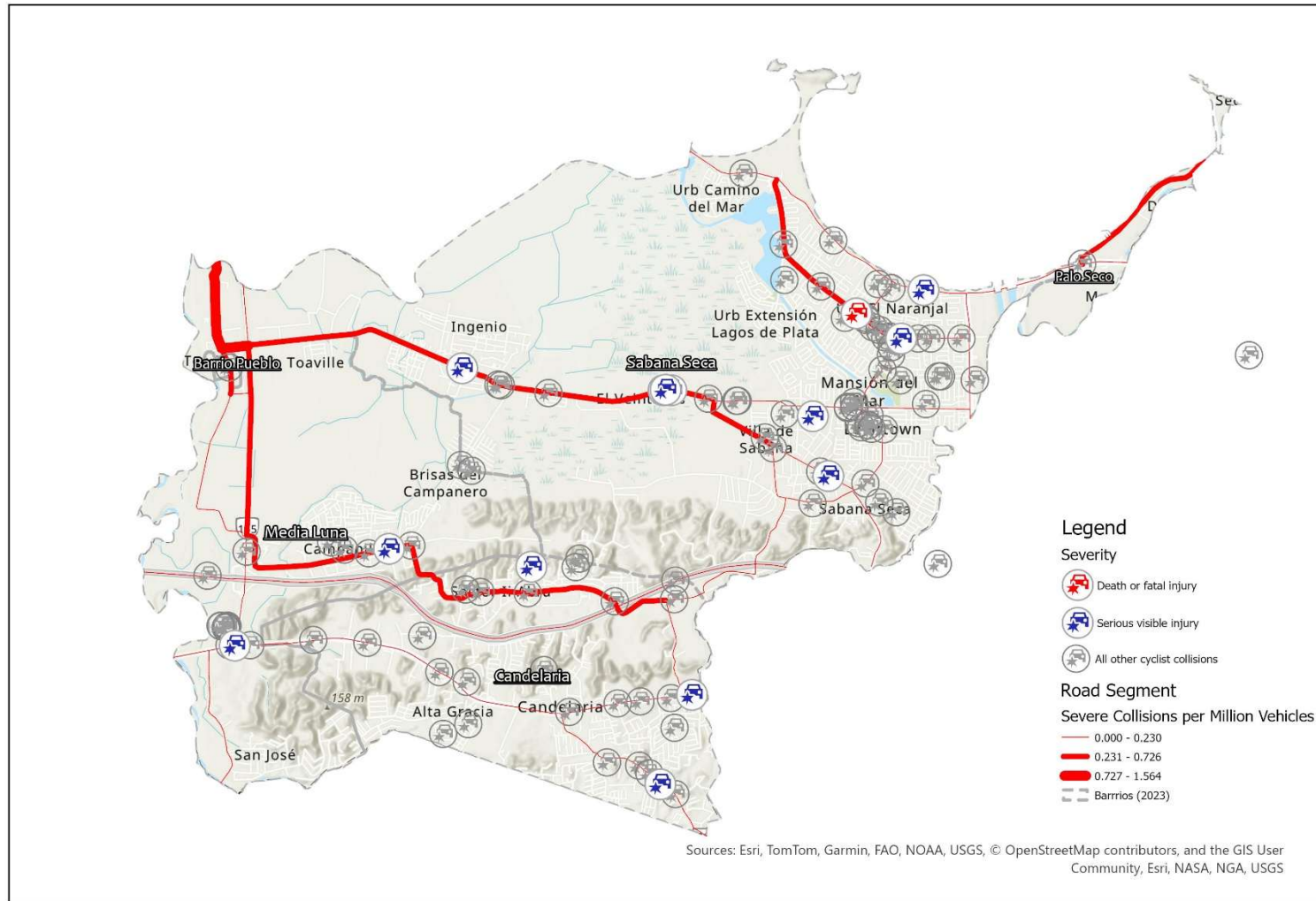


Figure 19 Bicyclist-related collisions by severity

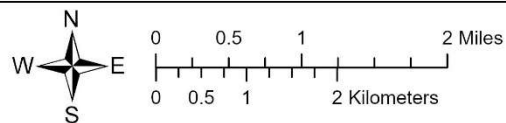
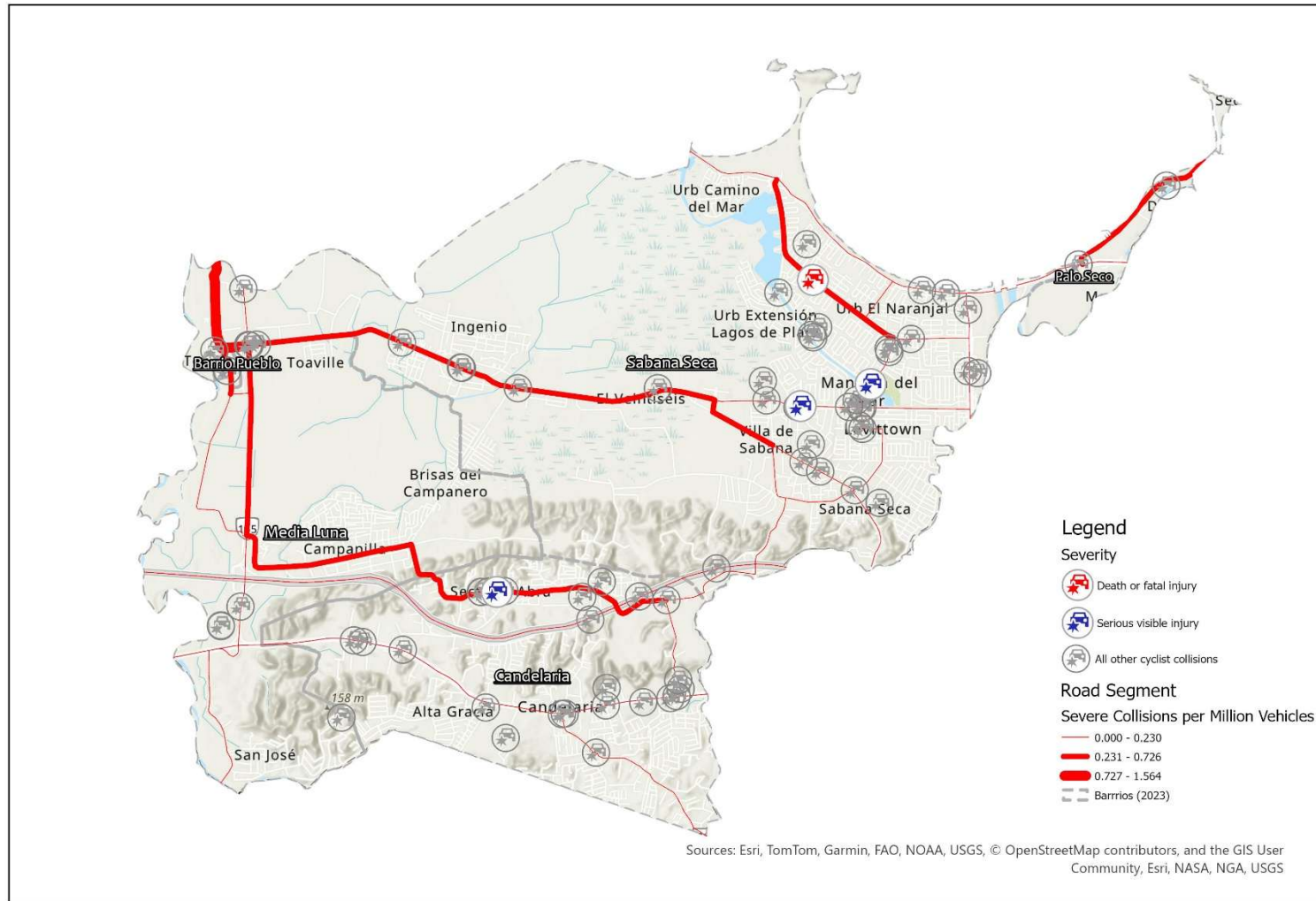
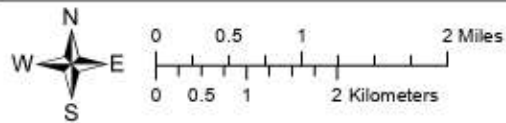
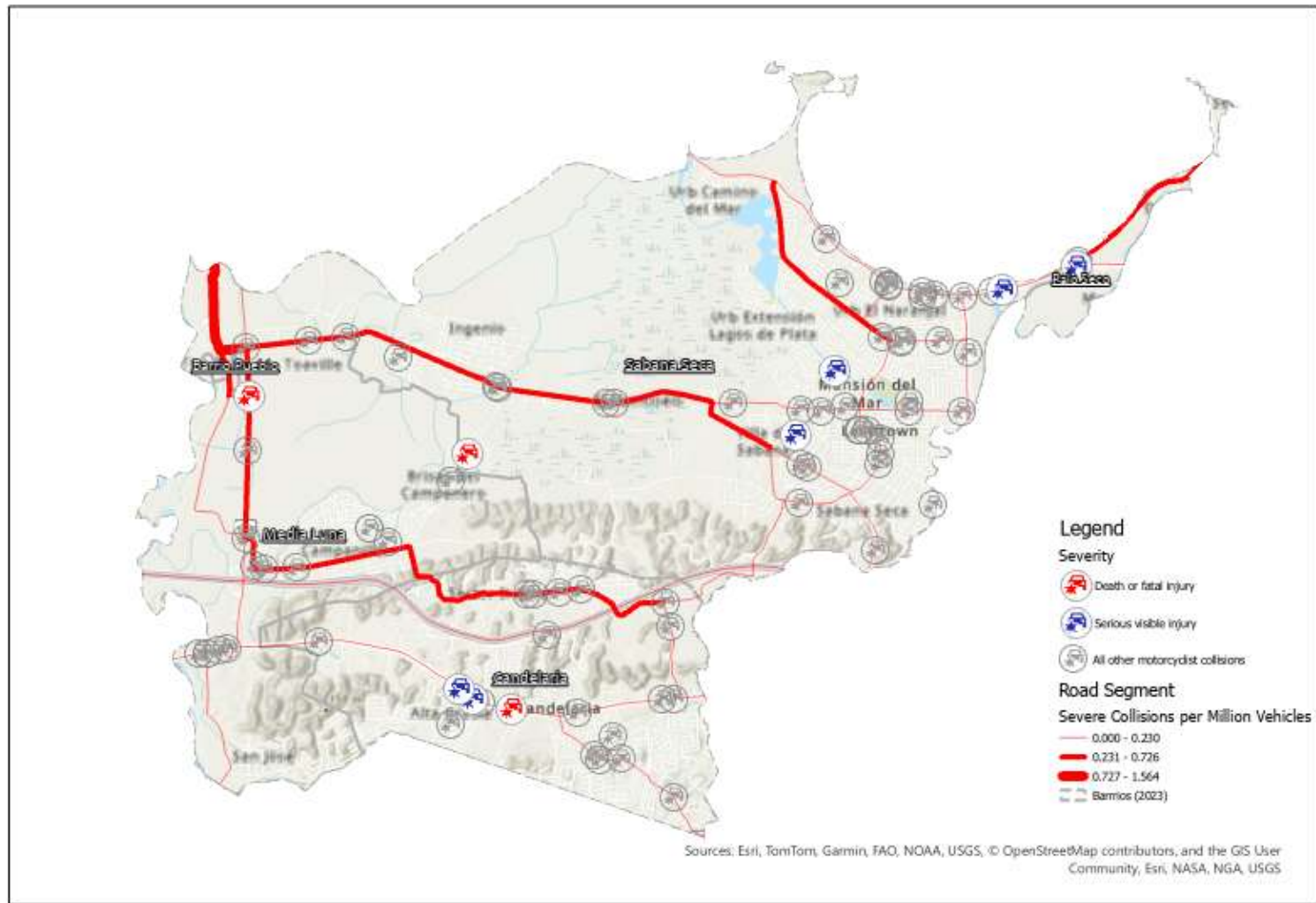


Figure 20 Motorcyclist-related collisions by severity



### *Aggressive driving*

Aggressive drivers were responsible for 48 percent of all collisions in Toa Baja between 2020 and 2024. Aggressive drivers were also responsible for 45 percent of severe collisions during this period, so there are clear associations between aggressive driving and collisions.

The most common type of aggressive behavior is following too closely, which is directly associated with rear-ending collisions. These types of collisions were most common on route PR-2.

Other actions, such as improper lane changes and driving out of control were common on routes PR-867, Avenida Ramón Ríos Román, route PR-866 and on Avenida Boulevard.

At Avenida Boulevard, aggressive drivers were responsible for collisions involving lane changes and improper turns.

### *Alcohol*

Alcohol was a contributing factor in 89 – or 0.5 percent – of the 17,862 collisions between 2020 and 2024. Alcohol was also a contributing factor in six (6) of the 148 severe collisions, or 4.1 percent of severe collisions. *Collisions involving the abuse of alcohol were found to be 8.1 times more likely to result in severe collisions.*

Severe collisions involving alcohol-related behavior occurred most commonly during afternoon and evening hours, between 4:00 PM and 1:00 AM.

Severe collisions occurred in parts of Sabana Seca, Levittown and in parts of Candelaria.

### *Distracted driving*

Distracted driving is a common cause of collisions. Reporting distracted driving as a cause of collisions, however, is a more problematic subject. Individuals who cause a collision may not provide the full picture of their slip to a Police officer if it means they are at fault for a collision. As a result, the Police report data in Toa Baja suggests that distracted driving is not a contributing cause, where just 2.0 percent of collisions are attributed to some type of distraction.

Distracted driving is categorized by object and location of distraction:

- Cellphone-related
- Other electronic
- Distraction outside of vehicle
- Distraction inside of vehicle

Distractions caused by cellphones account for 91 of the 17,862 collisions in Toa Baja during the 2020 – 2024 period. Two (2) of the 148 severe collisions were related to cellphone distractions, which accounts for 1.4 percent of severe collisions. *This means that collisions involving cellphone-distractions are 2.6 times more likely to be severe.*

Collisions caused by distractions outside of a vehicle were the second most common type of collision associated with distracted driving. Of the 17,862

collisions during the 2020 – 2024 period, 78 collisions were caused by distractions outside of the vehicle. Of the 148 severe collisions, only 1 was associated with a distraction outside of the vehicle. *Collisions caused by distractions outside of the vehicle were 1.55 times more likely to be severe.*

There were 23 collisions caused by distractions from electronics – not including cellphones. Of the 23 collisions in this category, none were severe collisions. Distractions inside the vehicles were responsible for 41 of the 17,862 collisions during the 2020 – 2024 period, none of which were severe.

#### Subject Attributes

Subject attributes include gender of the driver, the age of the driver and other conditions.

#### Gender

There are significant differences observed among motorists when gender is considered. In general terms, male motorists are more likely to incur in aggressive driving behavior, which leads to more severe collisions.

#### Male motorists

Male drivers were involved in 13,593 crashes, or 76.1 percent of all collisions. Moreover, male drivers were involved in 118 of the 148 severe collisions, or 79.7 percent of severe collisions. Male motorists are 5 percent more likely to be involved in severe collisions. Severe collisions involving male drivers were also

more likely to result in a fatality. Of the 31 fatal collisions, 25 involved male drivers.

Of the 118 collisions involving male drivers, a third occurred against female drivers and the other two-thirds occurred against other male drivers.

#### Female motorists

In comparison, female drivers were involved in 10,155 crashes, or 56.7 percent of all crashes. Female drivers were also involved in 61 severe collisions, or 41.2 percent of severe collisions. There were 21 severe collisions between female drivers and other female drivers, which account for 14.2 percent of all severe collisions.

#### Age

The age of the motorists involved affects the likelihood of collisions and the contributing circumstances of these. For analytical purposes, motorists are classified into three cohorts:

- 15 to 20 years old
- 21 to 64 years old
- 65 years and over

Young drivers are in the 15 to 20 age range. Adults are in the 21 to 64 age group and are the most numerous group and make up most of the collisions. Older adults are those age 65 and over.

#### Young Motorists

Young drivers, defined as those between the ages of 15 to 20, are generally associated with higher accident rates. Drivers in the 15 to 20 years old cohort are

involved in 10 percent of all collisions, despite being a small fraction of the universe of drivers.

Young drivers are less likely to be involved in fatal collisions. The likelihood of a young driver involved in a collision that is fatal is a third of the overall probability for being involved in any type of collision. During the 2020 – 2024 five year period, only one fatal incident involved a young driver. This collision took place at the unsignalized intersection of route PR-165 and Calle Jaime Fonalleda in Media Luna, and was caused by the failure of the driver to obey the stop sign entering route PR-165 from Calle Jaime Fonalleda.

When involved in a collision, young drivers were 1.5 times more likely to be in non-fatal severe collisions. Young drivers exhibited aggressive driving behavior on most of the severe collisions, making this a major contributing factor. The most common aggressive driving behaviors exhibited were:

- Following too closely (4 of 19),
- Improper lane changes (3 of 19),
- Failure to obey traffic sign (2 of 19)
- Disobeying traffic light (2 of 19)
- Improper passing (2 of 19)
- Driver out of control (2 of 19)

The most common types of collisions among young drivers were:

- Entering intersection in angle (4 of 19)
- Opposite direction – frontal (4 of 19)
- Same direction – rear-ending (4 of 19)

### Elderly Motorists

Collision data classifies elderly drivers into two groups:

- Age 65 to 79
- 80 and over

Drivers in the 65 to 79 age group are involved in a fifth of all collisions (19.3 percent). The drivers in this age group are less likely to be involved in severe collisions, accounting for 15.5 percent of collisions. Most of the collisions involving drivers between the ages of 65 to 79 are property damage only (O).

Drivers in the 80 years and over age group are more likely to be involved in a fatal collision, despite being fewer drivers on the road. This group is two times more likely to be involved in a fatal collision if the collision is severe. They are also half as likely to be involved in collisions that result in severe injuries.

## Equity Analysis

Transportation equity defines how transportation systems and services should be distributed and delivered in a way that is affordable, reliable, and safe. Transportation equity ensures fairness as to who benefits and who is impacted by its provision.

Transportation equity is defined into three types of fairness:

1. Procedural equity
2. Geographic equity
3. Social equity

Procedural equity focuses on the degree of involvement of public stakeholders in the processes by which transportation decisions are made. Geographic equity focuses on the distribution of impacts across geography and space. Social equity focuses on the distribution across population groups that can differ by income, social class, and mobility ability.

The equity analysis in this document focuses on geographic equity and social equity components.

### Elements of Analysis

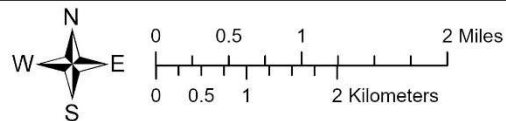
The equity analysis defines ten (10) components of social disadvantage and vulnerability. These are:

1. Poverty status
2. Number of caregivers in household or single-parent households
3. Overcrowding in households
4. Educational attainment

5. Employment
6. Disability status
7. Health insurance coverage
8. Age
9. Vehicles in household
10. Access to broadband internet

The equity analysis is performed at the Census tract a geographical level. Several communities may be found at each Census tract, and there is no differentiation between these when the analysis was performed. Figure 21 shows a map of the Census tracts of Toa Baja and the communities within each Census tract.

Figure 21 Census tracts and communities of Toa Baja



## Poverty

There are several other ways in which poverty impacts individuals in terms of transportation safety. For one, individuals who live under the poverty line tend to live in neighborhoods with poor infrastructure, particularly in terms of sidewalks, crosswalks, and street lighting. Roads in areas with high poverty rates may be maintained less frequently or not have appropriate water runoff infrastructure, which can create additional safety risks for all types of users.

Individuals who live below the poverty line are more likely to be dependent on non-motorized modes for traveling (walking or bicycling). They may also be more dependent on transit services, which requires them to walk to a bus stop to access the services. The previous chapter has shown that pedestrians are 19.7 times more likely to be involved in a severe collision.

The communities (Census tracts) with the highest proportion of households with incomes below the poverty level are:

- 1212: Villa Marisol, Villa Kennedy, La Vega
- 1217.02: Ingenio, Villa Calma, Monserrate, Villa del Sol, Urb. Campanilla I
- 1218.01: Candelaria Arenas, Villa Albizu, Villa Clemente, Dos Abras, Villa Dávila, Monte Bello, Sector María Lacén

- 1221: Parcelas Viejas San José, Parcelas Nuevas San José
- 1222.01: Villa Hostos, Parcelas Campanilla
- 1222.02: Villa Quintero, Villa Esperanza, Sector El Monte
- 1224: Pueblo Toa Baja, Residencial El Toa, Toaville

## Caregivers in Household

Caregivers are needed in households where individuals cannot live independently or take self-care. Caregivers can be parents or home-health aides. Single-parent households, defined as households with only one adult responsible for taking care of underage children, are also included in this group because single parents face greater economic and logistical burdens associated with being available to work or access to work when managing child-care responsibilities.

There are associations between caregivers in households and road safety inequities. Areas with high need for caregivers tend to with low-income communities, which are characterized by poor road maintenance, limited enforcement of local laws, and less investment in traffic calming and safety treatments. Where not overlapping, areas with high need for caregivers will have individuals with limited or reduced mobility, which means that significant investments in sidewalks and sidewalk crossings may be needed to improve mobility conditions for these individuals.

The communities with the highest number of individuals with self-care difficulties are:

- CT 1226: Los Magos, Sabana Seca, Camasey
- CT 1217.02: Villa Calma I, Villa Calma II, Ingenio, Pabellones, Villas del Sol, Monserrate

Meanwhile, the areas with the highest number of individuals with independent living difficulties are:

- CT 1226: Los Magos, Sabana Seca, Camasey.

On the other hand, the communities (Census tracts) with the highest number of single-family households are:

- 1202: Palo Seco, 2da Sección Levittown, Villas de Levittown, El Atlántico, Paseo Abril, El Naranjal
- 1210.01: Mansión del Mar, Campamento, Las Gaviotas, Mansión del Sol, 5ta Sección Levittown
- 1214: El Veintiséis, Lagos de Plata, Parque del Lago, Mansión del Lago, Camino del Mar, Lago Playa, Oasis, Lagos del Norte, Punta Salinas, Parque de Punta Salinas
- 1217.01: Brisas del Campanero I, Brisas del Campanero II, Urb. Campanilla
- 1217.02: Villa Calma I, Villa Calma II, Ingenio, Villas del Sol, Pabellones, Monserrate.

### Overcrowding

There are several ways in which overcrowding in a household can lead to increased exposure to traffic safety risks, and some are:

- Stress and time pressure associated with meeting trip demands of more individuals,
- Increased exposure due to share travel, including overloading of transportation vehicle,
- Reliance on travel modes that have greater exposure to risk,
- Child safety risks.

Overcrowding in households is likely to generate more trips, increasing exposure to traffic risks. Overcrowded households are also found often in low-income areas with limited access to safe, reliable public transit.

Residents who live in overcrowded households may rely on walking or biking in unsafe conditions due to lack of alternatives, especially for short trips. Overcrowded households with multiple children show increased risks of traffic safety incidents involving small children. In some cases, children travel in unrestrained seats due to the lack of resources or vehicle overcrowding.

Overcrowding is measured in the Census data by the number of households with 2.01 or more occupants per room.

Toa Baja does not have significant overcrowding problem in households.

Less than two percent of households across each Census tract – except for Census tract 1221 – had 2.01 or more occupants per room. The communities found in Census tract 1221 are:

- Parcelas Viejas San José, and
- Parcelas Nuevas San José.

#### Educational Attainment

Individuals with low educational attainment tend to have a greater exposure to roadway safety risks through several pathways that reflect the broader patterns of social inequity. Some of these pathways to exposure are:

- Limited access to safety information and understanding of the rules of the road
- Higher reliance on riskier modes of travel for mobility
- Employment-related risks
- Geographic and environmental factors
- Health and cognitive factors
- Enforcement and legal vulnerabilities
- Underrepresentation in the planning process.

The Census data that describes low educational attainment are individuals age 25 and over who did not complete a high school diploma, and individuals who did not pursue additional education after completing a high school diploma.

The first measure reveals how many adults dropped out of high school and did not complete an equivalency. The second indicator of educational attainment are

adults 25 and over with a high school diploma but no college studies.

When combining these two indicators of (low) educational attainment, the Census tracts with the most population at risk are:

- 1217.02: Ingenio, Villa Calma I, Villa Calma II, Monserrate, Villa del Sol, Urb. Campanilla I
- 1218.01: Candelaria Arenas, Villa Albizu
- 1226: Magos, Sabana Seca, Camasey

#### Employment

Individuals who are out of work face greater economic insecurity, limiting their ability to adapt to macroeconomic conditions. It also impacts their ability to have stable housing and provide food security. Unemployed individuals or individuals without regular jobs tend to have lower income from their jobs or may be dependent on unemployment benefits that do not cover the cost of living. They may not be able to afford vehicle maintenance on their vehicles, insurance payments or they may rely on other modes of travel that carry greater risk. For individuals who are chronically out the labor force, their economic condition may lead them to live in economically disadvantaged neighborhoods, which are characterized by poor road conditions, fewer pedestrian protections and high traffic volumes or speeds. Police enforcement of local traffic laws may be more lax in economically disadvantaged communities.

There are two indicators of social vulnerability and inequity caused by employment related attributes. The first indicator consists of individuals in the labor force who are unemployed. The second indicator considers the percent of individuals age 16 to 64 who are out of the labor force. These two indicators reveal a composite index that identifies the areas that have the highest vulnerabilities in terms of employment data. These areas (and their communities) are:

- 1210.01: Mansión del Mar, Campamento, Las Gaviotas, Mansión del Sol, 5ta Sección Levittown
- 1212: Villa Marisol, Villa Kennedy, La Vega
- 1217.02: Ingenio, Villa Calma I, Villa Calma II, Monserrate, Villa del Sol, Urb. Campanilla I
- 1221: Parcelas viejas San José, Parcelas nuevas San José
- 1226: Los Magos, Sabana Seca, Camasey.

### Disability

Individuals with disabilities continue to experience social disadvantages to the rest of the population in how they receive or enjoy services and societal benefits from publicly funded activities. Individuals with disabilities can be at increased risk of roadway safety if the infrastructure is insufficient for them to travel safely. This may be in the form of ramps at pedestrian crossings, adequate signage and wayfinding, designated ADA parking next

to building entrances and continuous sidewalks.

The Census data categorizes disabilities across six major categories:

- Vision impairments
- Hearing impairments
- Ambulatory impairments
- Cognitive impairments
- Independent living difficulties
- Self-care impairments

Each of the disability types is weighted equally to identify the Census tract with the highest levels of social vulnerability from the different disabilities of the population. Of the 23 Census tracts of Toa Baja, only one was consistently identified in the top quartile: Census tract 1212. Census tract 1212 includes the communities of Villa Kennedy, Villa Marisol and La Vega.

### Health Insurance

The lack of health insurance coverage is identified as one of the components of social inequity. Many individuals without healthcare do not have access to healthcare from an employer because they are gig workers or informal workers. These types of workers tend to have irregular work shifts, travel during off-peak hours and night time hours which exposes them to more traffic risks (i.e. dark roads with limited visibility), and require them use of their personal vehicles for work. Transportation planning often overlooks health insurance status as a risk factor,

leading to underinvestment in safety infrastructure in areas with high uninsured rates.

Another component of health-insurance related inequities includes individuals with Medicaid coverage. These individuals, due to their limited financial means, often lack access to private vehicles, so they rely more heavily on public transit and paratransit services. For public transit users, safe access to bus stops is warranted by continuous sidewalks and separation from vehicular traffic – two conditions that are often missing in their neighborhoods. Individuals with Medicaid coverage include older adults, individuals with disabilities and those with chronic conditions. Due to their physical and sensory limitations, these groups tend to have slower reaction times as motorists and as pedestrians which increases their exposure to a potential traffic safety incident. Individuals with Medicaid coverage are often low-income individuals who live in economically disadvantaged neighborhoods with limited pedestrian infrastructure, poor road conditions and limited traffic calming measures to control high vehicle speeds. When they travel, they may need to travel longer distances to access healthcare services from their medical providers.

When the two indicators on health insurance coverage are weighed equally, the areas with the highest vulnerability associated with this indicator are:

- 1203: 1ra Sección Levittown
- 1212: Villa Kennedy, Villa Marisol, La Vega
- 1217.01: Brisas del Campanero I, Brisas del Campanero II, Urb. Campanilla
- 1221: Parcelas viejas San José, Parcelas nuevas San José
- 1222.01: Villa Hostos, Parcelas Campanilla
- 1222.02: Villa Quintero, Villa Esperanza, Sector El Monte
- 1226: Los Magos, Sabana Seca, Camasey

#### Age

The cognitive and physical abilities of individuals degrades over time, particularly among individuals age 65 and older. The decay results in slower reaction times, reduced vision and hearing and decreased overall mobility. Their decreased cognitive abilities can impact their ability to navigate complex road conditions, including high speed traffic environments and complex intersections – such as intersections that require two-stage crossings.

Older individuals are also at risk of higher injury severity caused by a reduction in bone mass and their ability to withstand impact. This is acute among individuals over 80 years of age, as data from the targeted safety investigations has revealed.

As motorists, older adults can also be impaired by medications that can reduce

their alertness and coordination, or by chronic conditions like arthritis or dementia that affect them physically and cognitively.

Another group of concern are underage children. Underage children have varying levels of awareness of their environment, which can be particularly dangerous in areas with high traffic volumes. Areas near schools tend to have high pedestrian activity from underage children, so there is a need to provide traffic calming infrastructure near schools and areas with high pedestrian activity from underage children.

The third group at risk are young adults. Young adults, defined within the 18 to 25 year-old cohort, are statistically more likely to participate in high-risk behavior. This includes speeding, driving under the influence and using smartphones while driving. Research data shows disproportionately high crash rates among young adults during nighttime hours and weekends.

Age data is weighed equally for each cohort, yielding a higher equity score for the communities in Census tract 1222.01, which includes the communities of:

- Campanilla, and
- Villa Hostos.

#### Access to Vehicles

Lack of transportation limits the mobility of individuals and their access to jobs, education, services and activities. The

lack of vehicles for mobility can be addressed by the provision of public transportation. However, even with the provision of public transportation in Toa Baja, the services are not available throughout the entire day and every day of the week. Therefore, the population living in households without vehicles can continue to face inequities at times of the day when public transportation is not available.

The Census tracts (and communities) with the highest proportion of households with no vehicles are:

- 1212: Villa Kennedy, Villa Marisol, La Vega
- 1218.01: Candelaria Arenas, Villa Albizu, Villa Clemente, Dos Abras, Villa Dávila, Monte Bello, Sector María Lacén
- 1221: Parcelas Viejas San José, Parcelas Nuevas San José
- 1226: Los Magos, Sabana Seca, Camasey.

#### Access to Broadband Internet

Lack of internet can prevent timely receiving emergency alerts, reduce access to health services, and exacerbate existing inequalities. Access to broadband internet also enables individuals to connect with services and enables commerce. Individuals who do not have access to broadband internet are at a social disadvantage because they do not have the tools for digital communications

or may not be able to afford the costs associated with the service.

The Census tracts in the highest quartile in the percent of households without broadband internet access are:

- 1217.02: Ingenio, Villa Calma, Monserrate, Villa del Sol, Urb. Campanilla I
- 1221: Parcelas viejas San José, Parcelas nuevas San José
- 1222.01: Villa Hostos, Parcelas Campanilla
- 1222.02: Villa Quintero, Villa Esperanza, Sector El Monte

- Ingenio
- Monserrate
- Pabellones

### Equity Scores

After weighing each component equally, the team constructed a matrix of the total equity score. The Census tract with the highest score in terms of inequity is 1221, which includes the communities of Parcelas San José. Other Census tracts that are found in the top quartile in terms of the highest inequities are Census tracts 1221, 1217.02, 1222.01 and 1226.

Table 7 shows the equity scores across each element of analysis for each Census tract.

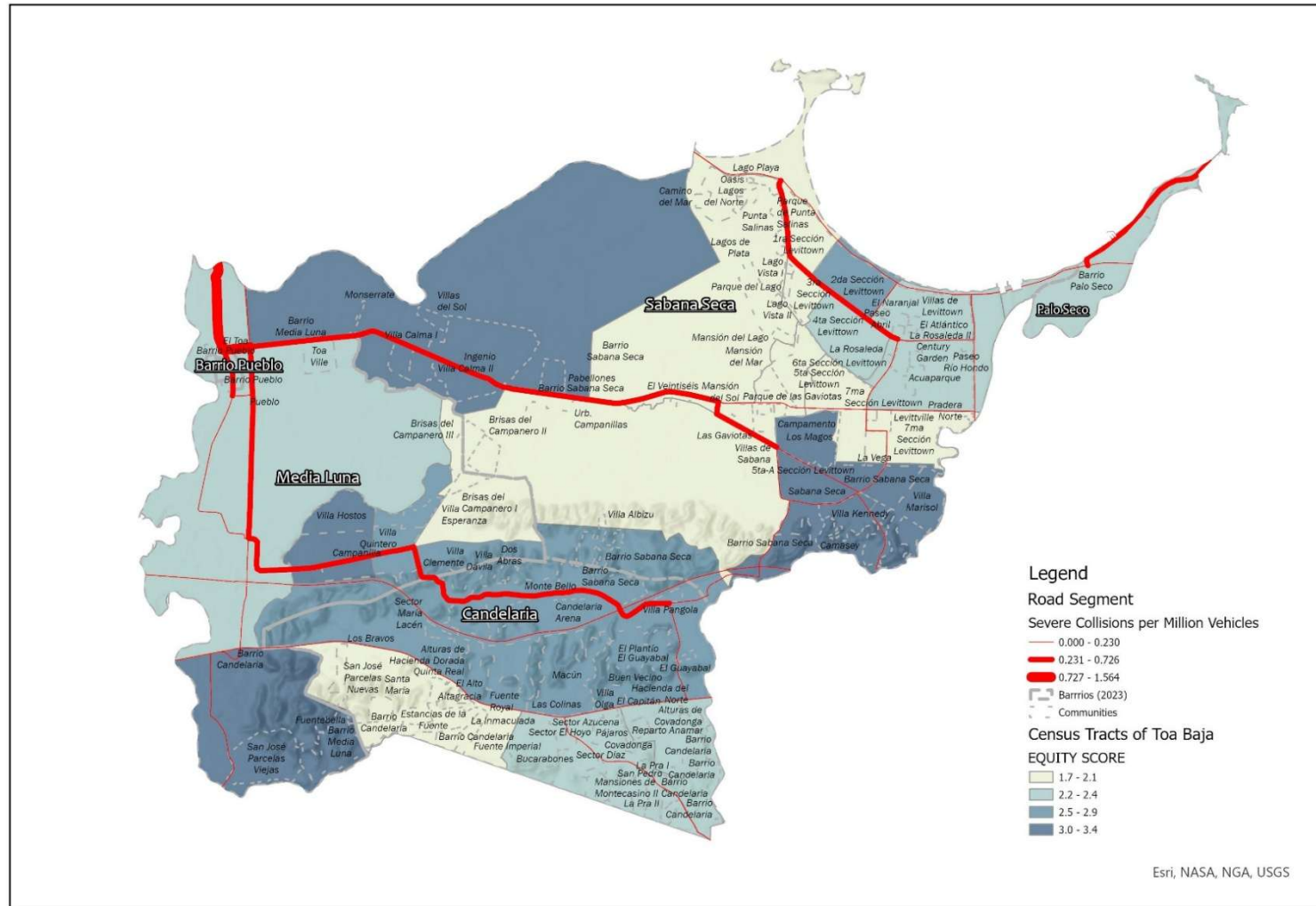
The distribution of the equity scores is found in Figure 22. The communities with the highest inequities which are found closest to the high injury network are:

- Campanilla
- Villa Hostos
- Villa Calma I
- Villa Calma II

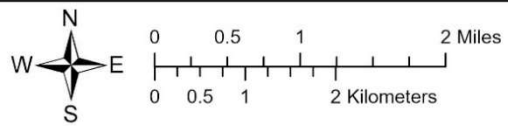
Table 7 Equity score for each Census tract

Census Tracts	Equity Score	Poverty	Caregivers in Household	Overcrowding	Educational Attainment	Employment	Disability Status	Health Insurance Coverage	Age	Vehicles in Household	Access to Broadband Internet
1202	2.3	2	3	1	3	2	2	3	2	3	2
1203	2.6	3	2	1	2	3	2	4	3	3	3
1204	2.0	2	2	1	1	2	2	3	2	3	2
1205	1.7	1	1	1	1	2	2	3	2	3	1
1206	2.2	1	2	1	3	2	3	2	3	3	2
1209	1.8	1	2	2	2	1	2	2	3	2	1
1210.01	2.1	3	3	1	3	4	1	2	2	1	1
1210.02	1.9	1	2	1	3	1	3	3	3	1	1
1212	3.2	4	2	1	3	4	4	4	3	4	3
1214	2.0	1	3	3	3	1	2	2	3	1	1
1217.01	2.1	2	3	1	2	3	1	4	2	1	2
1217.02	3.2	4	4	1	4	4	3	3	2	3	4
1218.01	3.0	3	3	1	4	3	3	3	3	4	3
1218.02	2.6	2	3	2	3	3	3	2	3	2	3
1219	2.2	3	2	1	2	2	3	2	3	1	3
1220.01	2.4	2	3	1	3	2	2	3	2	3	3
1220.02	2.1	2	3	1	3	3	2	2	2	1	2
1221	3.5	4	2	4	3	4	3	4	3	4	4
1222.01	3.1	4	3	1	3	3	3	4	3	3	4
1222.02	3.0	4	2	1	2	4	3	4	3	3	4
1224	2.4	4	1	1	2	2	3	3	2	3	3
1225	2.3	2	3	1	3	2	3	3	3	2	1
1226	3.1	3	3	1	4	3	3	4	3	4	3

Figure 22 Equity score for Census tracts of Toa Baja



Esri, NASA, NGA, USGS



## Safety Analysis

The safety analysis considers potential countermeasures to mitigate and reduce common types of severe collisions that have been taking place in Toa Baja. Each of the countermeasures considered in this analysis has been studied comprehensively by safety experts. Their effectiveness is subjected to the specific types of road configurations, location settings, types of collisions and traffic demand. Each countermeasure can be effective in reducing a specific collision type under certain conditions. Some countermeasures may work together more effectively in reducing collisions, while others could result in more collisions when used in combination with other countermeasures.

The effectiveness of a safety countermeasure is determined by its Crash Modification Factor, or CMF. Each CMF has an ID that identifies the specific conditions in which a countermeasure can achieve the desired reduction in crashes, and the types of crashes for which its application is effective. For example, a countermeasure can have a CMF that determines its effectiveness in reducing fatal angle collisions at stop-controlled intersections. The same countermeasure can have a different CMF to determine its effectiveness in reducing severe injury and injury related collisions at stop-controlled intersections. The quality of the effectiveness of a CMF is

determined by a 1-to-5 star-rating system, where a 1-star rating is applied to CMFs with poor statistical quality (high variability of results, where applied) while 5-star ratings are applied to countermeasures with a high level of statistical quality (low errors).

Safety evaluations included in this report follow the set of categories defined from the FHWA Proven Safety Countermeasures website from the FHWA's Highway Safety Program:

- Speed Management
- Roadway Departure
- Pedestrians and Cyclists
- Intersections
- Crosscutting

### Speed Management

Speed management is an essential element of the Safe Systems Approach (Safer Speeds). Safe speeds consider how vehicle speeds are managed by motorists, the interactions between speeding road users and the roadway attributes, and the differentials in speeds between road users.

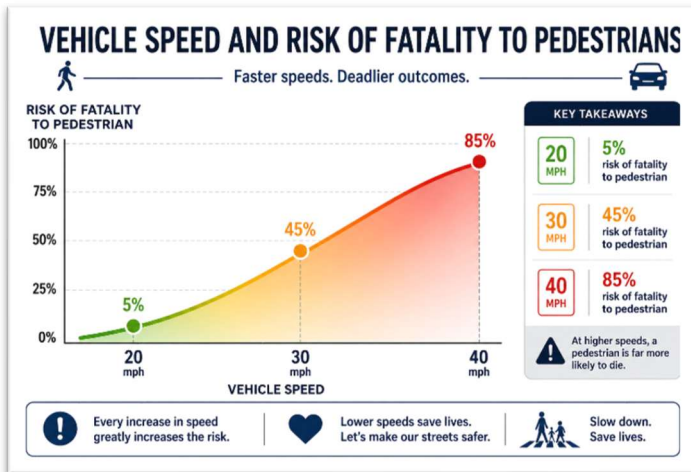
There is broad consensus that speed control is one of the most important methods for reducing the number of deaths and serious injuries.

Speed is a key factor on urban streets used by both drivers and vulnerable road users such as pedestrians and bicyclists. A driver may not see or be aware of the conditions within a corridor and may drive at a speed that is comfortable to them, but

that may not be safe for all system users - including school-age children and older adults.

Studies published by the European Traffic Safety Council have shown that a pedestrian struck by a vehicle at 20 mph has a 95 percent probability of survival. By comparison, a pedestrian struck by a vehicle traveling at 30 mph has a 55 percent probability of survival, and a 15 percent probability of survival when the vehicle is traveling at 40 mph, as Figure 23 shows.

Figure 23 Risk of fatality in pedestrians involved in collisions with vehicles



Similarly, the AAA Foundation for Traffic Safety analyzed the National Highway Traffic Safety Administration's (NHTSA) NASS Pedestrian Crash Data Study which showed that the average risk of severe injury for a pedestrian increased from 10 percent at 16 mph, to 25 percent at 23

mph, and up to 90 percent at 46 mph, as shown in Figure 24.

Figure 24 Risk of severe injury to pedestrians involved in collisions with vehicles



### Countermeasure 1: Setting Appropriate Speed Limits

The first countermeasure focuses on the Safe Systems Approach principle of Safe Speeds and reducing the energy produced by a collision.

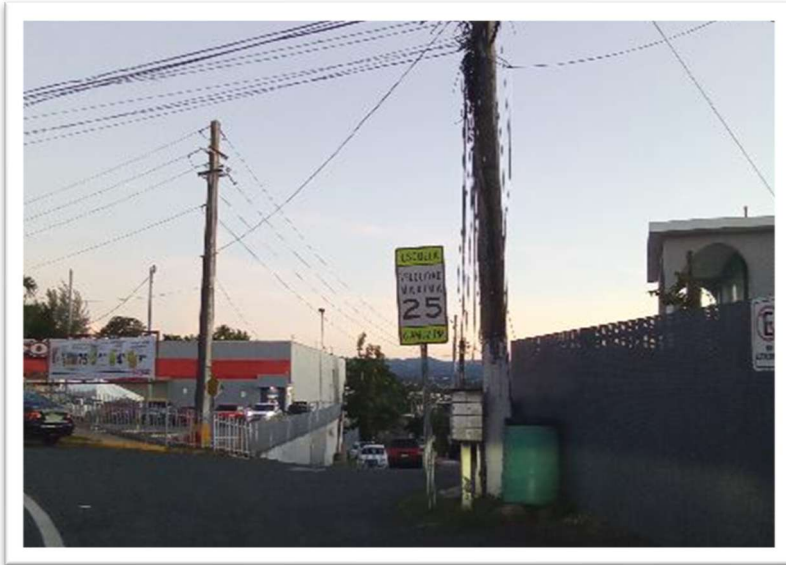
Speed limits over 35 mph create conditions adverse to the Safe Systems Approach. This means that minor arterials and collectors should have 35 mph speed limits. Areas with higher volumes of foot traffic, including residential areas, should have a statutory speed limit of 20 mph across the entire jurisdiction.

School zones are required to have 15 mph speed limits on all urban areas<sup>7</sup>. Speed limit signs on school zones located along routes PR-863, PR-865 and PR-8865 need

<sup>7</sup> 9 LPRA § 5122 (c)

to be updated according to the legal standard.

Figure 25 Speed limit sign for rural area posted in urban school zone, route PR-863<sup>8</sup>



Speed setting at minor arterials shall be based on speed studies and engineering evaluations. Setting speed limits should be accompanied by before and after studies to evaluate the effectiveness of the speed limit signage and policy.

#### Countermeasure 2: Speed Safety Cameras

Speed safety cameras are an automated enforcement tool used to reduce speeding on roads. Speed safety cameras supplement traditional police enforcement to reduce speeding and severe crashes. Speed safety cameras can be installed at locations where traditional methods of speed enforcement

are unsafe or impractical due to resource limitations. Speed safety cameras are commonly used on areas such as school zones, construction areas, residential streets and high crash corridors.

The core components of speed safety cameras are:

- 1) A speed measurement device, typically radar, LIDAR, or road embedded sensors such as inductive loops, to measure how fast each vehicle is traveling through the enforcement zone<sup>9,10</sup>.
- 2) A camera is linked to the speed detector and is programmed to activate only when a vehicle speed exceeds a preset threshold.

Many jurisdictions in the United States use 10 to 11 mph over the speed limit to activate the camera<sup>11</sup>.

- 3) A processing unit that records the speed, the posted limit, date, time and location of the speed safety camera, and associates these data with images of the vehicle and its license plate.
- 4) A secure communications system to transmit the violation record to a back-office system where authorized staff review the violation case and, if valid, issues a citation or warning notice by mail or electronically.

<sup>8</sup> Photo source: Miguel Vescovacci

<sup>9</sup> Source: <https://www.verramobility.com/how-do-speed-enforcement-cameras-work/>

<sup>10</sup> Source:

<https://highways.dot.gov/safety/proven-safety-countermeasures/speed-safety-cameras>

<sup>11</sup> Source:

<https://workzonecameras.penndot.gov/faqs/>

Speed safety cameras rely on precise speed measurement before any image is taken. Radar and LIDAR units calculate speed by sending out waves or laser pulses and measuring how long they take to return from a moving vehicle, while inductive loops in the pavement can calculate speed from the time it takes a vehicle to pass between two points. The system compares this measured speed to the posted speed limit plus any enforcement buffer defined by law or policy (for example, 11 mph over the limit in some work-zone programs). Only when that threshold is exceeded does the camera capture images of the vehicle (usually from the front, rear, or both) along with the associated data.

Figure 26 Fixed speed safety camera installed in school zone<sup>12</sup>



Research from the Insurance Institute for Highway Safety shows that speed safety

cameras have been adopted in more than 300 communities and 26 States across the United States. Contrary to media reports, speed safety cameras are found to be highly popular in communities where these are adopted, with approval rates of 62 to 77 percent.

Fixed speed safety cameras are effective in reducing severe collisions in rural areas by as little as 1 percent and as much as 24 percent. Fixed speed safety cameras are preferred where one or more of the following conditions are met:

- Where problems are long-term and site-specific
- Where clear enforcement is legally required, like school zones
- Where sight distance for the enforcement unit is limited
  - Enforcement sites are multilane facilities.

In Toa Baja, fixed speed safety cameras can provide benefits by reducing the rate of severe collisions by as much as 22.0 percent. The application of fixed speed safety cameras would reduce the collision rate per million vehicles from 0.3183 to 0.2723, a reduction of 14.5 percent in the collision rate. The application of the fixed speed safety cameras would reduce the severe collision rates from 0.0199 to

<sup>12</sup> Photo source: <https://www.arlingtonva.us/About-Arlington/Newsroom/Articles/2024/Arlington->

[County-Launches-School-Zone-Speed-Safety-Camera-Program](#)

0.0155 for a reduction of 22.0 percent in the severe collision rate.

Mobile speed safety cameras have shown benefits in reducing severe collisions and injury-related collisions by as much as 21 percent. Mobile speed cameras are preferred alternatives where one or more of the following conditions are met:

- Where problems are network-wide and where the speeding issues shift based on enforcement efforts
- Where speeds at enforcement sites vary largely from downstream sites
- Where clear enforcement is legally required, such as work zones.

In Toa Baja, speed related collisions have had a collision rate of 0.4763 collisions per million vehicles, and a severe collision rate of 0.0939 per million vehicles.

The implementation of mobile speed safety cameras would reduce the collision rate per million vehicles from 0.4763 to 0.3805. This reduction amounts to a decrease of 20.1 percent in the collision rates and in the severe collision rates

The use of mobile speed safety cameras is expected to yield the best results in terms of reducing collisions and severe collisions at the following places:

Table 8 Road segments for placement of speed safety cameras

Road	Segment Begin	Segment End
PR-2	C/ Colina Real	C/ El Acto
PR-2	PR-165 On Ramp	PR-8865
PR-165	PR-865	C/ Jaime Fonalledas
PR-165	C/ Camino del Mar	Río Cocal bridge
PR-865	C/ Roble	C/ Tamarindo
PR-867	Via Arcoiris	Ave. Sabana Seca
PR-867	Sector El 26	Urb. Pabellones
PR-867	C/ 11	C/ La Monserrate
Ave. Juan "Picolino" Hernández Ferrer	C/ Luis Llorens Torres	C/ Antonio Paoli

Countermeasure 3: Variable Speed Limit Signs

Variable speed limit (VSL) signs are electronic speed limit signs that can change the posted limit in real time to match current roadway conditions where free flow travel is affected by traffic, weather, crashes, or by temporary work zones. By aligning legal speed limits with actual conditions, VSLs aim to smooth traffic flow, reduce speed differences between vehicles, and lower crash risk<sup>13,14</sup>.

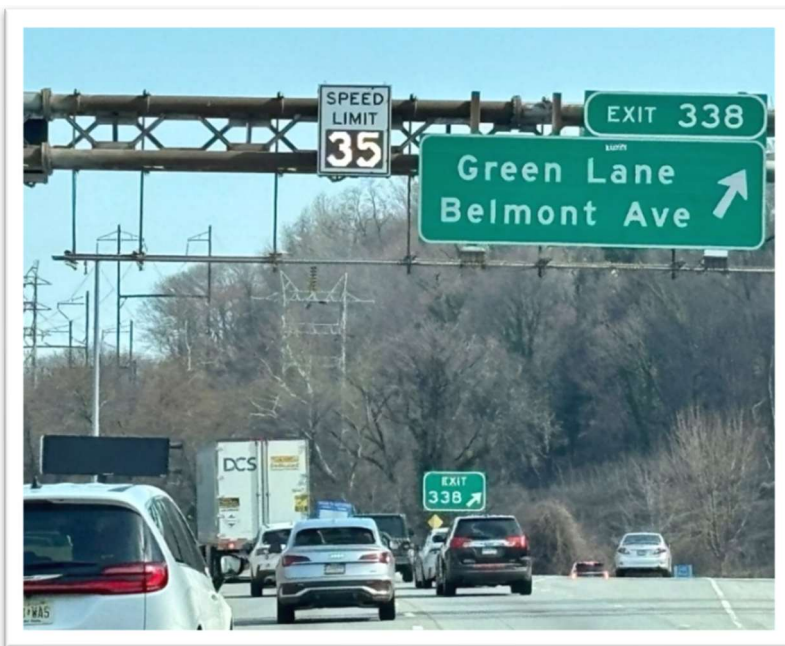
VSL signs look similar to conventional speed limit signs but use Light-Emitting Diode (LED) displays so the posted number can be updated automatically or by operators. A VSL sign mounted on a

<sup>13</sup> Source: <https://highways.dot.gov/safety/proven-safety-countermeasures/variable-speed-limits>

<sup>14</sup> Source: <https://www.nhtsa.gov/book/countermeasures-that-work/speeding-and-speed-management/countermeasures/legislation-and-1>

freeway overhead structure is shown in Figure 27. They are usually part of an intelligent transportation system that includes sensors in or along the roadway to measure traffic speeds, volumes, and sometimes weather and pavement conditions. Traffic management centers receive these data and use predefined algorithms or operator judgment to select appropriate speeds for each segment or lane, often lowering limits in small steps as congestion, incidents, or dangerous weather develop. The updated speed limit is then displayed on overhead gantries or roadside signs and is typically regulatory and enforceable, though some systems only use advisory speeds.

Figure 27 Variable speed limit sign<sup>15</sup>



On a busy freeway, for example, detectors may identify that speeds several miles ahead are dropping because of a crash or

a recurring bottleneck. In response, the system may lower upstream limits from 55 mph to 45 mph and then to 35 mph as drivers approach, creating a more gradual slowdown instead of a sudden stop. In work zones or in rainy conditions, operators can reduce limits to reflect lower visibility and reduced friction, then restore higher speeds when conditions improve.

The main safety benefit of VSL systems is improved speed harmonization, meaning they reduce the variation between the fastest and slowest vehicles. Studies in freeway and work-zone applications have found that VSLs can reduce maximum speed differences by around 10 mph,

lower the risk of rear-end collisions by roughly 30 percent, and decrease lane-changing conflicts by about 20 percent.

The application of VSL signs on highway PR-22 is included as a speed management countermeasure. While the application of VSL would be a corridor-wide recommendation - along the entire 52-mile long corridor - the safety benefits in Toa Baja would amount to a reduction of 36.1 percent in all speed-related collisions. This amounts to a reduction of 0.1191 collisions per

million vehicles.

<sup>15</sup> Photo source: Miguel Vescovacci

#### Countermeasure 4: Traffic Calming

Traffic calming is defined by projects and actions to reduce speeding and high traffic volumes on local roads, collectors and minor arterials.

Traffic calming considers two types of projects:

- Horizontal deflections
- Vertical deflections

Traffic calming measures included in this report are limited to speed reduction techniques. Site specific evaluations should include traffic engineering analysis to determine the effectiveness of the measures in reducing traffic volumes on local roads that are affected by unwanted through traffic.

#### *Horizontal Deflections*

Horizontal deflections create conditions for the motorists to slow their speeds on a road and at an intersection approach. There are two types of horizontal deflections considered:

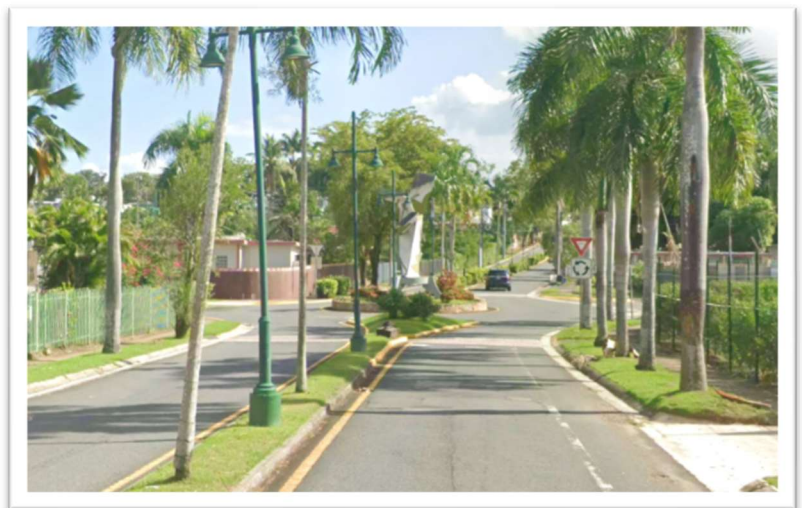
- Traffic circles
- Chicanes

Traffic circles are a popular choice at small intersections that connect local roads with collectors or between collectors. Like roundabouts, traffic circles eliminate left turns by forcing all motorists on a counterclockwise traffic pattern at the

intersection, and creates the conditions for slowing down speeding vehicles. When paired with upstream left turn restrictions, the traffic circles effectively allow vehicles to circle around the intersection to get to their destination.

Unlike roundabouts, which handle large traffic volumes, traffic circles are intended for local roads and can usually accommodate no more than three vehicles within the circular intersection. The circular apron should be raised at least 3 inches from the pavement. A traffic circle is intended at the intersection of Avenida del Lago and Avenida Dr. Álvarez Chanca as part of the complete streets redesign of Avenida del Lago. Other areas where traffic circles can provide speed reduction benefits are at:

*Figure 28 Traffic circle at Avenida Washington, Guaynabo<sup>16</sup>*



<sup>16</sup> Photo source: Google Streetview. Coordinates 18.368584, -66.097073

- Intersection of Calle Jose De Diego and Avenida Luis Pales Matos
- Intersection of Avenida Luis Pales Matos and Calle Luis Llorens Torres
- Intersection of Avenida La Fuente and Calle del Rey

Another type of horizontal deflection is the chicane. Chicanes disrupt the continuity of a lane by creating lane shifts so the lane has a curvilinear trajectory. Chicanes can be placed in a series of patterns along a segment of road, or these can also be installed at the intersection of two roads. Chicanes are most effective on local roads and collectors where slow speeds are desired. Where used, the chicanes can provide the impression of a reduced right of way, making motorists more aware of their surroundings.

*Vertical Deflections*

The most common vertical deflection used in many municipalities is the speed bump. Speed bumps are appropriate in areas where vehicles are encouraged to stop. As an example, this would be appropriate exiting a parking lot onto a collector or minor arterial. Speed bumps are a popular choice on local residential streets with low volumes and where travel speeds are measured above 25 mph. Speed bumps tend to be ineffective on roads with higher operating speeds and higher volumes. Motorists will travel over the speed bump at a higher speed to offset the deflection, rendering the speed bump ineffective.

Speed bumps are recommended at the following sites:

*Table 9 Road segments recommended for speed bumps for speed control*

Road	Segment Begin	Segment End
C/ Veronica (Campanilla)	C/ Pangola	C/ Fortaleza
C/ Los Quinteros (Campanilla)	C/ Del Carmen	C/ Maria Isabel
C/ 1 (San José)	C/ 2A	C/ 3
C/ 14 (San José)	C/ 5	C/ 17
C/ Colina Real (Urb. Las Colinas)	PR-2	C/ 2 (Las Colinas)
C/ Las Flores (Macún)	C/ F	C/ B1
C/ Las Flores (Macún)	C/ D	C/ F
C/ Acueducto (Sabana Seca)	C/ Parque N	Ave. Ramón Ríos Román
C/ Acueducto (Sabana Seca)	C/ Parque de las Gaviotas	C/ Higüero

Another common type of vertical deflection is the speed hump (see Figure 29). Speed humps are wider than a speed bump, and are intended on minor roads and collectors with higher volumes and speeds under 25 mph. Speed humps generally look to reduce the speed of the vehicle without forcing the vehicle to a full stop.

Speed humps are recommended on minor arterials and collector roads shown in Table 10.

Figure 29 Speed hump<sup>17</sup>



speed hump is that the speed table has a flat top. On some applications, the flat top is used as a pedestrian crossing.

Speed tables are considered at these road segments:

- Avenida Boulevard in front of Pedro Albizu Campos High School.
- Avenida Jose de Diego in front of Basilio Milán Middle School.
- PR-865 in front of Campanilla Community Center.

Table 10 Road segments recommended for speed humps for speed control

Road	Segment Begin	Segment End
Ave. El Capitán	C/ 1	C/ Martínez
Ave. Montecasino	C/ Bohío	C/ Luquillo
Ave. Don Pelayo	Marginal PR-2	C/ Asturias
Ave Campanilla	C/ Topacio	C/ Miosotis
Ave. Campanilla	C/ Topacio	PR-867
Ave. Ramón Ríos Román	C/ La Milagrosa	C/ Nueva
Ave. Ramón Ríos Román	C/ Vázquez	C/ Luz
Ave. Ramón Ríos Román	C/ Gardenia	C/ La Rosa
Bldv. Monroig	C/ 6A	C/ Marisol
Bldv. Monroig	C/ Margarita	C/ Melba
Bldv. Monroig	C/ Magaly	C/ Magdalena
C/ Nárceas	C/ Nueva	C/ Pravía
C/ Nárceas	C/ Palacio Valdés	C/ Cerebros
C/ del Carmen	C/ 3	C/ Nueva
PR-863	C/ Ruisseñor	C/ Los Plas
PR-866	KM 2.8	KM 3.2
PR-867	KM 0.2	KM 0.3
PR-870	KM 1.6	KM 1.7

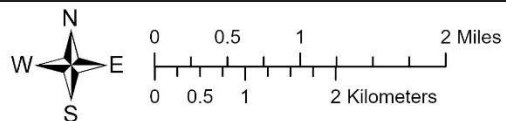
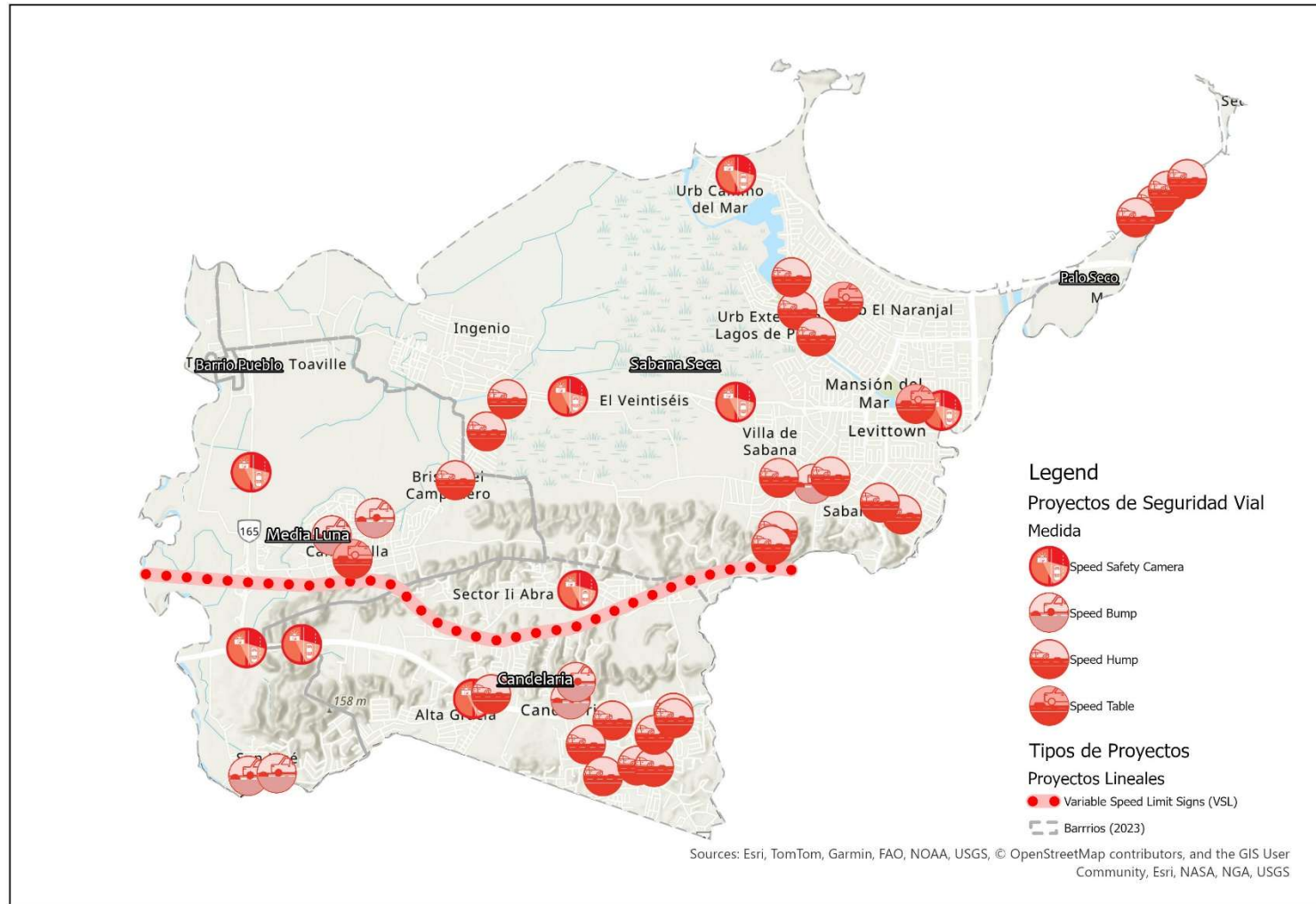
Each of these sites have been selected for increased pedestrian visibility countermeasures, which are included as a separate category of safety countermeasures. The applicability of each vertical deflection measure depends on the context of the road.

Figure 30 shows the locations of proposed speed management countermeasures.

A speed table is a third option. The difference between a speed table and a

<sup>17</sup> Photo source: Miguel Vescovacci

Figure 30 Map of Safety Countermeasures for Speed Management



## Roadway Departures

Roadway departure (also called lane departure) crashes include several specific events: a vehicle running off the road, crossing the median into opposing traffic, striking fixed objects such as trees, poles, or culverts, or becoming airborne and rolling over. National data from the Federal Highway Administration (FHWA) show that from 2016 to 2018, an average of about 19,158 people per year were killed in roadway departure crashes, representing roughly 51 percent of all traffic fatalities<sup>18</sup>. In Toa Baja, crashes related to roadway departures resulted in 47 out of the 148 severe collisions that occurred during the 2020 to 2024 period.

Roadway departures are especially severe because the roadside environment may contain unforgiving hazards such as non-breakaway utility poles, trees, rock outcrops and steep slopes.

A series of countermeasures are considered to address roadway departures. These are:

- Enhanced delineation and signage of horizontal curves
- Rumble strips
- Roadside design improvements at curves

## Countermeasure 5: Enhanced Delineation and Signage of Horizontal Curves

Enhanced delineation and signage of horizontal curves is a roadway safety strategy that makes curves more visible and understandable to drivers so they can slow down, stay in their lane, and avoid leaving the roadway. It is promoted by the Federal Highway Administration (FHWA) as a proven, low-cost countermeasure to reduce roadway departure crashes, especially on rural two-lane roads where many serious curve-related crashes occur<sup>19</sup>.

This countermeasure uses a combination of devices placed in advance of and within the curve to better guide drivers. Typical treatments include upgraded pavement markings (standard or wider edge lines, centerlines, and in line curve warning markings), post mounted delineators, and chevron alignment signs that show the direction and sharpness of the curve. Other enhancements involve using larger, more conspicuous curve warning signs, fluorescent or higher retro reflectivity sign sheeting, and retroreflective strips on signposts to improve nighttime visibility. Emerging options such as dynamic curve warning signs, speed feedback signs, and sequential dynamic chevrons can actively alert drivers who are approaching too fast.

<sup>18</sup> Source: <https://highways.dot.gov/safety/RwD>

<sup>19</sup> Source: <https://highways.dot.gov/safety/rwd/keep-vehicles-road/horizontal-curve-safety>

The safety concept behind enhanced delineation is to improve guidance so that drivers recognize a curve early and adjust their speed and path smoothly. By seeing prominent warnings, clear lane lines, and a continuous line of chevrons or delineators, drivers are informed of how sharp is the curve and what is the appropriate speed. This reduces sudden braking, late lane changes, oversteering and other maneuvers that can lead to roadway departure, particularly at night or in poor weather when the curve alignment is harder to see<sup>20</sup>.

The combined treatments work together to reduce the probability of a collision associated with a roadway departure on the horizontal curves. The applications of these countermeasures are intended to reduce the collision rates by 53.5 percent where applied:

- PR-865 KM 0.5 (American Gas Station)
- PR-865 KM 3.0 (Cuesta El Guano)
- PR-867 KM 2.4 (Sector El 26)
- PR-867 KM 4.2 (Curva La Monserrate)
- PR-8865 KMs 1.1 to 1.3 (San José)

#### Countermeasure 6: Rumble Strips

Rumble strips are one of the most cost effective ways to reduce roadway and lane departure crashes. Longitudinal rumble strips run parallel to the direction of traffic, usually along the centerline or edge line, and are a widely used, low-cost

countermeasure to reduce severe roadway departure and head-on crashes.

In general, longitudinal rumble strips work by providing an immediate, physical alert when a vehicle begins to drift. As the tires cross the grooved or raised pattern, the resulting vibration and noise are hard to ignore, even for a drowsy, distracted, or momentarily inattentive driver.

Agencies often place the rumble strips in combination with clear pavement markings so that the rumble pattern aligns with painted centerlines or edge lines, reinforcing the visual cue with a tactile and auditory one.

#### *Edgeline Rumble Strips*

Edgeline rumble strips play a significant role in reducing roadway departures to the outside of the lane. Many serious crashes occur when vehicles leave the road entirely, striking trees, utility poles, embankments, or other fixed objects, or overturning on steep slopes. Edge-line or shoulder rumble strips are placed where this type of run-off-road risk is high—such as rural two-lane roads, high-speed highways, and curves with limited shoulders.

Edgeline rumble strips can be placed along the edge line of the road (white line) or on the shoulder if the shoulder has sufficient width to accommodate the rumble strip.

<sup>20</sup> Source: <https://highways.dot.gov/safety/proven-safety->

[countermeasures/enhanced-delineation-horizontal-curves](https://highways.dot.gov/safety/proven-safety-countermeasures/enhanced-delineation-horizontal-curves)

### *Centerline Rumble Strips*

Centerline rumble strips are installed along or directly within the painted centerline between opposing lanes of traffic. Their primary function is to reduce lane departures toward the opposing travel lane, which can lead to head-on or opposite-direction sideswipe collisions—some of the most severe crash types.

Figure 31 shows the rumble strip treatments on a rural road.

*Figure 31 Edgeline and centerline rumble strips<sup>21</sup>*



On narrow rural two-lane roads, where traffic volumes may be moderate but speeds are high and shoulders are limited, centerline rumble strips provide a critical safeguard against brief lapses in attention, distraction, or drowsiness that might otherwise result in a catastrophic crash. Installed systematically across many miles of roadway, they can reduce the overall risk of cross-centerline collisions,

especially on curves, hills, and segments with a history of head-on crashes.

Table 11 highlights the road segments where the use of longitudinal rumble strips or the use of centerline rumble strips, or a combination of both, can provide significant reductions in collision rates.

The use of edgeline rumble strips and centerline rumble strips can reduce overall collision rates by up to 38.7 percent.

<sup>21</sup> Photo source:  
<https://highways.dot.gov/safety/proven-safety->

[countermeasures/longitudinal-rumble-strips-and-stripes-two-lane-roads](https://highways.dot.gov/safety/proven-safety-countermeasures/longitudinal-rumble-strips-and-stripes-two-lane-roads)

Table 11 Road segments recommended for rumble strips

Road	Segment Begin	Segment End	Edgeline Rumble Strips	Centerline Rumble Strips
Ave. Campanilla	PR-867	C/ Topacio	--	X
Ave. Campanilla	C/ Zacarias	Mausoleo	--	X
PR-2	PR-8865	Home Power Sun Frontage Road	X	--
PR-165	KM 14.0	KM 14.8	X	--
PR-854	Blvd. Bruno Cruz	PR-6165	--	X
PR-863	PR-2	PR-862	--	X
PR-865	Ave. Campanilla	C/ Caoba	--	X
PR-865	PR-22 Exit 17 Off Ramp	C/ Ausubo	--	X
PR-866	KM 1.8	KM 2.4	X	X
PR-866	KM 2.9	KM 3.2	X	X
PR-866	KM 3.2	KM 3.4	--	X
PR-866	PR-867	C/ Jose Pedreira	--	X
PR-867	PR-866	C/ Zafiro	--	X
PR-867	KM 2.2	KM 3.1	--	X
PR-867	KM 3.1	KM 3.8	X	X
PR-867	KM 4.0	KM 4.4	X	X
PR-867	KM 4.5	KM 5.9	--	X
PR-867	KM 5.9	KM 6.4	X	X
PR-867	KM 6.4	KM 7.2	--	X
PR-867	KM 7.2	KM 7.7	X	X
PR-870	PR-165	C/ Nueva	--	X
PR-872	C/ Garage Ortiz	C/ Los Olvidados	--	X
PR-8865	PR-2	C/ 7 San José	X	X
PR-8865	C/ 7 San José	C/ 1 San José	--	X

### Countermeasure 7: Roadside Design Improvements at Horizontal Curves

The third type of countermeasure involves modifying the geometry or design of horizontal curves to reduce the severity of collisions when drivers make an error. These countermeasures focus on the high-risk roadside area outside the curve, where roadway departure crashes often become severe because vehicles encounter steep slopes, fixed objects, or insufficient recovery space to correct the trajectory of the vehicle.

These improvements are especially valuable on horizontal curves because curve-related crashes are disproportionately severe and many are roadway departures. In Toa Baja, there were 2,677 collisions reported as a roadway departure, of which 26 were severe collisions.

Guardrails are one of the most important roadside design improvements when hazards cannot be removed or moved far enough away from the roadway. A guardrail does not prevent every departure, but it intercepts a vehicle before it reaches a dangerous object or embankment, thereby reducing the chance of a fatal or severe injury crash. In practical terms, guardrails are often installed on the outside of curves where a run-off-road vehicle would otherwise strike trees, poles, steep slopes, drainage structures, or other fixed hazards.

A key reason guardrails matter so much at curves is that they change the outcome of a departure. Without a barrier, a vehicle may leave the roadway and hit a rigid object or overturn down a steep embankment; with a properly designed and placed guardrail, the vehicle is redirected or absorbed in a controlled way. FHWA notes that roadside barriers should be used to shield unmovable objects or steep embankments when those hazards *cannot be eliminated through clear zone expansion or slope flattening*. That means guardrail is often not the first option, but it is a critical final layer of protection when geometric redesign alone cannot make the roadside forgiving enough.

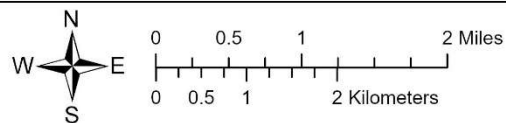
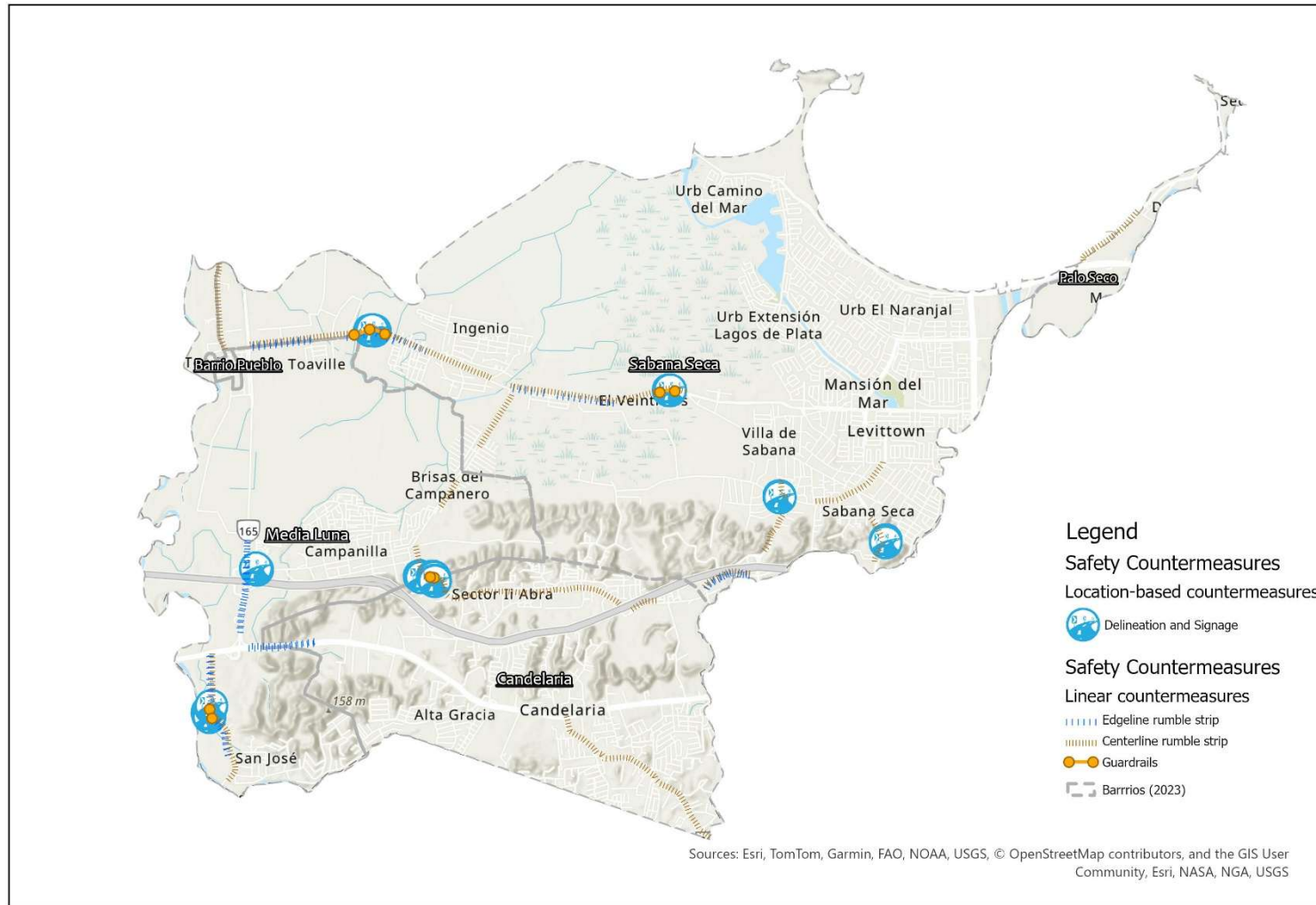
There are four locations where the installation of a guardrail is expected to improve the safety of road users, and where the conditions of a horizontal curve, limited clearance area and presence of embankments or fixed objects are met. These are:

- Route PR-865 kilometer 2.8 to 3.0
- Route PR-867: kilometer 2.4
- Route PR-867: kilometer 6.2 to 6.3
- Route PR-8865: from kilometer 1.0 to 1.3

The installation of guardrails at these four locations are expected to decrease the rate of severe collisions at these locations by 44 percent, and the rate of collisions by 28.5 percent.

Figure 32 shows the location of the countermeasures presented in this section.

Figure 32 Map of Safety Countermeasures for Roadway Departures



## Pedestrians and Bicyclists

Pedestrians and cyclists are a vulnerable group of users who are disproportionately affected by roadway crashes. Speed differentials between motorists and other users such as cyclists and pedestrians are one of the primary determinants of the severity of a collision. As mentioned in the targeted safety investigations, pedestrians are 19.7 times more likely to be involved in a severe collision and cyclists are 6.0 times more likely to be involved in a severe collision, when these are compared to motorists. These are some of the reasons why Safe Road Users and Safe Speeds are two of the core principles in the Safe Systems Approach.

A series of countermeasures are considered to address pedestrian and bicyclist related vulnerabilities. These are:

- Bicycle lanes
- Crosswalk visibility enhancements
- Leading pedestrian intervals
- Rectangular rapid flashing beacons
- Road reconfiguration

### Countermeasure 8: Bicycle Lanes

Bicycle lanes are marked portions of the roadway reserved for bicyclists, usually identified by pavement markings and signs, that help separate cyclists from motor vehicle traffic. As a safety countermeasure, they are intended to reduce conflicts, improve bicyclist

comfort, and create a more predictable operating space for both cyclists and drivers.

A bicycle lane gives cyclists a dedicated space along the roadway rather than requiring them to mix fully with faster motor vehicle traffic. This separation matters because the speed and size difference between bikes and cars can make even small mistakes dangerous, especially where motorists overtake cyclists or make turning maneuvers. In practice, the lane helps define where bicyclists should ride and where drivers should expect to see them, which can reduce side-swipe, passing, and dooring conflicts.

FHWA materials note that adding bicycle lanes can mitigate or prevent interactions, conflicts, and crashes and can create a safer, more comfortable network for bicycling<sup>22</sup>. On urban roads, bicycle lanes have been associated with substantial crash reductions, including reductions reported on four-lane and two-lane urban roads. They can also improve sight distance and may encourage drivers to slow slightly and give bicyclists more room, which further lowers risk.

Bicycle lanes are a relatively low-cost way to improve cyclist safety by creating a dedicated operating space, reducing crash opportunities, and increasing

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<sup>22</sup> Source: Publication FHWA-SA-21-051. Office of Safety. Proven Safety Countermeasures. Bicycle Lanes.

predictability for all road users. They are especially effective on roads where traffic speeds and volumes are moderate, and they become even more beneficial when upgraded to separated or protected facilities on busier streets (see Figure 33). In the context of Toa Baja, bicycle lanes are considered in areas with documented bicycle traffic and in areas where bicycle trips can be generated under safe conditions.

Figure 33 Bicycle lanes on Avenida Luis Muñoz Rivera, San Juan<sup>23</sup>



The locations of bicycle-related crashes were concentrated in Sabana Seca, where 25 of the 40 incidents have occurred. Of the 25 bicycle related collisions in Sabana Seca:

- 6 occurred on route PR-867
- 4 occurred on route PR-165

- 4 occurred on Avenida Ramón Ríos Román
- 2 occurred on Avenida Boulevard
- 2 occurred on Avenida Olga Tañón (Avenida Los Dominicos)

The roadways where bicycle lanes were considered are:

- Avenida Boulevard
- Avenida Ramón Ríos Román
- Avenida Juan “Picolino” Hernández Ferrer
  - PR-165 (Media Luna)
  - PR-865 (Candelaria)
  - PR-867 (Ingenio)

The use of bicycle lanes is expected to reduce the collision rate for severe collisions involving cyclists by 41.6 percent, and the overall collision rate for incidents involving cyclists by 35.9 percent.

#### Countermeasure 9: Crosswalk Visibility Enhancements

Pedestrian crashes often happen because drivers do not detect a person in the crosswalk early enough to slow down or yield. Visibility treatments address that problem by making the crossing itself more obvious and by making the pedestrian stand out sooner in the driver’s field of view. This is particularly valuable at multilane crossings, where one stopped vehicle can

<sup>23</sup> Photo source: Miguel Vescovacci

block the view of another driver approaching in the adjacent lane.

The crosswalk visibility enhancements included in this evaluation are a set of low-cost countermeasures that make pedestrians easier for drivers to see at crossings (see Figure 34). They are especially important at locations where lighting is poor, traffic is heavy, or parked vehicles and roadway geometry reduce sight lines<sup>24</sup>.

The main treatments are high-visibility crosswalk markings, improved lighting, and enhanced signing and pavement markings. High-visibility crosswalks use ladder, continental, or bar-pair patterns that are more noticeable from a distance than standard transverse lines. Agencies may also place "Yield Here to Pedestrians" or "Stop Here for Pedestrians" signs before the crossing, along with stop or yield bars that show drivers where to stop. Lighting can be aimed to create positive contrast, which helps drivers distinguish pedestrians from the background instead of seeing them only as silhouettes.

Crosswalk visibility enhancements are most useful at midblock crossings,

uncontrolled intersections, school areas, and other locations where pedestrians need clearer guidance and drivers need stronger visual cues. They are also important at night, because many pedestrian fatalities occur in dark conditions and lighting greatly improves conspicuity<sup>25</sup>. In Toa Baja, this is an important consideration because 55 of the 98 pedestrian crashes between 2020 and 2024 occurred during reduced visibility conditions such as nighttime, sunset and sunrise.

Figure 34 Crosswalk visibility enhancements<sup>26</sup>



On busy streets, these treatments often work best as part of a broader safety package that may include curb extensions, medians, signals, or pedestrian refuge islands. The main benefit of improving pedestrian visibility at crossings is simple:

<sup>24</sup> FHWA Crosswalk Visibility Enhancements: <https://highways.dot.gov/safety/proven-safety-countermeasures/crosswalk-visibility-enhancements>

<sup>25</sup> NACTO overview of high-visibility crosswalk markings: [https://nacto.org/wp-content/uploads/overview\\_and\\_recommendation](https://nacto.org/wp-content/uploads/overview_and_recommendation)

[s high visibility crosswalk marking styles mcgrane.pdf](https://high-visibility-crosswalk-marking-styles-mcgrane.pdf)

<sup>26</sup> Photo source:

<https://raleighnc.gov/transportation/news/new-raised-crosswalks-improve-safety-st-marys-street>

drivers notice people sooner, and pedestrians are easier to understand and yield to.

The countermeasures considered for improving pedestrian safety across Toa Baja include:

- Improving intersection lighting (at intersections)
- Installing advanced yield or stop markings and signs
- Installing high visibility crosswalk
- Installing raised pedestrian crosswalk
- Presence of pedestrian crosswalk at midblock locations

The crosswalk visibility countermeasures are considered at 23 sites across Toa Baja identified on Table 12.

These sites are located primarily on minor arterials. The countermeasures have the potential to decrease pedestrian-related crashes by as much as 60 percent.

Table 12 Road segments recommended for crosswalk visibility improvements

Road	Segment Begin	Segment End
Ave. Amalia Paoli	C/ Gregorio Ledesma	Ave. Antonio Paoli
Ave. Boulevard	C/ Alondra	C/ Aurora
Ave. Boulevard	C/ Aurora	Paseo Alicea
Ave. Boulevard	Paseo Alicea	C/ 4
Ave. Boulevard	Ave. Olga Tañón	Blvd. Monroig
Ave. Boulevard	C/ Leila	Ave. Dos Palmas
Ave. Boulevard	Ave. Dos Palmas	Paseo Diamante
Ave. Boulevard	Paseo Durazno	C/ Myrna
Ave. Boulevard	C/ Mireya	C/ Magda
Ave. Boulevard	Ave. del Lago	Paseo Costa
Ave. Olga Tañón	Canal Toa Baja	C/ Jose de Diego
Ave. Dos Palmas	C/ Atenas	PR-165
Ave. Ramón Ríos Román	C/ La Milagrosa	C/ Nueva
Ave. Ramón Ríos Román	C/ Luz	C/ Vega
PR-165	Ave. Dos Palmas	C/ Aldita
PR-863	Ave. Nárceas	C/ Campeche
PR-865	C/ 13	C/ Los Quinteros
PR-865	C/ Francisco Arriví	C/ El Monte
PR-865	C/ Tito Rodríguez	Ramal PR-865R
PR-865	C/ 1	C/ Eucalipto
PR-866	C/ G. Arizmendi	Ave. Amalia Paoli
PR-867	KM 2.3	KM 2.4
PR-867	C/ Escopeta	C/ Jazmín

**Countermeasure 10: Leading Pedestrian Interval**

At signalized intersections, leading pedestrian intervals (LPIs) are a simple but highly effective intersection safety treatment that gives pedestrians a head start of about 3 to 7 seconds before parallel vehicle traffic gets a green light. This brief timing change helps pedestrians establish themselves in the crosswalk first, making them more visible to turning drivers and reducing the chance of a conflict.

The treatment is usually programmed into existing signal timing, so it can often be implemented at relatively low cost without

major construction. For most intersections with pedestrian signal heads installed and in operation, the leading pedestrian interval is programmed into the signal-phase system by adding the amount of time needed for a pedestrian to cross at least half of the intersection.

The main safety benefit of an LPI is that it reduces pedestrian-vehicle conflicts, especially conflicts involving turning vehicles. FHWA identifies several benefits: increased visibility of crossing pedestrians, reduced conflicts between pedestrians and vehicles, increased likelihood that motorists will yield, and better protection for pedestrians who start more slowly. Research summarized in the literature shows that LPIs can reduce pedestrian-vehicle crashes, with reported reductions ranging from about 13 percent overall in some studies to larger reductions at certain locations and for certain crash types. One before-and-after study also found a marked reduction in conflicts when LPIs were installed, supporting the idea that the extra crossing time helps drivers notice people in the crosswalk sooner<sup>27</sup>.

The use of leading pedestrian intervals will improve the safety of pedestrians at 17 signalized intersections across Toa Baja. These intersections are included in Table 13.

Table 13 Intersections identified for pedestrian improvements

Main Road	Cross Street
Ave. Boulevard	Ave. Olga Tañón
Ave. Boulevard	Ave. del Valle
Ave. Olga Tañón	C/ José de Diego
Ave. Juan “Picolino” Hernández Ferrer	PR-167
Ave. Juan “Picolino” Hernández Ferrer	Ave. Olga Tañón
Ave. Juan “Picolino” Hernández Ferrer	Ave. Dr. Álvarez Chanca
PR-2	Ave. Don Pelayo
PR-2	Ave. Norte
PR-2	C/ Coto
PR-2	PR-863
PR-2	C/ Colina Real
PR-165	PR-867
PR-165	Entrada Balneario
PR-165	Ave. del Valle
PR-165	Ave. Dos Palmas
PR-866	PR-867
PR-867	Via Arcoiris

Countermeasure 11: Rectangular Rapid Flashing Beacon

Rectangular rapid flashing beacons (RRFB) are used at uncontrolled marked crossings to increase the visibility of crossings at times when pedestrians are using these. An RRFB is an actuated traffic control device which emits a light sequence as a warning beacon on an LED panel installed along with the pedestrian crossing sign (W11-2), a school crossing sign (S1-1) or a trail crossing sign (W11-15), and a diagonal downward arrow plaque (W16-7P), as seen in Figure 35.

Research has shown that RRFBs are highly effective at multilane crossings where

<sup>27</sup> Source: NACTO/FHWA research summary on LPI effectiveness: <https://nacto.org/wp->

[content/uploads/safety\\_effectiveness\\_of\\_lpi\\_fayish.pdf](content/uploads/safety_effectiveness_of_lpi_fayish.pdf)

speed limits are less than 40 mph<sup>28</sup>. Research has also shown that the placement of RRFBs at marked crosswalks can improve motorist yield rates by as much as 98 percent with variations observed depending on the location of the crosswalk, the pedestrian crossing distance, whether the road is a one-way or a two-way road, and the number of travel lanes.

Figure 35 Rectangular Rapid Flashing Beacon (RRFB)<sup>29</sup>



The applicability of RRFBs in Toa Baja will be limited. Despite the benefits of RRFB, most of the potential applications for Toa Baja require as a prior condition the presence of crosswalks. With a few exceptions, like Avenida Boulevard, many areas in Toa Baja are lacking crosswalks.

The use of RRFBs on existing crosswalks was evaluated and recommended at the following places:

- Avenida Ramón Ríos Román at the segment between Calle Nueva and Calle La Milagrosa
- PR-865 in front of Campanilla community center
- PR-865 at the intersection with Calle Emilio S. Belaval in Campanilla
  - PR-865 at the segment between Calle Tamarindo and Calle Ceiba in front of Ernestina Bracero Pérez Elementary School
  - PR-866 between Calle A-5 and Calle Acueducto, in front of Francisca Dávila Sempritt Elementary School
  - PR-867 at the segment with Golden Age Tower, and at Bus Stop #2 for the West Route of the municipal transit system.

Countermeasure 13: Pedestrian Hybrid Beacons (PHB)

Another type of pedestrian signal control at uncontrolled crossings is the Pedestrian Hybrid Beacon, also known as a HAWK beacon. A Pedestrian Hybrid Beacon (PHB) is a traffic control device designed to help people cross busy or higher-speed roads safely at midblock crossings and uncontrolled intersections. In a Safe System, the PHB is valuable

<sup>28</sup> Rectangular Rapid Flash Beacon in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. FHWA, (2013).

<sup>29</sup> Photo source: Miguel Vescovacci

because it reduces the consequences of human error by making the crossing more controlled, more visible, and more forgiving. The PHB stays dark until a pedestrian pushes the button at the crossing, then it alerts drivers through a sequence of flashing yellow, solid yellow, and red indications, while giving pedestrians a WALK indication to cross (see Figure 36). This design creates a clear right-of-way for pedestrians without requiring a full traffic signal at every crossing.

Figure 36 Sequence of a Pedestrian Hybrid Beacon (PHB)  
30



The PHB helps reduce fatalities and severe crashes in two important ways. First, it gives drivers a strong and unmistakable prompt to slow down and stop for people crossing, which is

especially valuable where traffic speeds are higher or gaps in traffic are not long enough for a safe crossing. Second, because the beacon remains dark until activated, it tends to capture driver attention more effectively than a continuously operating signal, increasing the chance that motorists notice pedestrians before conflict occurs.

FHWA reports that PHBs can reduce pedestrian crashes by up to 69 percent and total crashes by up to 29 percent, with severe crashes also reduced. Other summaries note that severe crashes may decline by about 15 percent, and rear-end crashes do not increase when PHBs are installed properly. Those outcomes matter because pedestrian crashes on higher-speed roads are often the most serious type, especially where crossing distances are long and drivers have little time to react.

Jurisdictions often install PHBs where pedestrians need a protected crossing but a full traffic signal is not justified by traffic volume or delay concerns. A PHB installed on a roadway must also include roadway elements that guide motorists and pedestrians, such as stop bars to show motorists where to stop, marked crosswalks across the length of the

<sup>30</sup> Source: San Luis Obispo Police Department. City of San Luis Obispo, California. <https://www.slocity.org>.

crossing, a countdown pedestrian signal, and public education so drivers understand how the sequence works.

Volume and speed based engineering studies are required to determine if a PHB can be installed at a location. The recommended minimum pedestrian volume to support a PHB installation is 20 pedestrian per hour, and the minimum vehicle volume per hour would depend based on the length of the crossing and other factors such as the width of the median.

Applicability of a PHB in Toa Baja is limited to midblock crossings on minor multi-lane arterials with a history of pedestrian-related crashes or with pedestrian volumes. There are three roads that meet the criteria for a multilane arterial:

- Avenida Juan “Picolino” Hernández Ferrer
- Route PR-165
- Route PR-167

These roads have uncontrolled pedestrian crossings at the following locations:

- Route PR-167 at Bus Stop across the road from Supermercado Econo.
- Avenida Juan “Picolino” Hernández Ferrer in front of Coliseo Antonio R. Barceló and old City Hall building.
- Avenida Juan “Picolino” Hernández Ferrer at pedestrian access near the

intersection of Calle Dr. Emigdio Antique and Calle Dr. José Castelar.

- Avenida Juan “Picolino” Hernández Ferrer in front of the Museo de Toa Baja.

Where applied, the use of the PHB has the potential to reduce the collision rates with pedestrians and bicyclists by 36 percent.

#### Countermeasure 14: Road Reconfiguration

Roadway reconfiguration is a safety treatment that changes a street’s cross-section to better match how people use it. The most usual form converts an undivided four-lane roadway into three lanes — one through lane in each direction plus a center two-way left-turn lane, as Figure 37 shows — while reclaiming space for bicycle lanes, wider sidewalks, or pedestrian refuge islands.

Roadway reconfigurations reduce the number of lanes a pedestrian must cross, which shortens exposure time and lowers the chance of being struck. They also reduce speeds and speed differences between vehicles, which makes crossings more predictable and gives drivers more time to react. FHWA identifies crash reductions of about 19 to 47 percent on corridors where roadway reconfigurations are implemented, with especially strong benefits for rear-end, left-turn, and right-angle crashes<sup>31</sup>.

For pedestrians, the biggest advantage is simpler crossing geometry. A four-lane

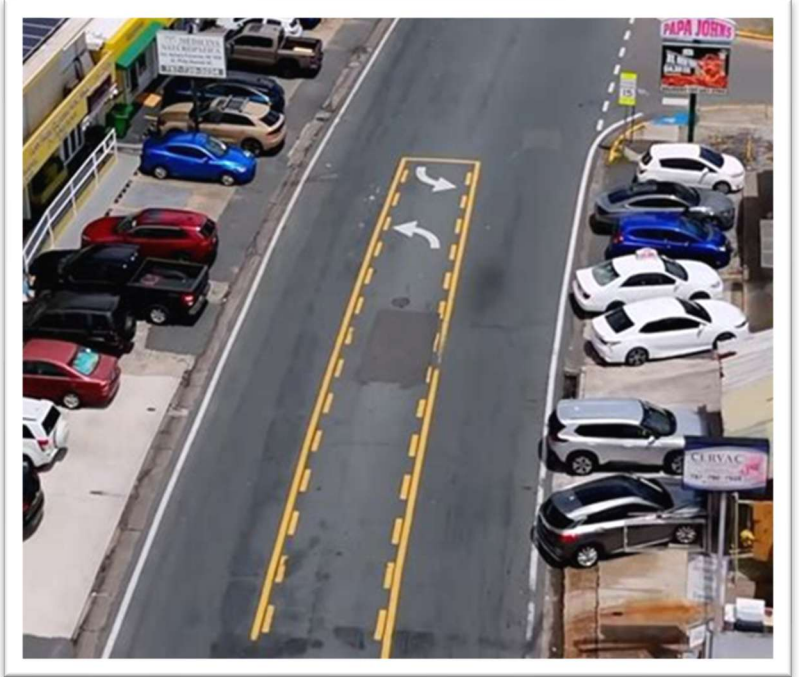
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<sup>31</sup> *Evaluation of Lane Reduction “Road Diet” Measures on Crashes*, FHWA-HRT-10-053, (2010)

undivided road can force people to judge traffic in multiple directions at once, while a roadway reconfiguration reduces that complexity and can create a center refuge area for people crossing in two stages. FHWA notes that roadway reconfigurations create “fewer lanes for pedestrians to cross” and may provide space for pedestrian refuge islands, both of which improve safety and comfort at crossings. These changes are especially useful near commercial corridors, transit stops, schools, and places with frequent driveway or side-street activity. In Toa Baja, Avenida Boulevard in Levittown is a perfect example for these conditions: it is a commercial corridor with transit stops used by AMA and by the municipal transit system, with schools located along the corridor and with the presence of many driveways that are used as perpendicular parking, which also create the conditions for a high number of left turns. Another road that meets most of the criteria is Avenida Dos Palmas.

FHWA generally recommends roadway reconfigurations on four-lane undivided roads with daily traffic volumes at or below about 25,000 vehicles, although some corridors with higher volumes may still work depending on conditions. They are especially promising where there are many pedestrian crossings, bicycle demand, or frequent turning movements.

Figure 37 Roadway reconfiguration of Avenida Esmeralda, Guaynabo<sup>32</sup>

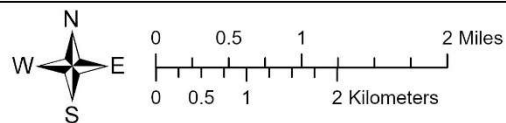
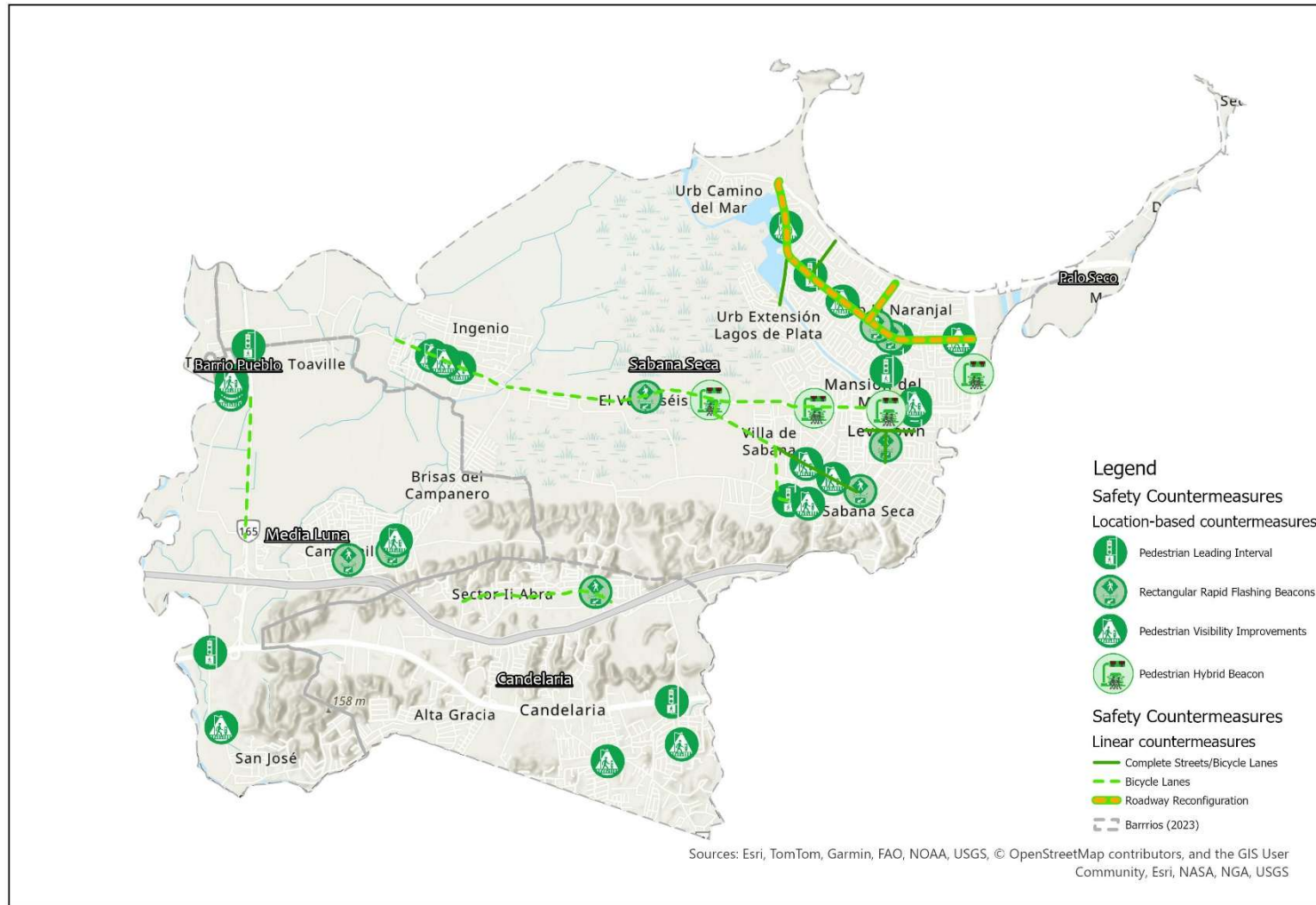


The conversion of four lane roads to two-lane roads with center left turning lane was evaluated from a safety perspective for Avenida Boulevard and Avenida Dos Palmas. The roadway reconfigurations on these two roads are expected to decrease the collision rates on both roadways. The collision rates on these two roads decreases from 26.2610 collisions per million vehicles to 19.6432, and the severe collision rate from 0.1527 per million vehicles to 0.1143 per million vehicles, for a reduction of 25.2 percent.

Figure 38 shows the location of pedestrian and bicycle safety countermeasures.

<sup>32</sup> Photo source: [www.facebook.com](http://www.facebook.com)

Figure 38 Map of Pedestrian and Bicyclist Safety Countermeasures



## Intersections

Intersections are a major emphasis area in roadway safety programs because they concentrate turning movements, crossing conflicts, and driver decision points in one location. Severe crashes at intersections often involve angle crashes, pedestrian conflicts, red-light running, and left-turn conflicts, so agencies commonly use a mix of geometric, operational, and signing treatments to reduce risk.

Intersection crashes are especially serious because multiple traffic streams cross or merge in a small area, which creates more opportunities for error. Safety programs therefore focus on treatments that reduce impact speeds, simplify decisions, and make right-of-way clearer for all users.

The following countermeasures are considered in the evaluation of intersection crashes:

- Roundabouts
- Systemic improvements to signage and markings at unsignalized intersections
- Revision of yellow clearance times

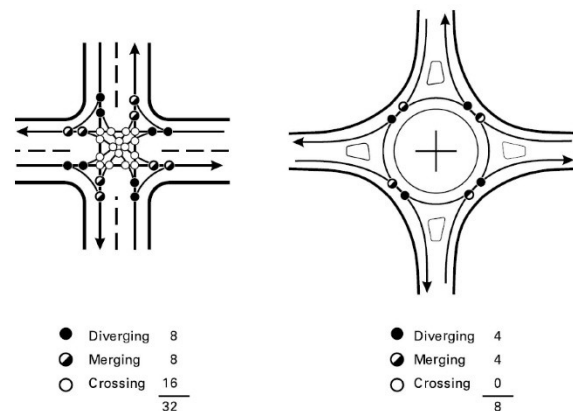
### Countermeasure 15: Roundabouts

Roundabouts are one of the most effective intersection countermeasures because they slow vehicles and replace high-speed crossing conflicts with lower-speed merging and yielding movements. FHWA describes roundabouts as an effective option for managing speed, transitioning

traffic from high-speed to low-speed environments, and reducing both the number and severity of crashes. In practical terms, roundabouts reduce the likelihood of severe angle and right-angle crashes because drivers enter at lower speeds and traffic moves in one direction around the central island rather than crossing directly through the intersection.

Roundabouts are effective in reducing the amount of conflict points at intersections. Because left turns and through movements are eliminated at a roundabout, the number of conflict points at a four-legged intersection decreases from 32 to eight (8), as shown in Figure 39. Another benefit from a roundabout is that it eliminates the need for a traffic signal, so there is no need for providing power for a traffic signal.

Figure 39 Conflict points at regular intersection and at a roundabout



Roundabouts are used in many types of intersections (signalized, unsignalized), several types of roadways (arterials, collectors) and in different settings (urban, suburban, rural). For this analysis,

roundabouts were considered at intersections with safety performance history associated with right angle crashes, red light running crashes and high-speed crashes.

The intersections in the top 25 percent in highest predicted reduction in the collision rates are:

1. Intersection of Avenida Boulevard and Calle Aurora/Calle Gautier Benítez.
2. Intersection of route PR-865 and route PR-866.
3. Intersection of route PR-165 and route PR-867.
4. Intersection of Avenida Ramón Ríos Román, route PR-866 and route PR-872.
5. Intersection of Avenida Olga Tañón (Los Dominicos) and Avenida Juan “Picolino” Hernández Ferrer.
6. Intersection of Avenida Dos Palmas and PR-165.
7. Intersection of route PR-165 and route PR-167.
8. Intersection of route PR-865 and Avenida Campanilla.
9. Intersection of Avenida Dos Palmas and Avenida Boulevard.
10. Intersection of route PR-867 and Avenida Campanilla.
11. Intersection of Avenida Boulevard and Avenida Olga Tañón (Los Dominicos).
12. Intersection of route PR-2 and route PR-8865.
13. Intersection of Avenida Boulevard and PR-165.

14. Intersection of route PR-865 and route PR-165.

15. Intersection of Avenida Juan “Picolino” Hernández Ferrer and route PR-167.

An additional group of intersections were evaluated for their safety performance with a conversion to a roundabout. These intersections are:

16. Intersection of Avenida Juan “Picolino” Hernández Ferrer and Avenida Dr. Álvarez Chanca.

17. Intersection of Avenida Juan “Picolino” Hernández Ferrer and Calle Dr. Villalobos.

18. Intersection of PR-866 and PR-864.

Collision rates could decrease by as much as 73 percent and severe collision rates by as much as 77 percent across the 19 intersections if these are converted to roundabouts.

**Countermeasure 16: Systemic Signage and Improvements at Unsignalized Intersections**  
At unsignalized intersections, systemic signage helps drivers recognize the presence of a crossing or side-road conflict sooner and respond more consistently. Typical treatments include advance warning signs, stop or yield signs, oversized or highly visible signs, and reflective or enhanced retroreflective borders or sheeting that improve nighttime conspicuity. Improvements to sight distance at these intersections include clearing vegetation, eliminating or prohibiting parking near the intersection and removing other objects that can

obstruct the visibility of motorists entering the intersection.

A systemic approach means agencies do not wait for a crash history at a specific location before acting. Instead, they identify common risk factors across many intersections and apply low-cost improvements broadly. This is useful because many unsignalized intersections have similar problems: poor conspicuity at night, faded signs, confusing channelization, limited sight distance and drivers approaching too fast for the available stopping distance. By treating many sites at once, agencies can reduce crash risk on an entire network rather than only at isolated hotspots.

The systemic signage and improvements to unsignalized intersections have shown to produce safety benefits by decreasing crashes by about 10 percent. The unsignalized intersections considered for systemic improvements, based on the crash history and predictive methods, are at:

1. Avenida Amalia Paoli and Calle Gregorio Ledesma
2. Avenida Amalia Paoli and Avenida Olga Tañón (Los Dominicos)
3. Avenida Boulevard and Avenida del Lago
4. Avenida Olga Tañón (Los Dominicos) and Calle Rosa de Tejas
5. Calle Jaime Fonalleda and route PR-854 (Avenida Muñoz Rivera)
6. Calle Jaime Fonalleda and route PR-165
7. Carretera Candelaria and route PR-2
8. Exit 16 PR-22 off ramp with route PR-866
9. Route PR-165 and Calle Camino del Lago
10. Route PR-854 and Boulevard Bruno Cruz
11. Route PR-863 and route PR-819
12. Route PR-865 and Avenida Campanilla
13. Route PR-865 and route PR-865R (Calle Eucalipto)
14. Route PR-865 and Calle 6 Candelaria Arenas (Supermercado Econo)
15. Route PR-865 and route PR-866
16. Route PR-866 and Calle Vertedero
17. Route PR-866 and Avenida El Plantío
18. Route PR-867 and Avenida Campanilla
19. Route PR-867 and Avenida Galaxia
20. Route PR-867 and Avenida Universo
21. Route PR-872 and route PR-866
22. Route PR-8865 and Calle 7 (San José)
23. Route PR-8865 and Calle 6 (San José)
24. Route PR-8865 and Calle 1 (San José)

The improvements at these intersections are expected to decrease the collision rates by 7.4 percent, and severe collision rates by 5.9 percent.

### Countermeasure 17: Revising Yellow Clearance Intervals at Signalized Intersections

At signalized intersections, the yellow change interval is the time between green and red, and it is a critical safety parameter because it tells drivers when the green phase is ending. Revising yellow intervals is an important safety practice under the Safe System Approach because it helps make signalized intersections more forgiving of human error. The basic idea is to time the yellow phase so drivers have a realistic and consistent opportunity to perceive the signal change, decide whether to stop, and clear the intersection safely. When the yellow interval is too short, drivers may enter on red unintentionally or brake too hard, increasing the risk of severe right-angle and rear-end crashes. When it is too long, drivers may speed up to “beat the red,” which also creates dangerous conflicts.

Under the Safe System Approach, the goal is not to assume perfect behavior. Instead, the signal timing is designed to account for normal driver reaction time, approach speed, road grade, and intersection width. This makes the intersection more predictable and gives road users a better

chance to avoid a crash when conditions change suddenly. In that sense, a revised yellow interval is a low-cost operational treatment that reduces reliance on last-second judgment and helps absorb human error before it becomes a serious collision. FHWA notes that red-light running is a leading cause of severe crashes at signalized intersections, so the yellow interval must be timed correctly<sup>33</sup>.

*Figure 40 Yellow light clearance interval*



FHWA reports that updating signal timing policies and regularly reviewing yellow intervals can reduce red-light running and improve overall intersection safety, with documented reductions in crashes and injury crashes in some applications. The Institute of Transportation Engineers (ITE) recommends setting yellow clearance intervals based on the following formula:

<sup>33</sup> Yellow Change Intervals, FHWA: <https://highways.dot.gov/safety/proven-safety-countermeasures/yellow-change-intervals>

$$Y(v) = T_{pr} + \frac{V_a}{2d_r + 2gG_r}$$

where:

$Y(v)$ : yellow interval for speed  $V_a = v$

$d_r$ : deceleration rate

$g$ : gravity acceleration rate

$G_r$ : approach grade

$T_{pr}$ : driver perception-reaction time

$V_a$ : speed of vehicle approaching the intersection.

Despite the use of the yellow time formula being a common industry practice, the formula does not capture all behavioral aspects of motorists or variable conditions. Motorist behavior could be influenced by road conditions upstream of an intersection such as delays caused by heavy congestion, or by weather conditions. Therefore, despite the widespread use of the yellow interval formula, there are many signalized intersections where crashes caused by red-light running are common.

Depending on the circumstances, some intersections were analyzed for an increase in yellow interval that is greater than the ITE recommended practice, a change in the yellow interval that is lower than the ITE recommended practice, or a change in the signal phasing plan which increases the yellow interval and adds an all red interval. An all-red interval is a phase in the signal phasing plan where all movements have red light.

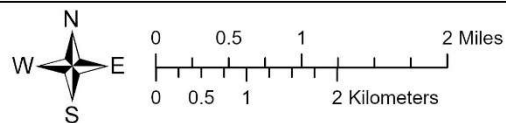
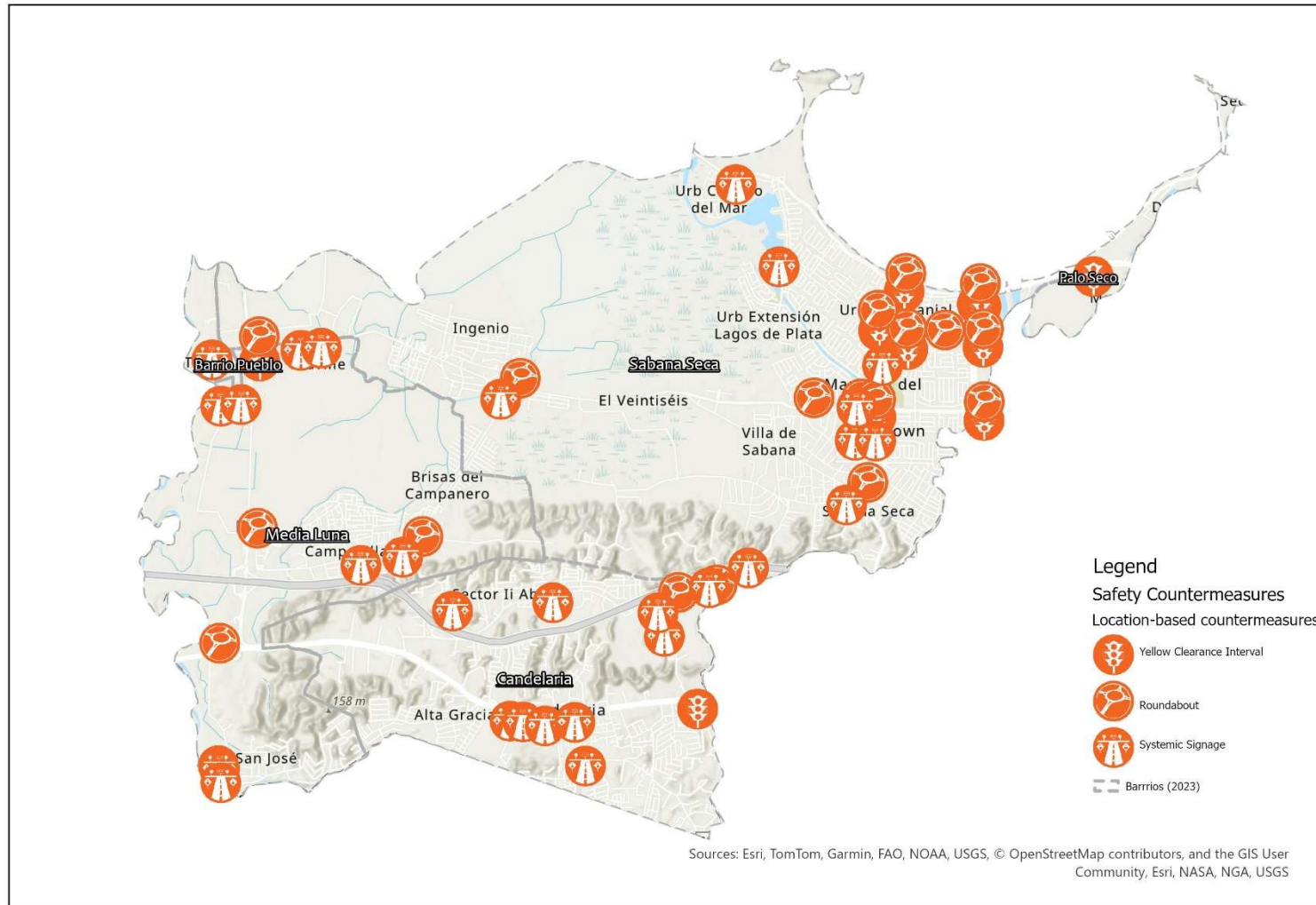
In Toa Baja, changes to yellow clearance intervals to reduce red-light running collisions were analyzed at 46 approaches for 20 intersections across Toa Baja. The intersection approaches with the most significant improvements in safety performance are:

1. Route PR-165 and PR-867
2. Route PR-2 and route PR-866
3. Route PR-167 and Avenida Juan "Picolino" Hernández Ferrer
4. Route PR-167 and Avenida Boulevard
5. Route PR-165 and route PR-167
6. Route PR-167 and route PR-165
7. Avenida Boulevard and Avenida Olga Tañón (Los Dominicos)
8. Avenida Boulevard and Avenida Dos Palmas
9. Avenida Olga Tañón (Los Dominicos) and Avenida Juan "Picolino" Hernández Ferrer
10. Avenida Dos Palmas and Avenida Boulevard
11. Route PR-165 and Avenida Dos Palmas

The collision rates were analyzed by intersection approach. This meant that not all yellow clearance intervals needed to be revised at an intersection. Overall, a revision of yellow clearance intervals at these intersections can decrease collisions by as much as 23 percent, and severe collisions by 26 percent.

Figure 41 shows a map with the intersection-related safety countermeasures.

Figure 41 Location of intersection-based safety countermeasures



## Crosscutting Measures

What makes any treatment “crosscutting” is that these work across many road contexts rather than solving only one specific crash type. Crosscutting measures add redundancy, which is a core Safe System idea; when one safeguard is not enough, another layer helps prevent severe harm. Two types of crosscutting measures are considered:

- Lighting
- High friction surface treatment

### Countermeasure 18: Lighting

From a Safe Systems Approach, providing lighting to dark roads creates an additional layer of safety where drivers can recognize threats and hazards sooner and react accordingly. It is a crosscutting measure because it helps in many contexts at once: intersections, crossings, curves, work zones, and corridors with heavy pedestrian activity. That broad usefulness fits the Safe System goal of reducing severe outcomes across the network instead of relying only on perfect behavior by drivers and pedestrians.

In Toa Baja, roadway lighting is a common concern among residents and one of the most mentioned road hazards during the community meetings. Crash data from the 2020 – 2024 period showed an increasing likelihood of severity; fatal collisions were 3.0 times more likely to occur in dark conditions without lighting, and 2.1 times more likely to result in serious injury under these circumstances.

Lighting as a countermeasure applies to intersections as well as roadway segments. At intersections, lighting helps improve the visibility at crossing points and crosswalks, thus helping motorists to detect and react appropriately to pedestrians and other road users.

For intersection lighting, a Virginia study found a 2.9 percent reduction in the night-to-day crash ratio for each 1-lux increase in minimum illuminance at intersection boxes. Intersection lighting on the roads of Toa Baja can reduce the collision rate by 5.9 percent, and severe collision by 2.8 percent.

At intersections in the highest quartile in terms of reduction in collision rates, there is an expected 7.3 percent reduction in the collision rates if lighting is used as a safety countermeasure. The intersections with the highest rates of severe collisions were:

1. Avenida Juan “Picolino” Hernández Ferrer and PR-167.
2. PR-2 and Calle Colina Real
3. PR-165 and PR-867
4. PR-165 and Avenida Dos Palmas
5. PR-165 and PR-870

On roadway segments, improving lighting conditions can result in greater safety benefits. In Toa Baja, 34 road segments were considered for improving lighting conditions. These segments are located on highways, primary arterials and minor arterials:

- Route PR-2

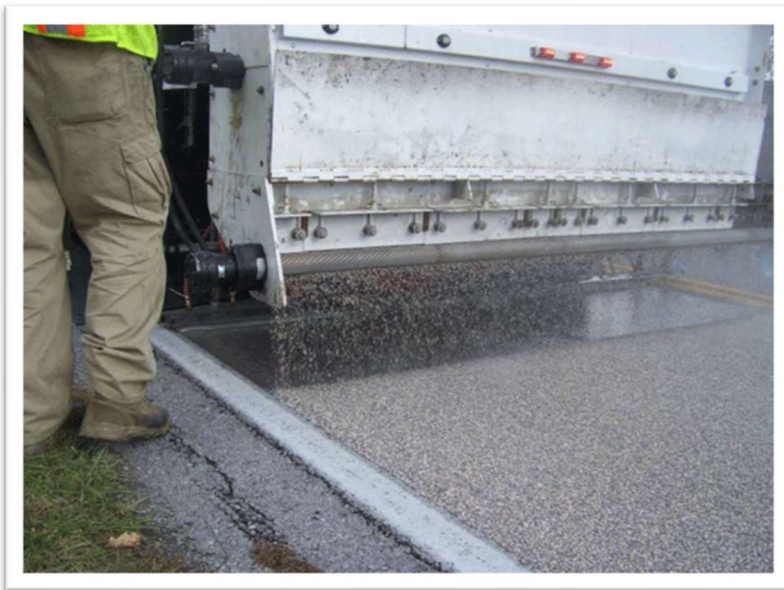
- Route PR-22
- Route PR-165

Overall, improving segment lighting conditions on these roads can reduce the collision rates by 29.3 percent, and the severe collision rate by 53.7 percent.

#### Countermeasure 19: High Friction Surface Treatment

High friction surface treatment (HFST) is a pavement safety measure that adds a very skid-resistant aggregate and binder to the roadway surface to restore or increase friction at locations where vehicles need extra grip. It is most often used on horizontal curves, ramps, intersections, and other sites with high friction demand, where loss-of-control and roadway-departure crashes are more likely.

*Figure 42 Application of High Friction Surface Treatment<sup>1</sup>*



HFST aligns strongly with the Safe System Approach because it assumes drivers will sometimes make errors and builds in a margin of safety to reduce the chance that an error becomes a severe crash. In Safe System terms, HFST helps create a more forgiving road environment by improving vehicle control in wet conditions, on sharp curves, and during braking or turning maneuvers. FHWA explicitly identifies HFST as a countermeasure that can “dramatically and immediately reduce crashes, injuries, and fatalities” where friction demand is high<sup>34</sup>. This makes it a classic crosscutting treatment: it does not eliminate human mistakes, but it reduces the consequences when those mistakes occur.

The safety benefit is greatest where the roadway geometry or weather makes skidding more likely. By increasing skid resistance, HFST shortens stopping distance, improves cornering traction, and reduces the likelihood of a vehicle leaving its lane or losing control. FHWA states that the treatment is estimated to reduce wet crashes by 83 percent and total crashes by 57 percent in the contexts studied. The treatment is particularly effective at curves and ramps, where the combined forces of speed, turning,

<sup>34</sup> High Friction Surface Treatment Site Selection and Installation Guide. FHWA (2021). FHWA Office of Safety.

and wet pavement create a high-risk environment for severe crashes.

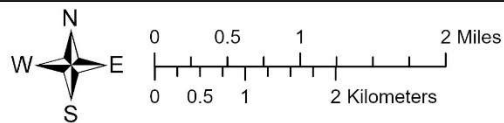
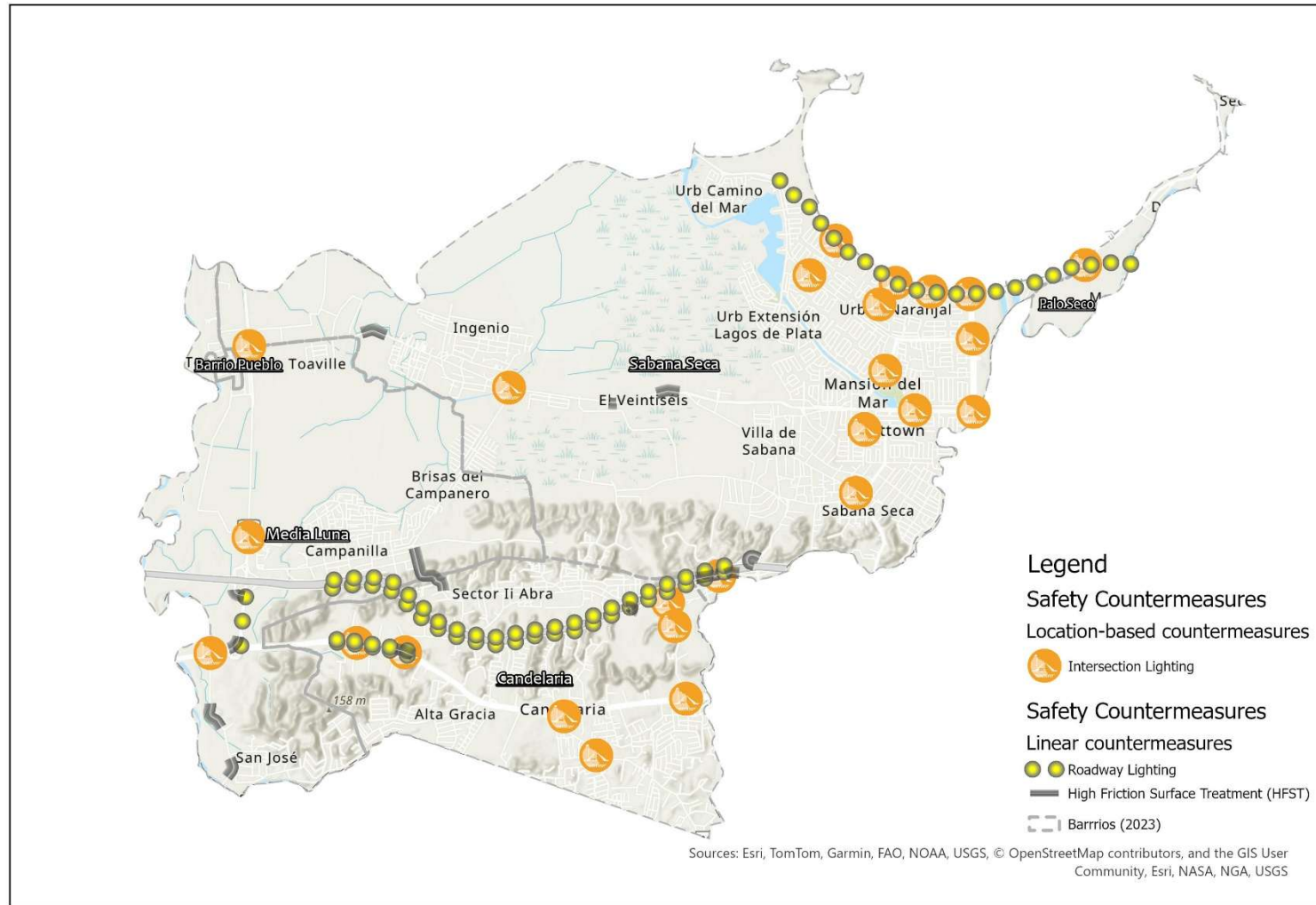
The applicability of HFSTs on Toa Baja's roads is recommended for the following road segments:

- Route PR-2
  - Km 20.4 to 20.5
- Route PR-22
  - WB Exit 16 Off Ramp to intersection with route PR-866 (NB)
  - EB Exit 16 Off Ramp to intersection with Calle Vertedero
  - EB Exit 17 Off Ramp to intersection with route PR-865
  - EB Exit 22 Off Ramp to intersection with route PR-165
- Route PR-165
  - SB Exit 14 Off Ramp to intersection with route PR-2
- Route PR-865
  - Km 2.5 to 3.1
  - Km 6.0
- Route PR-866:
  - Km 2.0 to 2.3
- Route PR-867:
  - Km 2.3 to 2.4
  - Km 3.0 to 3.1
  - Km 6.2 to 6.4
- Route PR-8865:
  - km 1.0 to 1.4
  - km 0.4 to 0.5

The predicted reductions amount to a 61.3 percent reduction in collision rates, and a 48.5 percent reduction in severe collisions.

Figure 43 shows the recommended locations for roadway lighting and high friction surface treatments countermeasures.

Figure 43 Location of crosscutting safety countermeasures



## Summary

The Second Phase of the Comprehensive Safety Action Plan for the Municipality of Toa Baja is a technical assessment of roadway safety focused on identifying where crashes are happening, why they are happening, who is most affected, and what treatments could reduce severe outcomes. The report is organized around four major tasks: network screening, safety investigations, equity analysis, and safety evaluations. Its overall goal is to support a safer transportation system for motorists, pedestrians, bicyclists, motorcyclists, and other road users by reducing the frequency and severity of collisions rather than assuming crashes can be eliminated entirely.

A central finding of the report is that Toa Baja has a serious and growing roadway safety problem. Between 2020 and 2024, the municipality experienced 17,869 traffic-related collisions, including 31 fatal crashes and 117 severe injury crashes.

The report notes that collisions increased steadily after 2020, rising by 41.3 percent over the five-year period. Toa Baja's severe injury crash rate is also about twice as high as Puerto Rico overall, while its fatal crash rate is slightly higher than the islandwide rate. This confirms that the municipality faces a disproportionately high burden of serious roadway harm. The network screening section identifies the highest-risk roads and segments.

Severe collisions were found on 32 roads, but the greatest concentrations occurred on PR-2, PR-867, PR-165, PR-865, and PR-866. Together, PR-2, PR-867, and PR-165 accounted for almost half of all severe collisions in the municipality. When crash counts are adjusted for traffic volume, PR-854 emerges as the most dangerous segment by rate, while the PR-867 segment between PR-165 and Avenida Campanilla recorded the highest number of severe collisions. The report also shows that minor arterials and principal arterials carry the greatest burden of severe crashes, suggesting that everyday circulation corridors are a major source of risk.

The safety investigations section shows that crash risk varies by time of day, day of week, roadway geometry, behavior, and user type. December had the highest number of crashes and severe crashes, while the highest-risk time period was between 12 PM and 8 PM. The deadliest hours were 7 PM to 8 PM and 2 PM to 3 PM, the latter of which aligns with school dismissal traffic. Severe crashes were most common on Wednesdays and Sundays, while fatalities were most frequent on weekends, especially Saturdays and Sundays. These patterns suggest that both commute-related travel and weekend nighttime behavior contribute to the municipality's severe crash profile.

Crash type analysis reveals that rear-end collisions are the most common overall,

while some collision types are much more likely to produce severe injuries or deaths. Rear-end crashes accounted for 26.7 percent of all collisions, followed by same-direction lateral crashes and collisions involving parked vehicles. Among severe collisions, the most common types were rear-end crashes, opposite-direction frontal crashes, same-direction lateral crashes, collisions with fixed objects, and angle collisions at intersections. The report emphasizes that front-end collisions, same-direction turning crashes, and fixed-object crashes are especially likely to be severe.

Behavioral factors such as following too closely, aggressive driving, improper lane changes, improper turning, and failure to yield were also responsible for a large share of severe crashes.

Several focused analyses deepen the understanding of the municipality's risk profile. Run-off-the-road crashes accounted for 26 severe collisions and were concentrated on 13 roads, especially PR-165, PR-866, and PR-867. Nighttime visibility was a major issue: 53 severe crashes occurred in dark conditions, making nighttime crashes about twice as likely to be severe as daytime crashes.

Weather and pavement conditions were less influential overall, but cloudy conditions, wet pavement, and dark environments still raised risk in some corridors. The report also notes that many severe crashes occur on straight flat

segments, but downhill stretches and flat curves are more likely to produce severe outcomes when crashes do happen.

The modal analysis highlights the vulnerability of pedestrians, bicyclists, and motorcyclists. Pedestrian crashes were rare in overall terms but highly severe: 117 pedestrian-involved crashes produced 14 severe outcomes, making pedestrian collisions 19.7 times more likely to be severe than other crashes. Bicycle crashes were also strongly overrepresented in severe outcomes, with bicyclists 6.0 times more likely to be involved in a severe crash. Motorcyclists faced the highest relative danger among the non-occupant groups analyzed, with crashes involving motorcycles 12.5 times more likely to be severe. The report identifies PR-2, PR-165, PR-867, PR-865, and Avenida Boulevard as recurring locations for vulnerable road user crashes.

The equity analysis connects roadway danger with social vulnerability. Using census-tract level indicators, the report evaluates poverty, caregiving burden, overcrowding, educational attainment, employment, disability, health insurance coverage, age, vehicle access, and broadband access. The most vulnerable tracts include 1221, 1217.02, 1222.01, and 1226, with communities such as Parcelas Viejas San José, Parcelas Nuevas San José, Campanilla, Villa Hostos, Villa Calma, Ingenio, Monserrate, Pabellones, and Sabana Seca appearing repeatedly in the highest-need categories.

These areas are significant because many lie near or along the high injury network, meaning residents in socially disadvantaged communities are more likely to face the highest transportation safety burdens.

The final section evaluates countermeasures using Safe Systems principles and FHWA's proven safety countermeasures framework. The recommended actions are layered and target different crash mechanisms. For speed management, the report recommends lower and more contextappropriate speed limits, speed safety cameras, variable speed limit signs, and traffic calming measures such as speed bumps, humps, tables, chicanes, and traffic circles. It also recommends guardrails in limited locations where roadway departure risk is high. For intersections, the report supports roundabouts, improved yellow clearance intervals, and systemic signage improvements at unsignalized intersections.

For pedestrians and bicyclists, the report recommends bicycle lanes, crosswalk visibility enhancements, leading pedestrian intervals, rectangular rapid flashing beacons, pedestrian hybrid beacons, and roadway reconfiguration in selected corridors. These treatments are aimed at reducing conflicts, shortening crossing distances, and improving motorist awareness. For crosscutting improvements, the report emphasizes

roadway lighting and high-friction surface treatment, both of which can reduce severe crashes across multiple settings.

Lighting is especially important because nighttime crashes are far more severe, while high friction surface treatment is especially valuable on curves, ramps, and wet or high-friction-demand locations.