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Development of Crash Modification Factors for Rumble Strips Treatment for Freeway Applications: Phase I Development of Safety Performance Functions

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GOOD DAY!

LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
CMF	Crash Modification Factor
CRF	Crash Reduction Factor
EB	Empirical Bayes
FHWA	Federal Highway Administration
HSM	Highway Safety Manual
NBD	Negative Binomial Distribution
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
PRHTA	Puerto Rico Highway and Transportation Authority
PRTSC	Puerto Rico Traffic Safety Commission
ROR	Run –off- the Road
SPF	Safety Performance Function
TA	Technical Advisory
WHO	World Health Organization

AGENDA

- Introduction
- Objectives
- Literature Review
- Methodology
- Study Location and Characteristics of the Region
- Data Analysis
- Conclusions and Recommendations
- References

INTRODUCTION: *Crash Trends*

WORLDWIDE TRENDS (WHO, 2013)

- WHO estimates that 1.24 million persons were killed on traffic crashes during the year 2010.
- Crashes are the 8th leading cause of death.
- In the future, road traffic injuries will become the 5th leading cause of death.

LOCAL TRENDS (PRTSC, 2014)

- 200,000 crashes occur yearly
- With approximately 35,000 injured and 366 fatalities.
- PR trends suggest that traffic fatalities had been decreasing over the years.
- Average of the last 5 years is 355 traffic fatalities.

INTRODUCTION (cont.)

- In the Commonwealth of Puerto Rico, the Road Safety Projects Division of the PRHTA is in charge of implementing safety countermeasures to existing roads on the island road network.

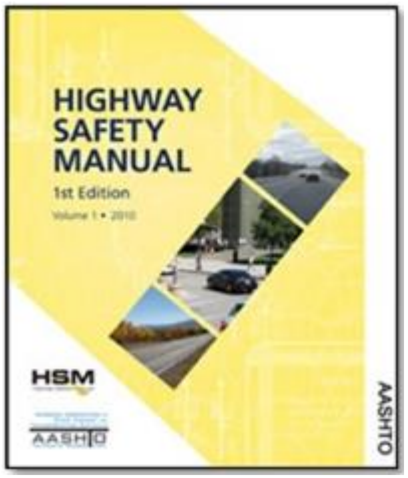
- Examples of such are:
  - Shoulder rumble strips
  - Centerline rumble strips
  - Crash attenuators
  - Pavement marking
  - Installation of safety barriers
  - Installation of signs
  - Pavement rehabilitation and safety improvements

Pavement Rehabilitation and Safety Improvements
(AC-200247, Sabana Grande)

INTRODUCTION (cont.)

- **Rumble Strips:**
  - Road safety treatment that produce a vibration or sound that alert drivers if they are leaving the travel way.
  - 250 kilometers of longitudinal rumble strips have been implemented with an estimate investment of 1.8 million dollars in the island road network. (Rivera, 2014)
  - PRHTA finished the first pilot project regarding longitudinal intermittent rumble strips along the NHS PR-52 on 2009.

INTRODUCTION (cont.)



- Crash Modification Factors (CMF):
  - Index that quantifies the expected change in crash frequency if a specific treatment is implemented.
    - CMF<1; Expected Reduction in Crashes
    - CMF>1; Expected Increase in Crashes
- CMF Applications (FHWA, 2010):
  - Estimate the safety effects of various countermeasures
  - Compare safety benefits among various alternatives and locations
  - Test alternative design options

Source:
http://www.highwaysafetymanual.org/
http://www.cmfclearinghouse.org/

OBJECTIVES

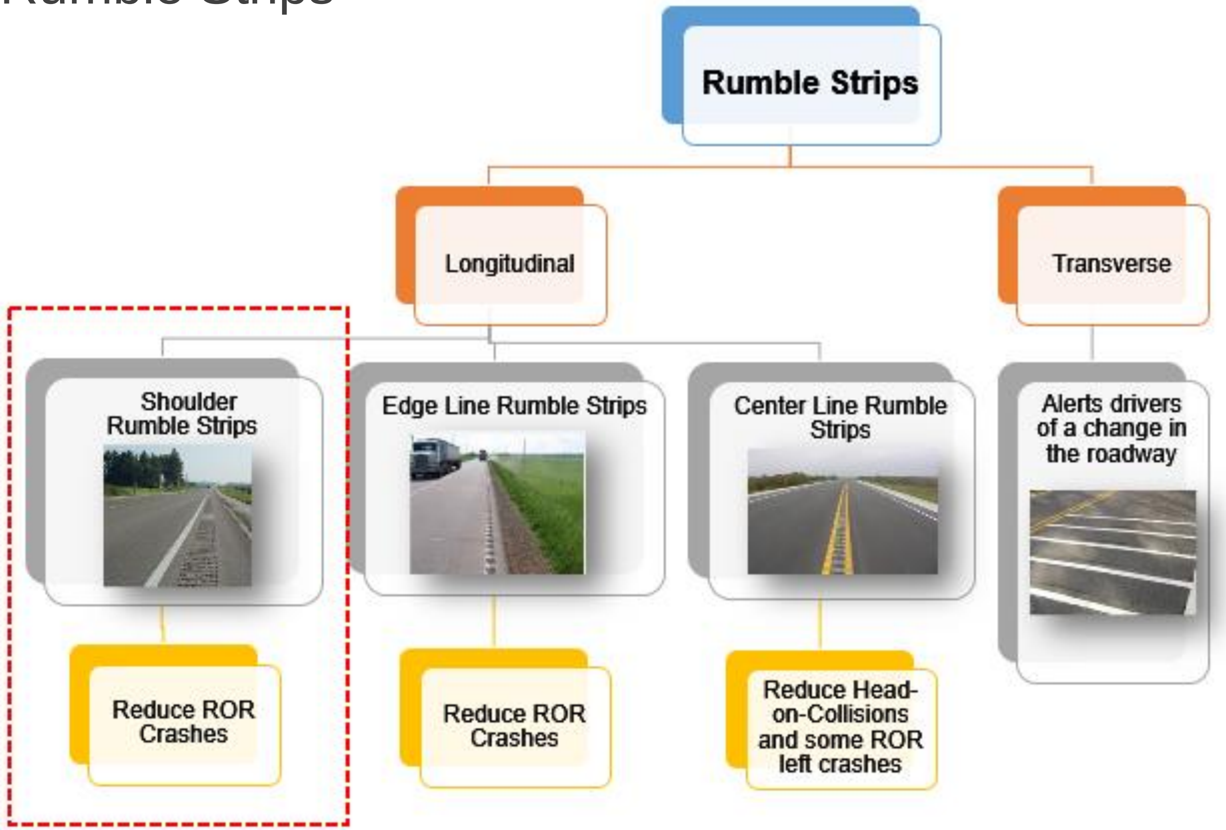
- Evaluate the pilot project associated with the installation of intermittent longitudinal shoulder rumble strips in the NHS PR-52 toll freeway.
- Perform the Empirical Bayes Method to evaluate the effectiveness of the intermittent longitudinal shoulder rumble strips along the NHS PR-52.
- Development of SPF’s associated to freeway segments for total crashes and ROR crashes.
- Generate CMF’s and CRF’s for intermittent longitudinal shoulder rumble strips.

Note: This paper is associated with the development of simple preliminary Safety Performance Functions associated to freeway segments.

Literature Review

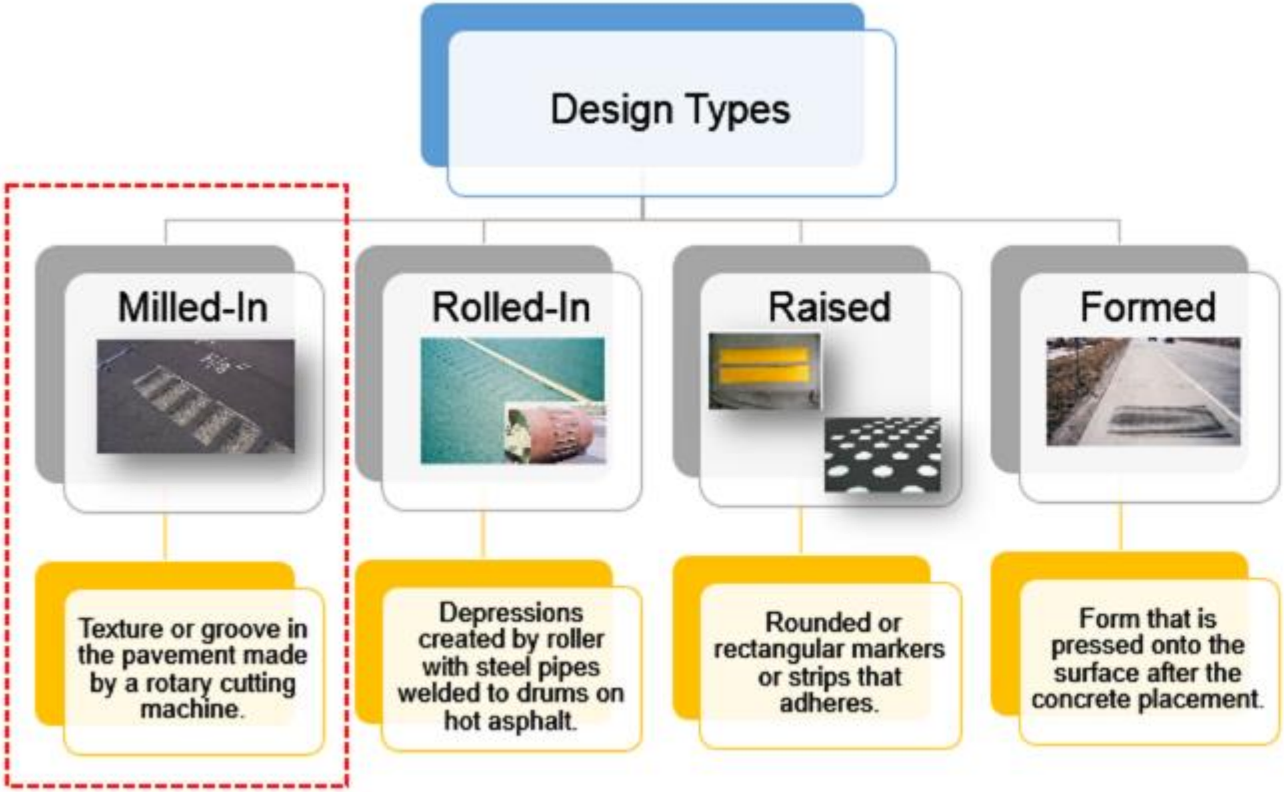
LITERATURE REVIEW

- Types of Rumble Strips



LITERATURE REVIEW (cont.)

- Types of Designs of Rumble Strips

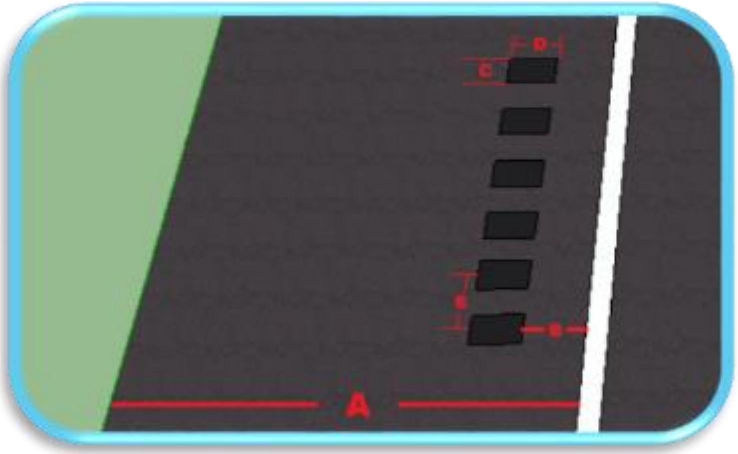


LITERATURE REVIEW (cont.)

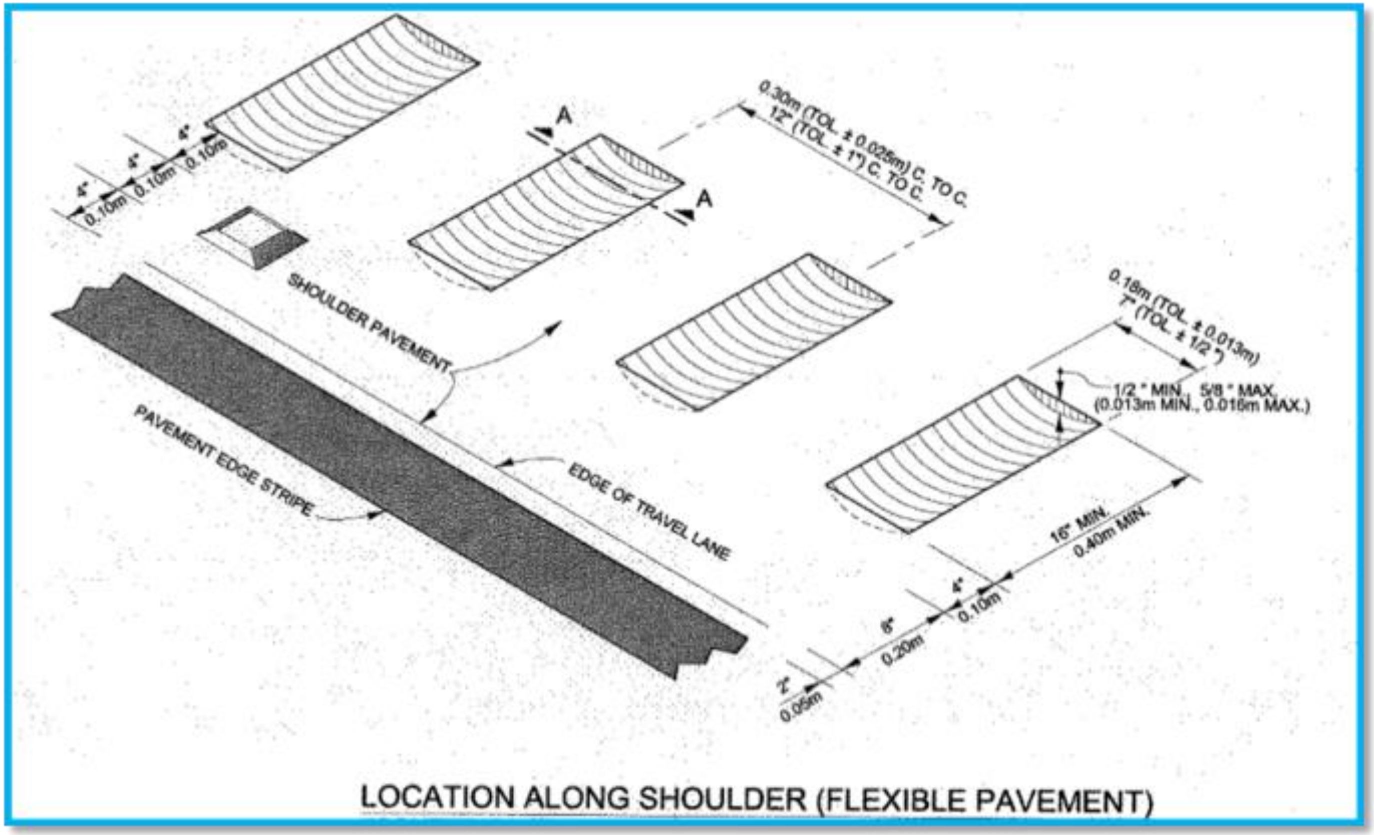
- Local and National Design Guidelines for Rumble Strips

REQUIREMENTS	FHWA (TA 5040.39)	PRHTA (DD#409)
A-Minimum Shoulder Width (feet)	4	4
B-Lateral Clearance (inches)	9	12
C-Rumble Strips Width (inches)	7	7
D-Rumble Strips Length (inches)	16	16 to 18
E-Center to Center Spacing (inches)	Not specified	12
Rumble Strips Depth (inches)	1/2	1/2 to 5/8
Bicycle Gap (feet)	10 to 12	6 to 12
Minimum Posted Speed (mph)	50	Not specified

- FHWA Technical Advisory for Shoulder and Edge Line Rumble Strips (TA 5040.39)
- PRHTA Design Directive for Rumble Strips (DD #409)



MILLED-IN SHOULDER RUMBLE STRIPS: INSTALLATION PLAN FOR PUERTO RICO



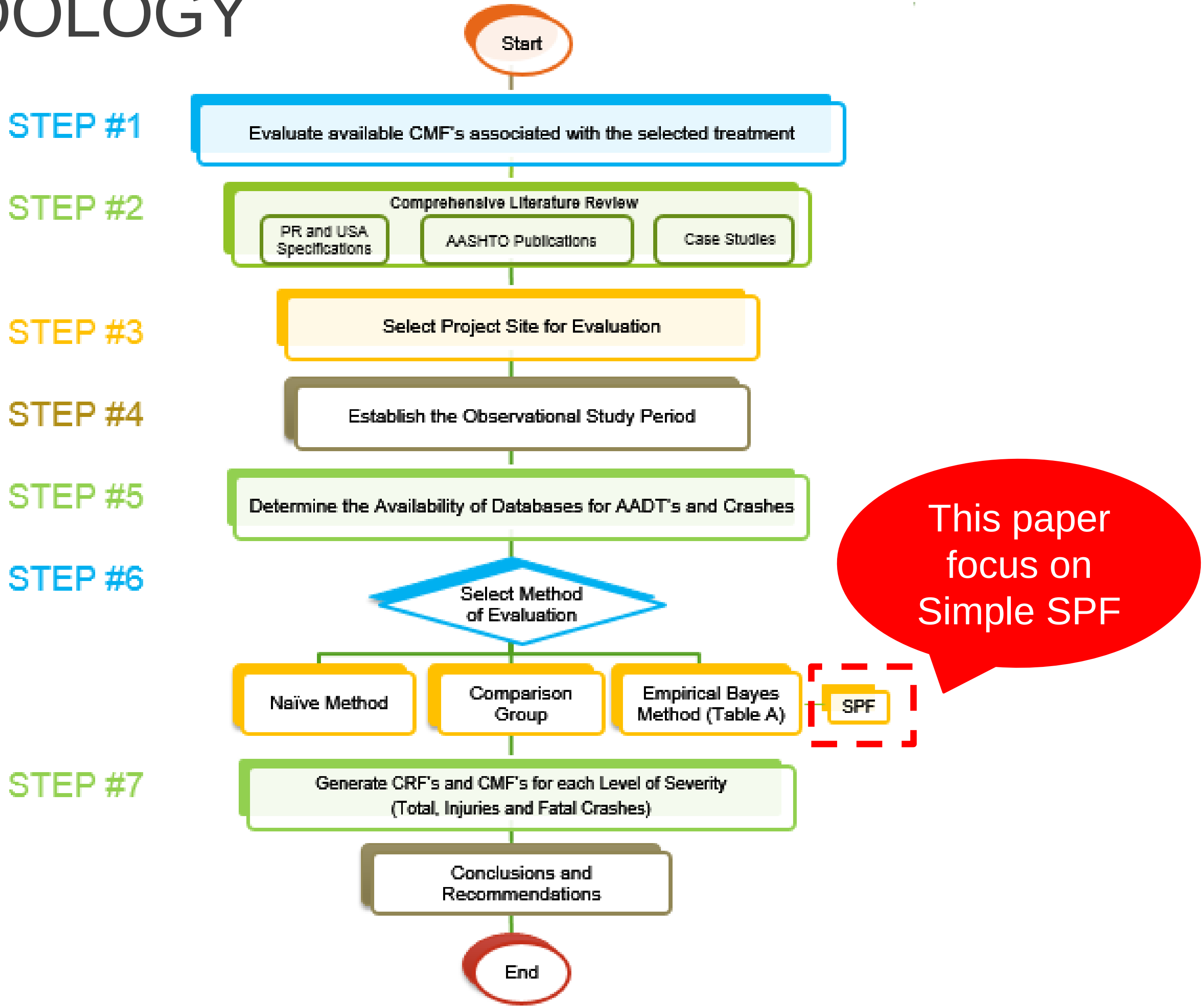
LITERATURE REVIEW (cont.)

RECENT RESEARCH STUDIES OF THE EFFECTIVENESS OF RUMBLE STRIPS

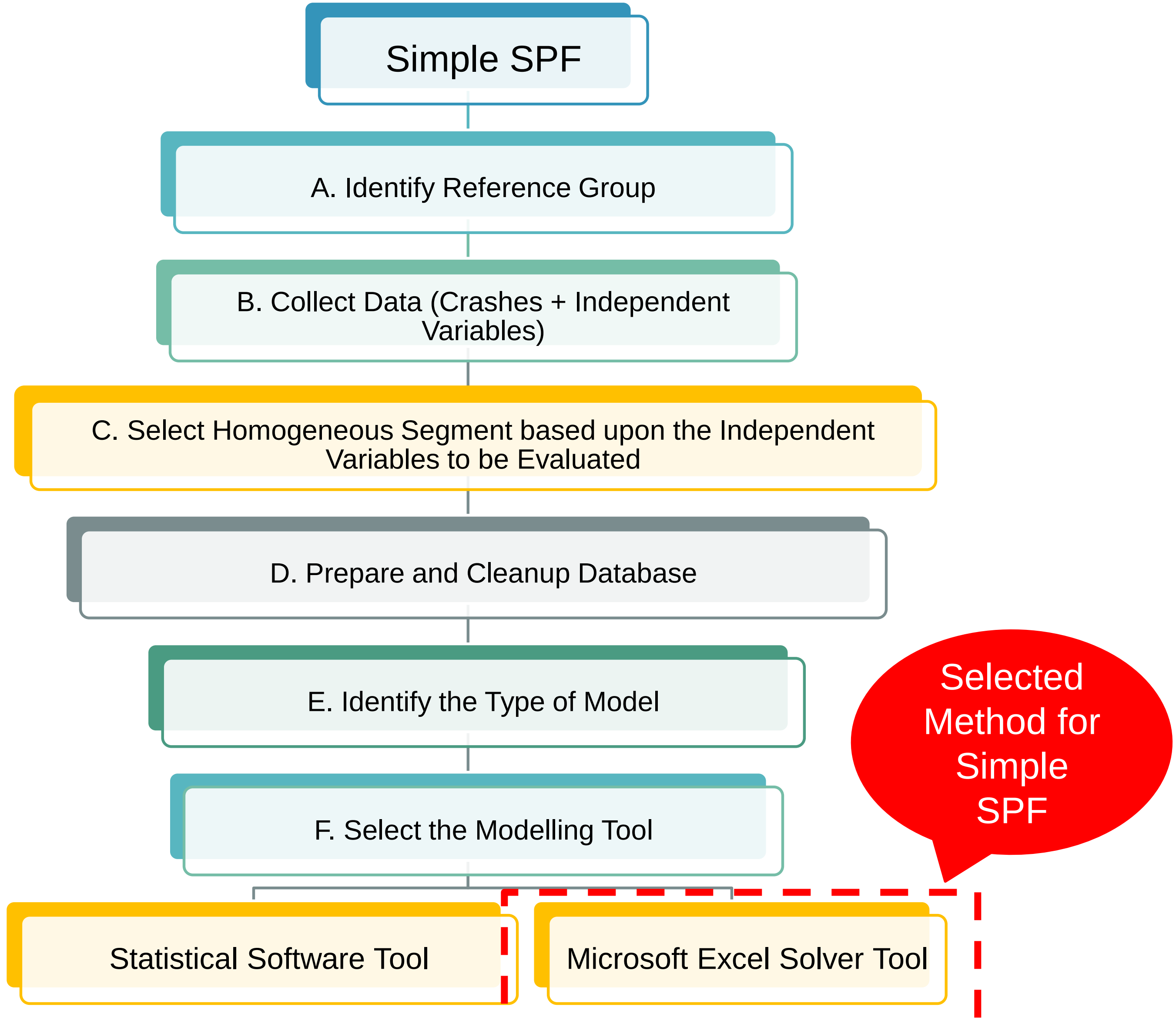
TREATMENT	AUTHOR	YEAR	LOCATION	TITLE OF INVESTIGATION	METHOD FOR EVALUATION	GENERAL FINDINGS
Install of shoulder and centerline rumble strips	Torbic et al.	2009	Minnesota, Missouri and Pennsylvania	NCHRP Report 641: Guidance for the Design and Application of Shoulder and Centerline Rumble Strips	Before and After Study – Empirical Bayes Method and Cross-Sectional Generalized Linear Model Analysis	-Reduction of 18% of ROR crashes on Urban/Rural freeways -Reduction of 11% of ROR crashes on rural freeways -Reduction of 15% of ROR crashes on rural two lane roads -Reduction of 22% of ROR crashes on rural multilane divided highways
Install shoulder rumble strips	Sayed, de Leur and Pump	2010	British Columbia, Canada	Impact of Rumble Strips on Collision Reduction on BC Highways	Before and After Study - Empirical Bayes Method	-Reduction of 18% of severe collisions -Reduction of 22.5% of ROR collisions
Install shoulder rumble strips	Olson, Sujka and Manchas	2013	Washington State	Performance Analysis of Centerline and Shoulder Rumble Strips Installed in Combination in Washington State	- % of Change in Crash Rates	- Reduction of 61.6% of all run off the road collisions - Reduction of 53.7% ROR collision involving fatal-serious injuries

Methodology

METHODOLOGY



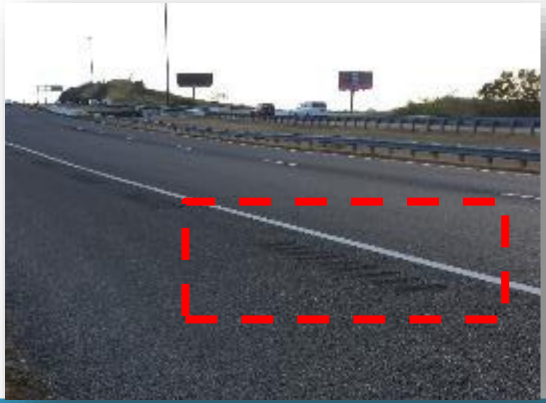
METHODOLOGY: PHASE I



Analysis

STUDY LOCATION

- TREATMENT NAME:
  - Milled-in Intermittent Longitudinal Shoulder Rumble Strip
- PROJECT LOCATION:
  - PR-52 Freeway
  - Begins: South Caguas Toll Plaza
  - Ends: Exit to the town of Salinas
  - Project Length: 43.2 kilometers



A. IDENTIFICATION OF REFERENCE GROUP

- Segment selection for the reference group were a combination of untreated segments in the NHS PR-52 and untreated segments of the NHS PR-22 with similar characteristics.

Characteristics of the Segments of the Reference Group	NHS PR-52	NHS PR-22
Functional Classification	Toll Freeway	Toll Freeway
Number of Lanes	4 to 6 lanes	4 to 6 lanes
Lane Width	12 feet	12 feet
Posted Speed Limit	55 to 65 mph	55 to 65 mph
Average Segments AADT’s (vehicles/day)	70,677	77,438
Average Crashes for Segments (per year)	30	23

B. DATA COLLECTION

CRASH DATA

- The Crash Analysis Office of the PR Transportation and Highway Authority:
  - Digitalize and create a database of all the crashes (including fatal, injuries and property damage).
- This database provides information of:
  - Case ID
  - Municipality
  - Road number
  - kilometer
  - type of severity

TRAFFIC VOLUME DATA

- The Office of Highway System of the PR Transportation and Highway Authority:
  - Creates and maintains the Highway Performance Monitoring System Database.
- This database provides information of:
  - Route Number
  - Municipality
  - Segment length
  - AADT
  - Functional classification

C. SELECT HOMOGENEOUS SEGMENTS

- The segmentation is based upon the Highway Performance Monitoring System Database:
  - Defines segment based upon the change of the Annual Average Daily Traffic.

Assuming a Reference Group with segments up to 6 lanes, segments starts in the intersection with PR-177.

D. PREPARE AND CLEANUP DATABASE

- Inaccurate or incomplete records were eliminated from the database.
- The data cleaning process was performed for the total segments for both freeways, including the reference group.
- A total of 491 crash records were eliminated because they lack the exact location of the crash or had errors related to the exact kilometer location.

E. IDENTIFY THE TYPE OF MODEL

- SPF's were developed assuming a Negative Binomial Distribution.
- An important parameter for the development of the Empirical Bayes method is the negative binomial dispersion parameter (Φ) obtained from this regression.
- The first preliminary models were performed by fitting a power function.

SPF #1: Segment Length

$$E(\mu) = \beta_0 * X_1^{\beta 1}$$

Where,
X_1 is the Segment Length (kms) and β's are the parameters

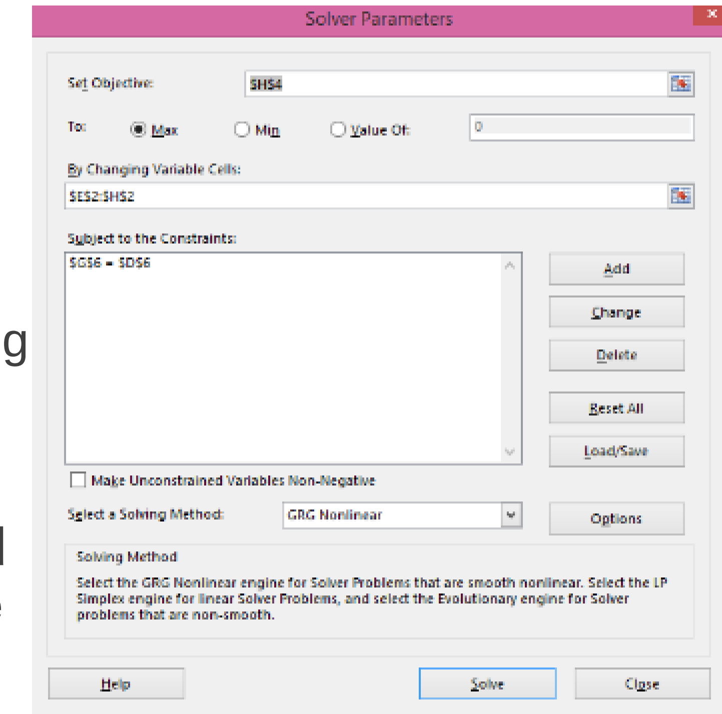
SPF #2: Segment Length + AADT

$$E(\mu) = \beta_0 * X_1^{\beta 1} * X_2^{\beta 2}$$

Where,
X_1 is the Segment Length (kms),
X_2 is the Average AADT's (veh/day) and β's are the parameters

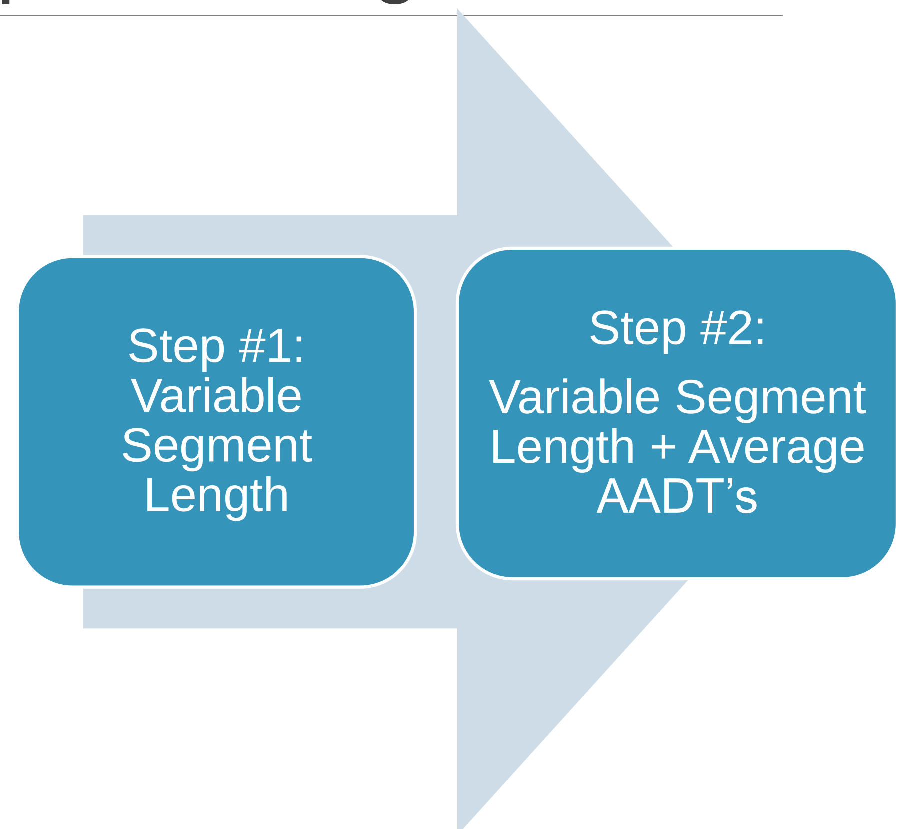
F. SELECT MODELLING TOOL

- The development of the preliminary SPF's for this investigation were obtained by using a curve fitting spreadsheet using Microsoft Excel.
  - On a publication from a seminar called "The Art of Regression Modeling in Road Safety" Ezra Hauer suggest this modelling tool for simple SPF.
- The curve – fitting spreadsheet was used in combination of a function called the "Solver Parameter" which can solve the parameters of practically any function that better fit the model.



Analysis: Step by Step Modelling Process

- Hauer suggest that SPF can be built by adding the variables on the model equation one at a time.
- If the modeler reports every SPF gradually obtained, practitioners than can use the model for which they have data available (Hauer, 2014).
- He suggest to start the modeling process with segment length as a simple model equation and then add the rest of the variables.



SPF #1: Segment Length

Model for Each Severity Type	Model for a 2 Year Period				Model for a 3 Year Period			
	β_0	β_1	Φ	Pearson Function Index	β_0	β_1	Φ	Pearson Function Index
Total Crashes	22.245	0.737	1.155	0.57	34.279	0.719	1.129	0.56
Crashes with Injuries	21.899	0.737	1.144	0.57	21.899	0.737	1.144	0.57
Fatal Crashes	0.338	0.744	5.95	0.36	0.483	0.760	1.813	0.39

- The model based upon segment length have a low Pearson Function Index and high overdispersion parameters.
- To better improve the model an additional variable will be add.
- Model Form: $E(\mu) = \beta_0 * X_1^{\beta 1}$, where X_1 is segment length (kms)

SPF #2: Segment Length + AADT Models

Model for Each Severity Type	Model for a 2 Year Period					Model for a 3 Year Period				
	β_0	β_1	β_2	Φ	Pearson Function Index	β_0	β_1	β_2	Φ	Pearson Function Index
Total Crashes	0.00042	0.847	0.963	2.576	0.85	0.00160	0.781	0.889	2.254	0.85
Crashes with Injuries	0.00037	0.855	0.974	2.554	0.85	0.00169	0.780	0.883	2.185	0.85
Fatal Crashes	0.0000034	0.928	1.012	2.666	0.61	0.000005	0.928	1.012	2.666	0.66

- ❑ The Pearson Function Index gets closer to 1 and reflects that there is a better relationship between two data sets (observed vs. fitted values).
- ❑ The overdispersion parameter is high which reflects there is greater variability between the two data sets.
- ❑ Model Form: $E(\mu) = \beta 0 * X_1^{\beta 1} * X_2^{\beta 2}$, where X_1 is segment length (kms) and X_2 is Average AADT's (veh/day).

CONCLUSIONS AND RECOMMENDATIONS

- This is the first attempts to develop simple SPF for the reference group of freeway segments using Microsoft Excel in order to achieve the objective of creating CMF's for intermittent shoulder rumble strips on freeways.
- The model that included the variables segment length and AADT's showed a better relationship between the data sets than the model that only included the variable segment length.
- Due to the lack of fatal crashes per segment, the SPF's regarding fatal crashes are not well adjusted.
- This is an ongoing investigation and further models will be develop by using a statistical software package.
- Future work will include the inclusion of a model to predict run-off the road crashes for a 2 and a 3 year period. Other variables such as speed limit, terrain and other geometrical characteristics of the reference group will be added to the models.

References

- American Association of State Highway and Transportation Officials (2010). “Highway Safety Manual”. Volume 1, pp. 4-84
- Federal Highway Administration (FHWA). (2010). A Guide to Developing Quality Crash Modification Factors. US Department of Transportation (USDOT). Washington, DC. pp. 1-62
- Federal Highway Administration (FHWA). (2013). Rumble Strips info. Retrieved from:
  - http://safety.fhwa.dot.gov/provencountermeasures/ - Accessed 25/Nov/2013
  - http://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/-Accessed 25/Nov/2013
- Hauer, E. (2014). The Art of Regression Modeling in Road Safety. University of Toronto. Canada. pp. 1-199
- National Cooperative Highway Research Program (NCHRP). (2009). Guidance for the Design and Application of Shoulder and Centerline Rumble Strips. Washington, DC, pp. 1-135

References

- National Highway Traffic Safety Administration (NHTSA). (2013). Traffic Safety Facts – 2011. United States, pp. 1-12
- Olson, D., Sujka, M. and Manchas, B. (2013). Performance Analysis of Centerline and Shoulder Rumble Strips Installed in Combination in Washington State. Washington State Department of Transportation, Washington
- Puerto Rico Highway and Transportation Authority (PRHTA). (2012). Design Directive for Shoulder Rumble Strips #409. San Juan, pp.1-2
- Sayed, T., deLeur, P. and Pump, J. (2010). Impact of Rumble Strips on Collision Reduction on Highways in British Columbia, Canada. Transportation Research Record: Journal of the Transportation Research Board. Washington, DC. Volume 2148. pp. 9-15
- Traffic Safety Commission of PR. (2013). Retrieved from: http://www.comisionparalaseguridadeneltransito.com/ - Accessed 18/Nov/2013
- World Health Organization. (2013). Global Status Report on Road Safety. Switzerland, pp.1-5