EVALUATION OF SAFETY PERFORMANCES ON FREEWAY DIVERGE AREA AND FREEWAY EXIT RAMPS

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By:

Hongyun Chen
Graduate Research Assistant
Outline

- Introduction
- Problem Statement
- Research Objective
- Research Subject
- Literature Review
- Methodology
- Data Collection
- Estimated Result
Introduction

Freeway  Diverge Area  Exit Ramp

Safety Performance
Problem Statement

Diverge Area

How many situation exist?
• Widely-spaced diverge area;
• Closed-spaced diverge area;
• Left-side off-ramp diverge area;

What are current design applications for these situations?
• Basic Number of Lane;
• Lane Balance Theory;

What are the safety performances for these designs?
• Not been well studied or documented until recently;
• No conclusions on the safety evaluation;
Exit Ramp Section

How many different considerations?
- Ramp Configuration;
- Terminal Control;

What are the safety performances?
- Little focuses on the safety issues;
- Need re-conclude the results;
Research Objective

- Evaluate impacts of different designs on the widely-spaced diverge areas and identify the factors that contribute to crashes for this situation;

- Define the current practical engineering design types at closed-spaced freeway sections and compare the safety performance among the defined types;

- Compare the crash records of those left-side and right-side off-ramps to see whether there is any significant difference between the widely-used design types;

- On the freeway exit ramp sections, safety impacts of different exit ramp configurations will be evaluated and the contributing factors will be identified;
Research Subject

- Diverge Area
  - Right-side off-ramp
    - Left-side off-ramp
    - Closed-Spaced Diverge Area
    - Widely-Spaced Diverge Area
  - Exit Ramp Section
**Widely-Spaced Situation**

- **Type 1**
  - Parallel from a tangent single-lane exit ramp design;
  - Lane balanced

- **Type 2**
  - Single-lane exit ramp without an taper design;
  - Lane not balanced

- **Type 3**
  - Two-lane exit ramp with an optional lane design;
  - Lane balanced;

- **Type 4**
  - Two-lane exit ramp without an optional lane design;
  - Lane not balanced;
• **Closed-Spaced Diverge Area**
  
  • **Type A**
    - A one-lane entrance ramp is closely followed by a one-lane exit;
  
  • **Type B**
    - A continuous auxiliary lane connects the entrance and exit with two-lane exit;
  
  • **Type C**
    - A continuous auxiliary lane connects the entrance and exit with one-lane exit;
  
  • **Type D**
    - A one-lane entrance ramp is closely followed by a two-lane exit;
  
  • **Type E**
    - A continuous auxiliary lane connects one-lane entrance and two-lane exit;
  
  • **Type F**
    - A two-lane entrance ramp connects a two-lane exit ramp with consistent basic lanes;
  
  • **Type G**
    - A two-lane entrance ramp connects a two-lane exit ramp without consistent basic lanes;
Type A (21 Sites)
Lane Balance: Yes
Basic Number of Lanes: Consistent

Type B (15 Sites)
Lane Balance: Depends
Basic Number of Lanes: Consistent

Type C (20 Sites)
Lane Balance: Depends
Basic Number of Lanes: Consistent

Type D (1 Site)
Lane Balance: Yes
Basic Number of Lanes: Not Consistent

Type E (3 Site)
Lane Balance: No
Basic Number of Lanes: Not Consistent

Type F (3 Site)
Lane Balance: No
Basic Number of Lanes: Consistent

Type G (2 Site)
Lane Balance: Yes
Basic Number of Lanes: Not Consistent
• **Left-Side Off-ramp**
  
  • **Un-assemble to drivers’ expectation;**
  
  • **Changing maneuvers;**
Type I: Two Left-Side Exit-Lanes with an Optional Lane

Type II: Two Exclusive Left-Side Exit-Lanes

Type 3

Type 4
• Entire Exit Ramp

  • Type 1
    • Diamond exit ramps;

  • Type 2
    • Outer connection exit ramps;

  • Type 3
    • Free-flow loop exit ramps;

  • Type 4
    • Parclo loop exit ramps;
Diamond Exit Ramps  

Out Connection Exit Ramps
Free-flow Loop Exit Ramps

Parcło Loop Exit Ramps
Previous Study

- Ramp definition: more on configurations;
- More crashes on off-ramps than on-ramps;
- A 100ft increasing the deceleration length with a 4.8% reduction in crash frequency;
- Poisson and Negative Binominal Models;
- Freeway AADT and ramp configuration appear to be significant in crash frequency;
- No focused on the impacts of the number of lanes used by traffic to exit freeways;
- Most believing: Lane balance exit much safer;
Methodology

Cross-sectional Comparison
- Crash Frequency
- Crash Rate
- Crash Type
- Crash Severity

Hypotheses Test
- Equality of two means
- Proportionality Analysis

Generalized Regression Model
- Poisson Regression Model
- Negative Binomial Model
• **Cross-sectional Comparison**

• **Crash Frequency**

  • Total number of crashes at certain segment in a particular time interval;

  • Average number of crashes - Mathematical Mean:

\[
C = \frac{\sum_{i=1}^{N} c_i}{N}
\]

- \( C \) = average number of crashes for the sites with a particular group;
- \( c_i \) = number of crashes at site \( i \) in the group;
- \( N \) = total number of sites within the group;
• Crash Rate:

• Crashes per million vehicles per vehicle miles traveled for a specific section;

\[ r = \frac{1,000,000 \times A}{365 \times T \times V \times L} \]

\( r \) = defined crash rate (crashes per million vehicles per mile);
\( A \) = number of report crashes (crashes per year);
\( T \) = time frame of the data (years);
\( V_1 \) = average daily traffic volume on selected segment;
\( V_2 \) = joint AADT = \( \sqrt{\text{AADT}_{\text{freeway}} \times \text{AADT}_{\text{ramp}}} \);
\( L \) = length of the segment (miles);

• Average crash rate-mathematical mean:

\[ R = \frac{\sum_{i=1}^{n} r_i}{N} \]

\( R \) = average number of crash rate with a particular group;
\( r_i \) = number of crash rates at segment \( i \) in the group;
\( N \) = total number of sites within the group;
Crash Type

Target crash type
- rear-end crashes,
- side-swipe crashes,
- angle crashes;

Proportional to the total crashes;

Crash Severity

Severity type
- property-damage-only (PDO) crashes
- injury crashes
- fatal crashes

Proportional to the total crashes;
• Hypotheses Test

• Equality of Two Means
  - Set up Hypothesis: $H_0: \mu_1 = \mu_2 \quad H_a: \mu_1 \neq \mu_2$
  - Determine the level of confidence $(1-\alpha) \times 100\%$
  - Calculate the statistical value:
    \[
    t_0 = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}
    \]
  - Compare the value: reject $t_0 > t_{\alpha/2}$ or fail to reject $t_0 < t_{\alpha/2}$

• Proportionality Analysis
  - Set up Hypothesis: $H_0: p_1 = p_2 \quad H_a: p_1 \neq p_2$
  - Determine the level of confidence $(1-\alpha) \times 100\%$
  - Calculate the statistical value:
    \[
    Z = \frac{|p_2 - p_1|}{\sqrt{\frac{p_2(1-p_2)}{m} + \frac{p_1(1-p_1)}{n}}}
    \]
  - Compare the value – reject $Z_0 > Z_{\alpha/2}$ or fail to reject $Z_0 < Z_{\alpha/2}$
Generalized Regression Model

• Poisson Model
  • Poisson distributed;
  • Probability Density Function:
    \[ p ( Y_i = y_i ) = p ( y_i ) = \frac{\mu_i^{y_i} e^{-\mu}}{y_i!} \]
  • Basic Assumption: Mean equals to variance;
  • Biased Estimation: over-dispersion;

• Negative Binomial Model
  • Poisson-gamma distributed;
  • Probability Density Function:
    \[ p ( Y_i = y_i ) = \frac{\Gamma ( y_i + a^{-1} )}{y! \Gamma ( a^{-1} )} \left( \frac{a \mu_i}{1 + a \mu_i} \right)^{y_i} \left( \frac{1}{1 + a \mu_i} \right)^{a^{-1}} \]
• **Linear function of the estimated model:**

\[ \mu_i = \exp(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3} + \ldots + \beta_m x_{im}) \]

- \( \beta_0, \beta_1, \ldots, \beta_k \) = coefficients of explanatory variables;
- \( x_{i1}, x_{i2}, \ldots, x_{ik} \) = explanatory variables.

• **Goodness of Fit**

  - Scaled Deviance:
  - Pearson’s \( \chi^2 \);
  - P-value;
Data Collection

Site Selection Criteria
- Freeway Diverge Area
- Exit Ramp Section

Segment Length Definition
- Widely-spaced
- Closed-Spaced
- Left-side Off-ramp Exit Ramp

Research Database-Final Database
- Site Information Geometric Data
- Traffic Data Crash Data
**Site Selection Criteria**

- Full control of accesses freeways;
- Posted speed limit $\geq 50$ mph on freeway mainline section;
- No large horizontal or vertical curve and no grade variations;
- Median separation and side clearance;
- No reconstruction in the research period;

- **Widely-Spaced**
  - Space between the previous and successive ramps is more than 0.5 mile;
  - Right-side off-ramps only;
  - Deceleration lane length long enough;

- **Closed-spaced**
  - Space between the previous and successive ramps is less than 0.5 mile;
  - Right-side on-ramps and off-ramps only;
  - Not cloverleaf loop ramps;

- **Left-side Off-Ramp**
  - Space between the previous and successive ramps is more than 0.5 mile;
  - Left-side off-ramps only and only two-lane exits considered;
  - Deceleration lane length long enough;

- **Exit Ramp**
  - Posted or suggested speed limit larger than 25 mph;
  - Right-side off-ramps only;
Segment Length Definition

- Influential Distance: 1000ft ~ 1500ft;
- Length of Deceleration Lane: 26 ft ~ 918 ft;
- Field Observation: ≤1500 ft;
- MUTCD & HCM;

Widely-Spaced
- Upstream 1500 ft;
- Downstream 1000 ft;
Closed-spaced

- From merge point to painted nose;
- 1000 ft upstream merge point;
- 1000 ft downstream painted nose;
Left-side Off-Ramp

- Upstream 1500 ft;
- Downstream 1000 ft;

**Type I:** Two-lane exit with an optional Lane

**Type II:** Two exclusive left-side exit-lane
- From Painted nose to the ramp terminals;
• **Research Database**

- Site Data:
  - Name;
  - Type;
  - Location;
  - Exit location;
  - Ramp Type;
  - etc.,;

- Geometric Data:
  - Deceleration Length;
  - Ramp Length;
  - Basic Lanes;
  - Lane balance;
  - Lane width;
  - Lane shoulder;
  - etc.;

- Traffic Data:
  - Milepost;
  - Section number;
  - Subsection number;
  - Volume;

- Crash Data:
  - FDOT CAR system;
  - 2004-2006;
## Final Database

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Estimated and Preliminary Results

- **Widely-Spaced Diverge Area**
  - Indicate best safety performance between four types for crash frequency and crash rate;
  - Obtain the significant higher percent for crash type and crash severity by four types;
  - Identify the contributing factors to crashes and how they impact safety performances;

- **Closed-spaced Diverge Area**
  - Indicate best safety performance between three types for crash frequency and crash rate;
  - Obtain the significant higher percent for crash type and crash severity by three types;
  - Identify the contributing factors to crashes and how they impact safety performances;

- **Left-side ramp Diverge Area**
  - Indicate the how the safety performance between left-side off ramp and right-side off-ramp on the diverge areas by two types;

- **Freeway Exit Ramp**
  - Indicate best safety performance between four types for crash frequency and crash rate;
  - Obtain the significant higher percent for crash type and crash severity by four types;
  - Identify the contributing factors to crashes and how they impact safety performances;
Questions?