LOUISIANA TRANSPORTATION RESEARCH CENTER

Technical Summary

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Safety and Traffic Operations at Cloverleaf Interchanges

Introduction

Interchanges are vital for efficient traffic flow, particularly on the U.S. Interstate Highway System, which features approximately 17,800 interchanges, with an additional 6,900 on other highways across the nation. Cloverleaf and diamond interchanges are prominent designs, accounting for approximately 24% and 62% of all U.S. interchanges, respectively. Cloverleaf interchanges are notable for their loop ramps, but they pose safety and operational challenges due to complex maneuvers and weaving sections. In contrast, diamond interchanges are favored for their economical layout. To enhance traffic safety and efficiency at both types of interchanges, analysts primarily utilize microsimulation tools and crash data analysis. However, it is still unclear which interchange configuration performs better in terms of safety and traffic operations under the same conditions. This study aimed to evaluate the safety and traffic operational performance of several cloverleaf interchanges in Louisiana, compare them with several diamond interchanges, and suggest countermeasures based on current and future performance predictions.

Objective

The primary objectives of this study were to:

1. Assess the safety and traffic operational performances of several cloverleaf interchanges in Louisiana and compare their performance with traditional diamond interchanges.
2. Predict the future performance of several cloverleaf and diamond interchanges in Louisiana.
3. Suggest countermeasures or alternative interchange solutions that can be implemented if a cloverleaf / diamond interchange is not an appropriate alternative based on their current and predicted future performance.

Scope

The project involved analyzing eight interchanges (4 cloverleaf and 4 diamond) in Louisiana to assess their safety and operational performance. The cloverleaf interchanges included two with collector-distributor (C-D) roads and two without C-D roads. The diamond interchanges consisted of one interchange with unsignalized intersections on the minor road, one interchange with signalized intersections on the minor road, and two interchanges with roundabouts on the minor roads. These interchanges were selected based on feedback from the project review committee. The study aimed to utilize microsimulation and crash data analysis to compare the performance of these interchange designs under various conditions, predict future performance, and suggest improvements.

Methodology

The methodology used in this study included multiple tasks assessing and comparing the safety and operational performance of cloverleaf and diamond interchanges in Louisiana. Initially, an in-depth literature review was conducted to gather existing knowledge on safety and traffic operation at these interchanges. Data collection involved gathering traffic volumes, travel times,

Figure 1. Cloverleaf interchange (top)
Figure 2. Diamond interchange (bottom)

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and speed data from field observations and the Regional Integrated Transportation Information System (RITIS). Microsimulation analysis using PTV VISSIM was employed to model and analyze the traffic operations of the interchanges. The models were calibrated and validated using real-world traffic data.

Additionally, crash data from 2016 to 2021 was analyzed. A comprehensive crash data analysis was conducted, and crash hot spots were identified at cloverleaf and diamond interchanges using GIS. Safety performance functions (SPFs) were also employed to predict crashes by incorporating traffic and highway parameters.

The study included evaluations of current conditions as well as the expected traffic safety and operational performance after 10 and 20 years. Based on these findings, recommendations for improvements and countermeasures were provided to enhance the safety and performance of the interchanges.

Conclusions

1. The analysis revealed that cloverleaf interchanges, especially those with collector-distributor (C-D) roads, handle heavy traffic volumes (>8000 vph) better than diamond interchanges but present significant safety concerns at weaving segments.
2. Diamond interchanges with roundabouts perform better in terms of safety at both low and high traffic volumes than cloverleaf interchanges with and without C-D roads.
3. Increasing weaving lengths improved safety and operations for cloverleaf interchanges without C-D roads, while increasing the diameters of roundabouts and adjusting traffic signal timings slightly improved diamond interchange performance.
4. Most interchanges under investigation were found to operate at acceptable levels under current conditions, though modifications will be needed after 10 to 20 years.
5. Crash data analysis shows that effective countermeasures for cloverleaf interchange include adding extra lanes, implementing semi-directional ramps, utilizing one-way frontage roads. Effective countermeasures for diamond interchanges included replacing stop-controlled intersections with signalized ones and raising driver awareness at roundabouts.

Recommendations

The study recommends implementing longer weaving sections for cloverleaf interchanges without C-D roads to mitigate safety concerns and reduce crash rates. Adding C-D roads to existing cloverleaf interchanges with no C-D roads can improve safety and traffic operations at high traffic volumes. Optimizing traffic signal timings at diamond interchange intersections can enhance traffic flow and safety, reducing delays and collisions. Further research and data collection are needed to develop local Safety Performance Functions (SPFs) that are tailored to Louisiana's conditions. Infrastructure improvements should target high-crash areas identified through crash data analysis, and efforts should be made to enhance driver awareness and education regarding priority and right-of-way at roundabouts.