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Evaluation of Geometric Highway Design Parameters for Enhanced Road Safety and Performance

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Abstract: *Traffic engineering aims to ensure the safe and efficient movement of people and goods through systematic analysis and management techniques. Traffic flow plays a vital role in achieving this objective and is primarily characterized by three key parameters: volume, velocity, and density. This study focuses on the T-section of NH-9, a six-lane roadway, to analyze traffic behavior under mixed traffic conditions commonly observed in developing regions. Such conditions involve diverse vehicle types, including heavy trucks, cars, and non-motorized vehicles, which significantly influence traffic dynamics. The research emphasizes the development of a cellular automata-based model to simulate bidirectional traffic flow and capture the complex interactions among different vehicle categories. Traffic surveys conducted at various times of the day provide a realistic understanding of traffic conditions, including variations in flow and speed. Spot speed studies are carried out to determine important percentile speeds (98th, 85th, 50th, and 15th), which are essential for evaluating safety, efficiency, and user comfort. The findings highlight the increasing pressure on existing road infrastructure due to rapid urbanization and rising vehicle ownership. The study suggests that appropriate traffic management strategies, along with improvements in lane width and speed regulation, are necessary to enhance road safety and optimize traffic flow performance..*

Keywords: Traffic Flow Modeling, Cellular Automata, Bidirectional Traffic, Heterogeneous Traffic, Traffic Volume.

I. INTRODUCTION

Highway infrastructure plays a vital role in the economic growth and social development of any nation by enabling the efficient movement of people and goods. With rapid urbanization, increasing population, and a significant rise in vehicle ownership, the demand on existing road networks has grown substantially. As a result, ensuring road safety and optimal performance has become a critical concern for transportation engineers and planners. One of the key factors influencing both safety and efficiency is the geometric design of highways, which governs how vehicles interact with the roadway environment.

Geometric highway design refers to the physical layout of road elements, including alignment, cross-section, sight distance, gradients, curves, lane width, shoulder width, and super-elevation. These parameters directly affect vehicle speed, driver behavior, comfort, and safety. Poorly designed geometric features can lead to increased accident rates, traffic congestion, and inefficient utilization of road capacity. Therefore, evaluating and optimizing these parameters is essential to achieve a balance between safety, efficiency, and cost-effectiveness.

In many developing regions, highways are often subjected to heterogeneous traffic conditions, where different types of vehicles such as heavy trucks, cars, two-wheelers, and non-motorized vehicles share the same roadway. This diversity in vehicle characteristics, including speed, size, and maneuverability, adds complexity to traffic flow and places additional demands on geometric design. Traditional design standards, which are often based on homogeneous traffic

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conditions, may not adequately address these challenges. Hence, there is a growing need to reassess and evaluate existing geometric design parameters in the context of real-world traffic conditions.

This study focuses on the evaluation of geometric highway design parameters with the objective of enhancing road safety and performance. By analyzing key design elements and their influence on traffic flow characteristics, the research aims to identify deficiencies in existing infrastructure and recommend appropriate design modifications. The findings of this study are expected to contribute to improved highway design practices, reduced accident rates, and more efficient transportation systems.

TRAFFIC VOLUME STUDY

Vehicle composition: Data collected from the traffic volume study during 12 hours. Total vehicles during study hours are an essential factor in the planning and construction of any road's geometry. The traffic analysis provides the fraction of the traffic. Therefore, understanding the volume of selected location. From the traffic count we have collected a data on hourly basis and plot a bar chart as shown below. From this chart we have identified peak hours in morning and evening.

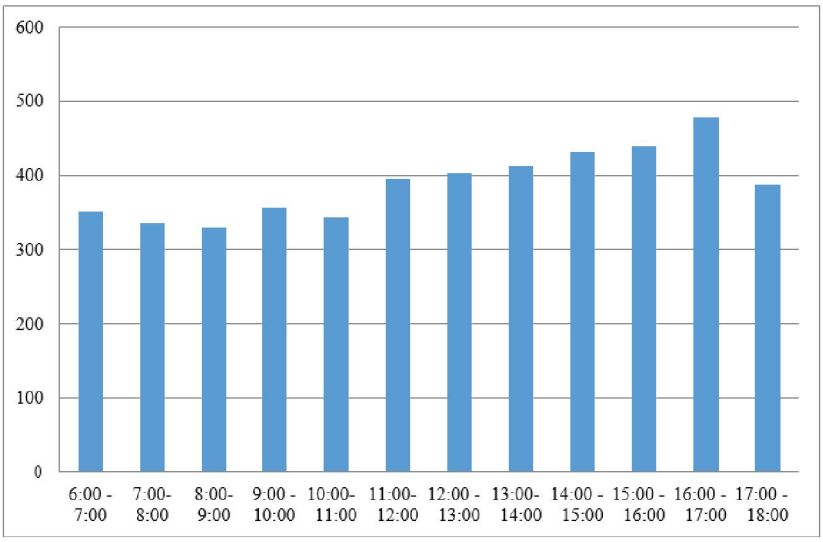

Fig 1 Traffic variation during the day.

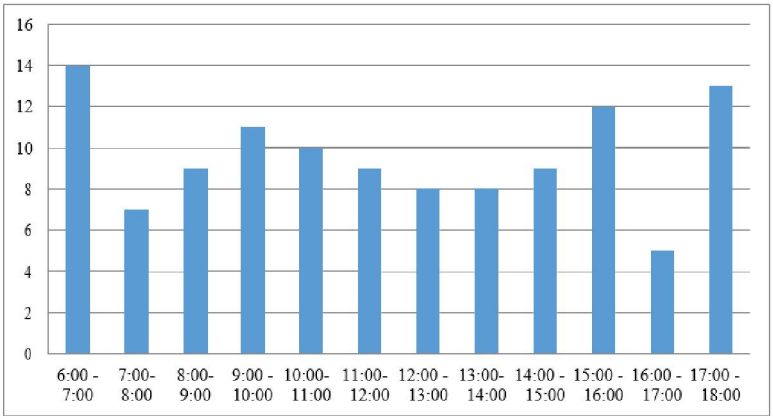

Fig 2 Auto Traffic variation during the day

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From the above chart we saw that all out number of vehicle is more in night hours (19:00-20:00) and in morning hours (9:00-10:00). During 14:00 to 20:00 expands development ofengine vehicle populace, the traffic out and about has been expanding, both regarding volume and thickness. The information on traffic qualities is valuable of an essential factor

Result Analysis

Table 1 shows the percentile speed of vehicle for each lane of NH-9. The maximum & minimum percentile speed Lane for 1 is 117Kmph to 35.7Kmph 7:00 am to 11:00 am. When the maximum percentile speed for lane 1 is 117kmph then the traffic movement is less. In this time traffic flow high then speed of vehicle less & traffic flow is low then speedis high. The traffic flow is uniform & each type of vehicle speed movement for per lane isselected road stretch. The modal speed of this time is 97.5kmph to 43.6kmph.

TABLE 1: Spot Speed for lane1of NH-9

LANE	LANE 1 (7:00-8:00)	LANE 1 (8:00-9:00)	LANE 1 (9:00-10:00)	LANE 1 (10:00-11:00)
98TH (KMPH)	117	101	99	110
85TH (KMPH)	104.5	88.6	90	97.6
50TH (KMPH)	78.5	62	64.5	64.5
15TH (KMPH)	43.7	39	39	41
MODAL SPEED(m/sec)	97.5	76.7	78.5	76.7

II. CONCLUSION

This study emphasizes the critical role of traffic volume analysis and vehicle composition in understanding traffic flow behavior and improving highway performance. The 12-hour traffic data reveals distinct peak periods during morning (9:00–10:00) and evening (19:00–20:00), indicating high travel demand and its direct impact on congestion and road efficiency. Such temporal variations highlight the need for careful planning of road geometry and traffic management strategies to ensure safe and smooth movement. The analysis shows a significant increase in vehicle count during afternoon and evening hours, reflecting the rapid growth in motorized traffic. This trend underscores the importance of adopting effective control measures to manage rising traffic demand. Additionally, vehicle composition plays a crucial role in influencing speed and flow characteristics, as different vehicle types contribute unevenly to congestion. The findings align with existing studies, confirming that higher traffic volume leads to reduced speeds, while lower density allows faster movement. The observed speed variation further demonstrates the dynamic nature of traffic flow. In conclusion, traffic volume, vehicle composition, and speed are strongly interconnected parameters that must be jointly considered for efficient highway design and management. The study provides valuable insights for enhancing road safety, optimizing traffic flow, and supporting informed decision-making in transportation planning.

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