Analysis of Overtaking Manoeuvres on Freight Corridors considering Road and Vehicle Parameters

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Abstract

Introduction

More than 60% of the freight movement in India is currently carried out on road networks, with 40% on National Highways (NHs) [1]. The Government of India aims to increase this load on NHs to around 70% by planning the construction of freight corridors. This would maximise the logistic efficiency of freight movement across the country by bridging critical infrastructure gaps. Efficient use of heavy commercial road vehicles (HCRVs) can uplift economic growth by optimising the number of truck trips, thus lowering operation and maintenance costs.

The geometric design of highway infrastructure needs to be revised in the context of today's emerging vehicular technologies. One of the important design elements is the passing sight distance (PSD), also known as overtaking sight distance, which governs the overtaking operations of vehicles. The minimum PSD, required for an overtake, is the sum of two distances, d_1 that indicates the distance required for the vehicle to accelerate to its overtaking speed, and d_2 that indicates the distance required for the lateral movement for overtaking [2]. While there has been significant research in this area from the perspective of passenger cars, on which the current standards are based, the same cannot be said for trucks. Harwood and Glennon [2] were one of the first to study passing operations of trucks with a sensitivity analysis for different passing situations. Their model was regarded as one of the most suitable analytical models for calculating the minimum PSD on a highway [3], but it only considered the lengths of the vehicles and basic kinematic parameters. Farah et al. [4] studied the passing behaviour of drivers and agreed that the completion chances of a passing manoeuvre are more with higher design standards, but failed to quantify the same. These traditional PSD models overlooked the microscopic motion of the vehicle and its constraints, which results in them often over or underestimating the PSD values. Further, there is still no agreement on vehicle classes [2] that can act as a reasonable basis for the design of PSD [5]. With the increasing adoption of electric vehicles (EVs), there is a need to focus on adapting road design standards for electric trucks as they have different kinematic capabilities compared to their conventional counterparts. The development of relevant standards is also motivated by their potential use in the development of advanced driver assistance systems (ADAS) like passing collision warning systems (PCWSs) [6], which are based on holistic PSD standards and can assist commercial drivers with safe passing operations.

Research objectives

In light of upcoming freight corridors in the country, it is essential to develop standards that encompass relevant parameters such as vehicle speeds, road gradients and vehicle classes. This will help sustain high flows and level of service on the freight corridors. Revised PSD values in the roadway design would result in enhanced safety and efficiency - in terms of road usage as well as vehicle energy usage. Also, this would reduce the number of aborted overtaking attempts [7], thus leading to energy savings.

Based on these gaps in the current standards, this study aims to revisit the PSD values for various road and vehicle characteristics. In this research, the impact of various road parameters such as gradients and vehicle characteristics such as vehicle type, vehicle speed and vehicular technology (IC vs electric) are studied. Following the results of the comparison, a suitable analytical model is developed, which provides more accurate values for PSD taking road and vehicle parameters into consideration.

Simulation results and development of analytical model

In this research, the minimum PSD values calculated using Glennon's method [2] are first compared with actual overtaking distances obtained from IPG TruckMaker®, a vehicle simulation software for HCRVs. In this study, a single unit 2-axle truck with twin rear tyres and a mass of 6488 kg is considered. The preliminary results show that for certain speed values, the overall PSD values differ by as much as 50%. Evaluating the PSD at different gradient levels shows that the standard PSD values are 75% lower for 6% grades. Increasing the loading of the truck to the maximum allowable gross vehicle mass of 16200 kg as per Indian standards [8] results in an offset of 45% over the traditional PSD values.

Comparing the PSD values for an HCRV with an electric powertrain shows an underestimation of up to 60% for the overall PSD values, and up to 65% for d_2. This is primarily due to different acceleration capabilities of electric HCRVs. The design of PSD standards in India for two-lane highways is based on IRC standards [9], which recommends conservative values for the minimum distances for complete highway alignment. A comparison of the values specified in the IRC standards with those from IPG TruckMaker® reveals an underestimation of 53%, despite the consideration of an additional distance d_4 in IRC based on the oncoming vehicle.

In order to account for these variations, an analytical model, which considers vehicle trajectories and capacities, is developed, which includes lateral movement of the vehicle via a cubic polynomial trajectory [10]. The trajectory employs constraints on the safe gaps which drivers maintain when overtaking and the curvature of the trajectory, and the most conservative value among these minimum required distances is chosen [11]. The safe headway spacing is estimated using the Forbes car-following model [12]. The value of d_2 is obtained by adding the headway spacing and the lane change distance from the cubic polynomial trajectory. When benchmarked against the IPG Truckmaker®, results show a maximum deviation of 7% in d_2 and a minimum deviation of 0.2%.

Conclusion

The preliminary results show that the road and vehicle characteristics have a significant effect on the PSD values and thus need to be suitably adapted for the design of freight corridors. The provision of a reasonable PSD can increase average vehicle speeds, which can have a notable impact on logistic efficiency. As part of the ongoing research, further models are being implemented for d_1 by considering the acceleration and braking capacities of vehicles, which could provide more interesting insights. Following this analysis, similar areas for analysing the cost-efficiency could be further explored.

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