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Macroscopic Traffic Flow Characterization at Bottlenecks

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Abstract

Traffic congestion is a significant issue in urban areas. Realistic traffic flow models are crucial for understanding and mitigating congestion. Congestion occurs at bottlenecks where large changes in density occur. In this paper, a traffic flow model is proposed which characterizes traffic at the egress and ingress to bottlenecks. This model is based on driver response which includes driver reaction and traffic stimuli. Driver reaction is based on time headway and driver behavior which can be classified as sluggish, typical or aggressive. Traffic stimuli are affected by the transition width and changes in the equilibrium velocity distribution. The explicit upwind difference scheme is used to evaluate the Lighthill, Whitham, and Richards (LWR) and proposed models with a continuous injection of traffic into the system. A stability analysis of these models is given and both are evaluated over a road of length 10 km which has a bottleneck. The results obtained show that the behavior with the proposed model is more realistic than with the LWR model. This is because the LWR model cannot adequately characterize driver behavior during changes in traffic flow.

Keywords: Macroscopic Traffic Model; Traffic Flow; Transition; LWR Model; Explicit Upwind Difference Scheme; Stability Analysis.

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1. Introduction

Traffic congestion is a critical issue in urban areas around the world [1] and it is getting worse. The Traffic Index (TI) is a composite index of the time to journey from home to work [2]. The 2017 TI indicates that congestion levels in Mexico City, Bangkok, Jakarta, Istanbul, and Beijing were 66%, 61%, 58%, 49%, and 46%, respectively [3]. According to the INRIX report [1], congestion costs in the UK were approximately £8 billion in 2018 which is over £1,300 per driver. Further, an average UK road user spent 178 h in congestion in 2018 [4]. Congestion occurs when there are traffic bottlenecks due to lane reductions, poor traffic light timing, accidents, and sharp curves. Bottlenecks can be recurring or nonrecurring. Recurring bottlenecks appear at the same time of day and day of the week, whereas nonrecurring bottlenecks appear randomly and are typically due to conditions such as accidents, precipitation and/or poor visibility [5]. In order to mitigate congestion, it is necessary to understand traffic behavior and characterize it realistically [6]. Transitions are large changes in density which can occur at the egress or ingress to a road or at lane reductions and can cause bottlenecks [7]. A traffic model based on driver response is required which characterizes traffic behavior during transitions. This can be employed to mitigate congestion and decrease travel time [6].

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