Microscopic traffic simulation modelling of 2+1-roads

Andreas Tapani*† Johan Olstam*

March 15, 2013

Abstract

Alternative road designs with overtaking restrictions and periodic overtaking lanes, so-called 2+1 roads, are used as low-cost alternatives to increase safety on two-lane roads. However, there are potential implications of these road designs on the quality of service. To ensure acceptable quality of service, there is a need for traffic analysis tools to support the design of 2+1-roads. This paper presents an extended version of the RuTSim microscopic traffic simulation model including models of characteristic speed adaption, overtaking and merging behaviour on 2+1 roads. Numerical experiments are used to verify that the model reproduces fundamental characteristics of traffic on 2+1-roads.

Background

Two-lane undivided highways make up the majority of the road mileage in many countries around the world. Many of these roads constitute important regional links between rural and urbanised areas. However, two-lane roads are also commonly overrepresented in the accident statistics. Road authorities are therefore interested in means to improve road safety properties of regional road networks without imposing restrictions on the quality of service. Conversion of two-lane undivided roads into four lane divided road designs are one way of achieving improvements both in terms of road safety and capacity. This measure is associated with high costs of construction and can often only be motivated by requirements imposed by high traffic demand. Road authorities have therefore searched for low-costs alternatives, which have resulted in new alternative road designs with overtaking restrictions and periodic overtaking lanes. Examples of such road designs include 2+1-roads (Bergh et al., 2005), super 2 highways (Brewer et al., 2011) and two-lane expressways (Catbagan and Nakamura, 2006).

Empirical evidence shows lower injury accident risk on these types of roads compared to two-lane highways. Swedish 2+1-roads with the overtaking restriction implemented as a median barrier feature accident risks comparable to Swedish four lane divided motorways (Carlsson, 2009). A downside of the no overtaking zone and periodic overtaking lane road design is its potential implications on the quality of service. The capacity of a 2+1-road is effectively restricted by the two-to-one lane merging section at the ends of the periodical overtaking lanes. In addition, the location, length and number of overtaking lanes per direction have to be adapted to the traffic demand as well as the road's geometric alignment.

*Swedish National Road and Transport Research Institute (VTI), Linköping, Sweden and Linköping University, Department of Science and Technology (ITN), Norrköping, Sweden

†Corresponding author, *address:* VTI, SE-581 95 Linköping, Sweden, *tel:* +46 13 20 42 80, *email:* andreas.tapani@vti.se

Consequently, to ensure acceptable quality of service, there is a need for traffic analysis tools to support the design of 2+1-roads.

Tools based on microscopic simulation modelling of traffic flows have become a standard part of the traffic engineering toolbox (Barceló, 2010). Traffic micro-simulation models consider individual vehicles in the traffic stream and could be suitable for use in analyses of 2+1-roads in which the effects of properties (length, power, weight, etc.) of different vehicle types and individual slow moving vehicles will be of importance. The micro-simulation tools are however commonly developed for simulation of traffic flows in urban or motorway networks and feature simple representations of the interactions between the driver-vehicle units in the simulation and the geometric road alignment. A finding of empirical studies of traffic on 2+1-roads is also changes in driver behaviour between the two- and one-lane sections of the road. To represent traffic operations on 2+1-roads, traffic simulation models including both sufficient representations of the interactions between driver-vehicle units and the road alignment and observed changes in driver behaviour between two- and one-lane sections are needed.

Aim

In this paper an extension of the Rural Traffic Simulator (RuTSim, Tapani (2005)), a microscopic traffic simulation model, for simulation of traffic on 2+1-roads is presented. The aim of the paper is to describe the behaviour models developed to govern movements of driver-vehicle units on 2+1-roads. Numerical experiments are presented verifying the representativeness of the simulation results for traffic operations on Swedish 2+1-roads.

The extended RuTSim model

RuTSim is a microscopic traffic simulation model developed for simulation of traffic in rural road environments. The basic RuTSim model includes sub-models of the relationship between the road alignment and the vehicle speeds. To extend the basic RuTSim model to allow simulation of traffic on 2+1-roads the required model extensions consists of modified overtaking and speed adaptation models and adding a merging model for the two-to-one lane merging sections. The developed overtaking decision model for vehicles on the two-lane sections is based on the drivers' consideration of the following three factors:

1. The remaining length of the two-lane section,
2. The traffic on the overtaking lane in a neighbourhood of the vehicle and
3. The driver's estimate of the ability to overtake the vehicle in front.

In the modified speed adaptation model, the finding from Swedish 2+1-roads that drivers increase their speeds on the two-lane sections in order to overtake slower vehicles before the upcoming one-lane section is taken into account. To model vehicle operations on the two-to-one lane merging sections a merging model based on the work of Hidas (2005) is implemented. Details of the models developed are given in the paper.

To verify the developed 2+1-road RuTSim model, experiments are conducted comparing simulation results to data collected on Swedish 2+1-roads. The results of the verification

show that the simulation model is representing the fundamental characteristics of traffic on 2+1-roads. Numerical results are given in the paper.

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