

Paper:

# Fuzzy Logic Based Lane Change Model for Microscopic Traffic Flow Simulation

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**Lane changing phenomenon is vital in representing individual vehicle behaviour in microscopic traffic simulation, yet many lane change models do not consider the uncertainties and perceptions in human behaviour that are involved in modelling lane changing. In the present study, fuzzy reasoning in lane changing model is introduced to reflect these uncertainties and perceptions to represent lane changing behaviour more realistically. The comparison of simulated results with observed data indicated that fuzzy reasoning represents driver behaviour more realistically than standard modelling. The effectiveness of the proposed technique is demonstrated in a real urban network with bus lane policy.**

**Keywords:** fuzzy reasoning, lane change model, traffic simulation, driver behaviour

## 1. Introduction

Traffic congestion is a major problem in urban areas that brings with its environmental pollution and accidents. Transport policies such as Travel Demand Management (TDM) especially encouraging public transport system are most appropriate in managing such situations [1]. However, their expected benefits and impacts must be carefully assessed before they are implemented. In this direction, microscopic simulation analysis has attracted increasing attention in the last two decades as it analyzes individual vehicle/driver<sup>1</sup> behaviour more precisely and realistically than other methods [2], although its accuracy and validity depend mainly on the quality of underlying driver behaviour models.

Generally in any microscopic simulation, traffic models namely car-following and lane changing models are considered to be the core part to estimate vehicular movements. Car-following model estimates acceleration and deceleration and positioning of vehicles in a link. Whereas lane change model evaluates lane change decisions on multilane roads based on individual driver goals

and purpose [2]. Vehicles often must change lanes, for example, to make a right turn at the next intersection, to speed up to pass slower vehicle, to slow down to let a faster vehicle pass or to obey transport policy such as lane restriction, bus lanes, priority lanes etc. The vehicular movements cannot be represented accurately in microscopic simulation, if a lane change model is not considered. Lane change and car-following models are thus equally important in microscopic simulation.

Lane change models mainly estimates driver lane change decisions, which are usually involved with approximations because of human element [3]. Yet, many lane change models do not considered these approximations and human decisions appropriately in several situations, but assume that drivers estimate current situation and evaluate lane change decisions accurately, which is not the case in reality. In this study, lane change model is developed for microscopic simulation taking uncertainties in driver perception into account in lane change decisions. Several approaches are recently become popular in attempting to overcome these problems include those based on artificial intelligence (AI). Among AI techniques, fuzzy logic introduces a quantifiable degree of uncertainty into the modelling process to react to natural or subjective perception of real variables [3]. In the present study, main focus is given to implement fuzzy logic technique in modelling drivers' lane change behaviour. Of the many lane change models developed thus far, fuzzy logic technique in modelling was considered only in FLOSIM study [3], which is appropriate for motorways and expressways only, but not suitable for urban congested traffic conditions. By keeping the necessity of fuzzy logic in lane change modelling, a lane change model based on fuzzy logic technique is formulated to overcome the problems in standard modelling without fuzzy logic. In this study, other appropriate and possible lane change purposes are considered in the modelling to describe drivers' behaviour in urban congested traffic conditions. The comparison of estimated lane change behaviour and observed lane change behaviour confirmed the validity and feasibility of proposed fuzzy logic based lane change model and results of microscopic simulation demonstrated the effectiveness of fuzzy logic in lane change model in bus lane policy for Gifu city network.

1. Driver and vehicle are considered as one unit in this study.

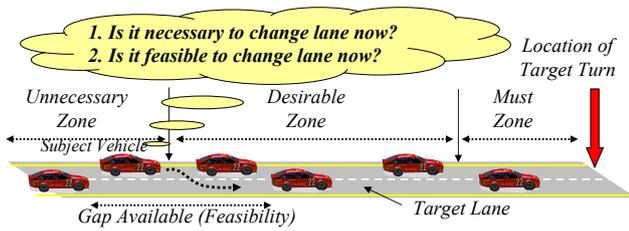


Fig. 1. Driver behaviour in lane change.

This paper is organized as follows. Section 2 discusses lane change process in microscopic simulation, briefly reviews the literature on lane change models, the outline of present microscopic simulation model and lane change with standard modelling. Section 3 explains the need for fuzzy logic technique in lane change modelling and fuzzy logic approach. Section 4 gives the formulation of fuzzy logic based lane change model along with the description of input, output variables and associated membership functions and the fuzzy inference rule base and also various possible purposes generally involved in urban travel conditions are given. Section 5 compares results of the proposed lane change model to observed lane change behaviour in an urban road network for validation purpose and assesses the impact of fuzzy logic in lane change modelling on bus lane policy in calculating the evaluation results. Section 6 presents conclusions and future scope of the work.

## 2. Lane Change in Simulation Model

### 2.1. Lane Changing Phenomenon

A microscopic simulation model basically estimates vehicular movements in each time interval under different traffic conditions. In that process, lane change model is mainly applied whenever drivers want to change lane while traveling on multi-lane road. A driver, for example want to turn at the next intersection if the current lane prevents the intended turn, increase speed, or follow traffic management measures such as a bus lane policy. The driver presumably is continuously thinking of both necessity and feasibility of lane change as shown in **Fig. 1**.

In modelling lane change behaviour, the decision taking process is generally formulated considering necessity and feasibility.

The necessity level is generally divided into unnecessary, desirable and must zones based on the distance or time to reach turn location. If the driver's purpose is to make a right turn at the next intersection, the location of the turn is that intersection. Links are assumed to be divided into these zones of necessity based on the purpose of the lane change.

Feasibility is checked based on the gap available in the target lane. If the vehicle is at unnecessary zone, then the driver will not try to seek for a lane change. If a lane change is needed at desirable zone, the driver will attempt to change lanes whenever sufficient gap opens up in the

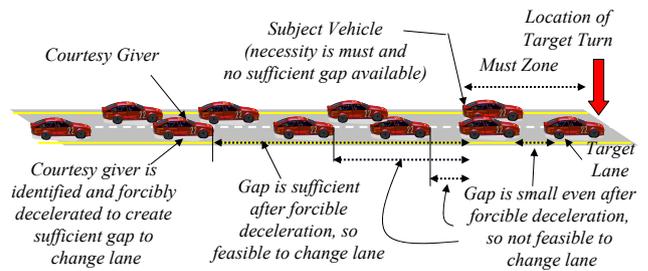


Fig. 2. Courtesy lane change process.

target lane [4] as described schematically in **Fig. 1**. Many lane change models assume that drivers estimate necessity and feasibility accurately, when they actually involve many uncertainties and approximations.

### 2.2. Review of Lane Change Models

The lane change model mainly determines the current lane of individual driver considering the present traffic conditions and objectives. Many simulation models consider lane change phenomenon but do not clearly describe it in the literature. In the 1980s, Gipps proposed a framework for the structure of lane change decisions in urban driving situations for the first time, but the model assumes that lane changing maneuver takes place only when it is safe, i.e., when a sufficient gap is available in the target lane [5]. Within the last decade, a number of simulation models have incorporated some form of lane change model [2, 6]. Most proposals state that their lane changing model is based on a set of rules, but fail to describe the rules in depth completely. Moreover, these lane change formulations neglect urban congested conditions and assume that lanes are changed only when it is safe. Hidas found that this assumption in lane change models has a serious limitation in dealing with congested and incident-involved conditions [4]. In the late 1990s some microscopic traffic simulation models such as MITSIM stated that incidents could also be modelled [6], but failed to provide sufficient information on how the model dealt with lane changes under such conditions. Hidas then proposed methodology for a forcible and cooperative courtesy lane change to deal with congested and incident-involved situations for SITRAS, a microscopic simulation model [4]. The schematic representation of courtesy lane change processes is given in **Fig. 2**.

If the driver is needed lane change at 'must' zone of necessity and the situation in target lane is not feasible (because of congested conditions) i.e. gap available is not sufficient to change a lane, the courtesy lane change module is applied as shown in **Fig. 2**. In this case, courtesy providing vehicle would be identified in the target lane so that if it forcibly decelerated, sufficient gap would be created to enable the subject vehicle to change lanes [4]. The congested situations are usually occurred on urban roads especially in peak hours and the courtesy lane change describes lane change behaviour in that situation. Realistic behaviour cannot be represented if it has not been considered in the lane change model. Wu et al. identified