**Literature Review: *Traffic Flow Modeling***

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# Background / Introduction

The volume of vehicles and the number of vehicles owned by each person has rapidly increased since the mass production of automobiles in the last century. Although started relatively late in time, China’s motor vehicle industry had also rapidly climbed to the 1st in the world thanks to the huge demand of Chinese people regarding transportation tools. But more cars on the road mean more “unpredictable” changes. There are more congestions happening in an urban city, and more car accidents occurred than ever before. All these problems in our traffic systems raise interest in the research of traffic and all of its relevant fields, including traffic flow.

The rapidly increased volume of vehicles in recent years has brought huge challenges to the present road networks and traffic management systems. The increasing diversity in vehicles’ types also creates troubles and burden to the management on the roads designed for situations in the old times. The outdated traffic design and architecture cannot fulfill the growing demand for traffic and transportation. In this case, traffic congestions and even road accidents occur much more frequently. The setback of outdated road designs has been seen by people participating in the transportation system, such as drivers, passengers, and pedestrians. The issues underlying in the unfit architecture have brought inconvenience and even harms to them. That is when intense interest and attention are paid into these issues, people start to consider the methods to alleviate the problems and provide a better solution. And the traffic flow is certainly a field that worth researching.

By researching the traffic flow theory and its modeling, we are hoping to be part of the team helping our traffic system and provide ideas and solutions for the real-world traffic problems mentioned above. In the year 2016 and 2017, cities like Shenzhen and Chengdu has brought huge changes to their traffic management. Ideas of “HOV” lane, “Array-style traffic control” and bus-only lane have been put into exercises. [1] We are glad to see the traffic management and control methods have been updating for the changing demands, and it is also what we are willing to achieve with our traffic flow modeling research. The traffic problems we face today can be classified into these categories: those of the road design, the traffic rules, and those related to the participants in the transportation system. Firstly, road designing engineers commonly face the problem of where is the better if not the best placement of the traffic lights and speed bumps on a road, whether it is acceptable to have an interchange, an off-ramp way off the freeway on the road, and what kinds of the pedestrian crossing should be used, a footbridge, a zebra crossing, a pedestrian scramble or else. And also, different situations as urban/countryside roads, roads in front of schools and etc. will need consideration. Secondly, traffic rules also have a great impact on the performance of the traffic system. The suitable maximum/minimum speed for different vehicles and different roads, the specified lanes for different vehicles and different time periods and traffic restrictions policies are all factors that will affect the efficiency of the traffic system. Thirdly, besides the two aspects mentioned above, driving behavior are also part of what influence the traffic. Drivers have different behaviors in driving, while they also have very different driving experiences. These factors impact how they will perform when driving, some of them are well-skilled and therefore being able to catch up with the front car, while others may have a hard time doing it and may cause congestion in a traffic block.

The traffic itself is a relatively broad topic, to consider the traffic flow of vehicles on the roads, there are some basic parameters we need to consider at the first hand, including the speed of the car, the maximum speed allowed on the road and also the minimum speed if there is one. We also need to consider the distance between cars, the car’s performance as acceleration and the number of road lanes, etc. However, if we want to build a more realistic model, there’s more we need to consider. To reach for a real-world simulation, other factors such as drivers’ behavior and their habit in driving, the road’s condition, whether there is a ramp, interchange on the road, or there is a traffic light or roadblock, need to be included in the calculation of modeling. And these factors can both have a significant influence on the model of our traffic flow theory.

# Related work and methods

As early as the late 50s to 60s in the 20th century, there are already researches done in the aspect of traffic flow theory and its modeling. We view this time as a start point in the research field of traffic flow, because the research outcomes in this time period are relatively mature among the other essays at their time or before, and they have been extensively quoted and referenced to by many of today’s researches.

As for the fundamental concept of traffic flow, the *Traffic Flow Theory* by L.H. Immers and S. Logghe is a very reliable source for us to build up our basic concept of traffic flow. It provides clear ideas of what to start for the traffic study, including the relationship between a car’s distance/displacement and time, a.k.a. the *vt* diagram, and the distance between cars and etc. Basing on this very premature but fundamental concept, we and other researchers can then start the research work on traffic flow. [2]

There is an enormous number of researches done in the past decades regarding the study of traffic and traffic flow, especially focused on the modeling of traffic flow. Researchers have been trying to find various mechanisms and methods for better results in their modeling, and to implement them later. In the time period of decades, the advancement of basic subjects such as mathematics and physics have helped people to collect more accurate and more amount of data, and greatly improved their ways handling the data. The progress of modem technology, especially in the field of electronic systems and IT also have their great contributions to the relevant research of traffic. In the beginning, many of the researches are using the fundamental mathematical methods in their modeling work. Pure statistical analyses are commonly used by then. Given that the traffic condition is not so sophisticated relatively at that time, these approaches have relatively satisfactory outcomes. Clayton, A J from the Institution Civil Engineers has done his very early in the history of traffic flow research in the year of 1941. He started to consider the relationship between vehicles’ speed and the road’s maximum safe density, which then was concluded into the method of determining the capacity of the multi-lane road. [3]

Later then, researchers have taken more sophisticated modeling methods, mainly nonlinear dynamics methods, fluid dynamics methods and etc. In their research paper, LH Immers and S Logghe introduced a way to study the traffic flow through the probabilistic cellular automaton model, which was used by them to describe properties of traffic flow on a single-lane road. [4] In 2006, S Sun, C Zhang and G Yu did their research on traffic flow forecasting using a different aspect in the stochastic filed, the Bayesian network approach. The outcome of the research showed that it was quite promising and satisfactory model in the field of traffic flow forecasting, given that the result is better and more accurate than researches using several other models. [5] The fluid dynamics, another method of describing the traffic flow as a dynamic object, was also been used in many types of research and has shown promising results. H Greenberg’s research viewed the traffic stream as a continuous fluid, which can be analyzed using similar principles in fluid dynamics. [6]

By recent years, thanks to the development of IT, there are more possibilities in modeling traffic flow and solving relevant problems. Researches using the technology of big data and machine learning emerges in the field study of traffic flow. In the project *Traffic Flow Prediction with Big Data: A Deep Learning Approach*, a group of Chinese researchers proposed their unique model of traffic flow prediction using big data and deep learning. This was the first time a deep architecture model was implemented for the traffic flow prediction, and the high-performance of today’s computer guaranteed that this model has superior performance. [7]

And also, there are many researchers who are willing to pay their interest and attention in real-world circumstances. There are different aspects of problems to solve. Some were aimed to alleviate the issue of congestion in traffic, others focusing on the impact of traffic light designs on the traffic. Also, researches have been down on different road conditions such as freeways, ramp road, etc. While the remains are trying to figure out what will the impact of driver’s behavior, attitude, etc. on traffic. For example, M Treiber and V Kanagaraj focus their work on the topic of car-following models, while M Treiber, this time with A Hennecke and D Helbing, researched into the congested traffic states. [8] [9]

We also want to show our respect and attention to the researches that focus on the application of traffic flow models. There were simulators built in modern programming languages like Java and Python, which could be run on high-performance computers and gains promising simulation of traffic flow. These researches demonstrate how we could apply our modeling results into a visualized and interactive form. Mr. M Treiber and A Kesting presented an interactive Java-based open-source traffic simulator in their project, with an online website which runs the simulator on it. [10]

# Project outline and overview

In our presented research, we will first discuss what is traffic and traffic flow, to be specific, what is the definition of these concepts, what is the problem they represent and they will solve, and what are factors we need consider as long as the data we need to collect. After defying the concept, we will build the mathematic model for our conceived concept.

## **Modeling**

In the modeling part of our research, we will choose one modeling method in the field of fluid dynamics, base on which we can do the modeling work of our research project.

## **Interpretation**

After the critical work of modeling, we also need to visualize our modeling by building a simulator for it. The simulator should take inputs like cars’ speed, location of traffic lights and roadblocks, the density of cars and etc., and implement our modeling to analyze them while giving visualized output for us.

## **Application**

With the simulator we build based on our model of traffic flow, we can simulate the traffic with our indented input and modification on our variables. It enables us with great opportunities to design different traffic architectures and rules and test them to decide which of them has a better outcome for real-world traffic situations.

We hope with the help from the application of our research project, we can alleviate the issues mentioned above and improve nowadays traffic condition.

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