CHAPTER 1 INTRODUCTION

1.1 Background and Motivation

To improve urban traffic conditions, it is indispensable to implement effective strategies from both demand and supply sides. Providing preferential treatment to high occupancy vehicles, such as bus transits, so as to encourage the use of public transport systems is one of the favorable demand-side strategies to alleviate traffic congestions. The concept of convoying a set of buses together into a dedicated lane has been developed for more than three decades. For instance, the cities of Curitiba, Sao Paulo and Porto Alegre in Brazil have introduced exclusive bus corridor, now called Bus Rapid Transit (BRT) since 1970s. This involves bus-only lanes that allow buses to travel efficiently along their routes without having to compete with other traffic. Low cost is the main consideration. Instead of costing from US$20 to $100 millions per mile like Light Rail Transit (LRT) or conventional metros, the BRT systems can squeeze out similar peak passenger capacities for only around $5 millions per mile. Thus, more countries like Jakarta, Indonesia and Quito, Ecuador are introducing this BRT approach, rather than the subways, due to the financial concerns. The success of the bus-based rapid transit projects in Brazil and other countries has attracted the interest of officials in the US Federal Transit Administration (FTA). The FTA's BRT initiative program, created in 1999, provides grants to agencies to explore BRT options. More than fifteen cities in the United States have been granted to build new BRT systems.

However, like the conventional bus systems, the BRT vehicles are subject to signal delays at the signalized intersections. To further facilitate the movement of the transit vehicles passing through the intersections, adoption of Transit Preemption Signal (TPS) has become an important operational strategy associated with the BRT systems design. It can be anticipated that implementation of a properly designed TPS strategy will effectively reduce the delays of transit passengers at intersections. Moreover, other benefits include: the enhancement of bus schedule reliability, the reduction in bus travel times, the reduction in unnecessary stops leading to increase the passengers riding comfort, curtailing the maintenance costs of bus equipments and pavement, and reducing the bus emissions and fuel consumption. Ultimately, an increase of competitiveness of transit over low occupancy vehicles can be anticipated. However, TPS can also cause remarkable negative impacts on the traffic from competing approaches. Without detailed evaluation and careful design for the signal timing, the benefits of TPS may be largely offset by its disadvantages.

While successful implementation of preemption signal for high occupancy vehicles has been practiced in Europe since 1968, the widespread installation of preemption signals in North America had not occurred. One reason is the lack of broad awareness of the cost-benefit (ITS America, 2004). It reveals that although preemption could be applied to provide priority to transit vehicles, the benefits and impacts of this action still needs to be carefully considered. Therefore, appropriate design of the control mechanism becomes an important issue if one intends to introduce the transit preemption signal control. However, although a variety of studies related to TPS have been conducted, only few of them have considered this issue so far (Jacobson and Sheffi, 1981; Chang *et al.*, 1996). Jacobson and Sheffi (1981) intended to minimize the total delays of cars and buses by optimally setting the signal timing with bus preemption strategies. Although the benefits and impacts had been both considered by these studies, the priority treatment is inactive. In other words, the timing plan is determined according to the historical traffic data regardless of whether a transit is present or not. Chang *et al.* (1996) presented an adaptive bus preemption control mechanism which made a phase switchover decision depending on the comparison of benefits between extending green phase and terminating it. The comparison was conducted on a performance index which consists of vehicle delay, bus schedule delay, and passenger delay. That is, this active control mechanism could evaluate both benefits and impacts by calculating the performance index of each time step. Although the abovementioned studies have included the evaluation of benefits and impacts in designing the TPS, a control mechanism with an active priority treatment which could appraise the entire system performance for the certain target duration is still an unexplored area.

In the recent years, Fuzzy Logic Controller (FLC), an expert system based on IF-THEN fuzzy rules, has been developed rapidly and successfully applied in control of complex process. It provides an approach to effectively conduct a control without need to know the exactly model formulation. In transportation related research, FLC has been applied to transportation planning (including trip generation, trip distribution, modal spilt, and route choice), selection of transportation investment projects, traffic control (including signal control for intersections, corridors and networks), accident analysis and prevention, level of service evaluation, aircraft control, and ship loading/unloading control (Teodorovic, 1999). Due to the complexity of trade-off assessment, the TPS control process is tough to be well modeled in precise mathematical equations. Therefore, this study attempts to employ the FLC to establish a novel active transit preemption control mechanism because of the excellent ability of the FLC in data mapping as well as in treating ambiguous and vague aspects of human perception and judgment.

A typical FLC system comprises four major components including rule base, data base, inference engine, and defuzzification. The methods used in the last two components of a FLC system, the inference engine and defuzzification, are rather consistent in previous literature; however, the methods for formulating the rule base and data base are too subjective. Without appropriately setting the rule and data bases, the performance of a FLC system can be greatly reduced and its applicability can be limited. Traditionally, the establishment of fuzzy rules and membership functions has been mainly based on the experts' control experience and actions. However, converting experts' knowledge into IF-THEN rules or fuzzy sets is difficult because the investigation result is often incomplete and conflicting. Therefore, the task of automatically defining the fuzzy rules and membership functions for a concrete application is considered as a significant issue and a large number of methods have been proposed to generate the involved algorithms from numerical data, making use of different techniques such as ad hoc data-driven methods (*e.g.* Bárdossy and Duckstein, 1995), neural networks (*e.g.* Nauck et al., 1997), fuzzy clustering (*e.g.* Babuška, 1998), genetic algorithm (GA) (*e.g.* Cordón et al., 2001), and ant colony optimization (ACO) (*e.g.* Casillas et al., 2000). In view of the powerful ability of GA and ACO for solving combinatorial optimization problems, this study aims to combine these two bio-inspired algorithms with a FLC to develop a Genetic Fuzzy Logic Controller (GFLC) and an Ant-Genetic based Fuzzy Logic Controller (AGFLC), respectively. By applying the GFLC and AGFLC, the TPS designed in the study could be controlled under the minimal total person delays with compromisingly selected fuzzy rules and tuned membership functions.

In this study, the proposed GFLC-based and AGFLC-based TPS models consider two state variables, traffic volumes in green phase and queue lengths in red phase, and one control variable, the necessity for giving priority to the actuated transit vehicles. Besides, two priority strategies including green extension and red truncation are adopted to implement the TPS at the signalized intersection. Furthermore, to investigate and compare the performance of the proposed models, exemplified examples and field cases are tested at an isolated intersection and then at two consecutive intersections along an arterial. The control performances for four control strategies – pre-timed signal without TPS, unconditional TPS, GFLC-based conditional TPS and AGFLC-based conditional TPS are compared.

1.2 Purposes and Scope

With the background and motivations mentioned above, the main purposes of this study are as followings:

(1) To develop a technique for TPS planners to carefully assess the benefit and impact of all users at the intersection.

(2) To develop an active TPS control mechanism with the consideration of all traffics at the intersection to minimize the intersection delay on a personal basis.

(3) To examine and compare the effectiveness and robustness of applying GFLC and AGFLC to TPS control at an isolated signalized intersection.

(4) To examine and compare the effectiveness and robustness of applying GFLC and AGFLC to TPS control along a signalized arterial.

There are many factors that affect the implementation of a TPS system, such as roadway geometry, traffic signal control system (including hardware and software), signal communication system, traffic detection system, transit system characteristics, and transit stop location and design. This study focuses on proposing a novel TPS control mechanism that could be integrated as part of the software of signal control system. The other components for implementing a TPS are assumed given and will not be discussed in this study.

1.3 Research Procedures

The research procedures is elaborated in the following and depicted in Figure 1-1.

(1) Problem identification

The first step is to identify the purposes and scope of this study, and to address problems which need to be explored.

(2) Literature review

The second step is to review the TPS related research. The methods, including FLC, GA, and ACO, used in this study are also reviewed. This step helps to realize the current state of development of transit preemption and to facilitate the theoretical modeling.

(3) TPS control logic and model development

A novel TPS control mechanism applying a FLC is formed first in this procedure. Then the models integrating GA and ACO into the FLC are developed and named as GFLC and AGFLC, respectively.

(4) Computational experiment and validation

To investigate the effectiveness of the proposed GFLC and AGFLC models, the TPS with the proposed GFLC and AGFLC is first implemented at an isolated intersection under an exemplified example and a field case. Sensitivity analyses are also conducted to examine the robustness of the proposed models. To generalize the implementation environment, the TPS with GFLC and AGFLC is then carried out along an arterial with two consecutive intersections. Similarly, an exemplified example, a field case, and sensitivity analyses of them are also conducted. In this procedure, the exemplified examples and field cases are simulated by the programs coded by the FORTRAN.

(5) Conclusions and suggestions

The major findings in the processes of model formulation and model validation will be summarized. The strengths and weaknesses of the proposed models will be thoroughly discussed. At last, some suggestions for future studies will be identified.

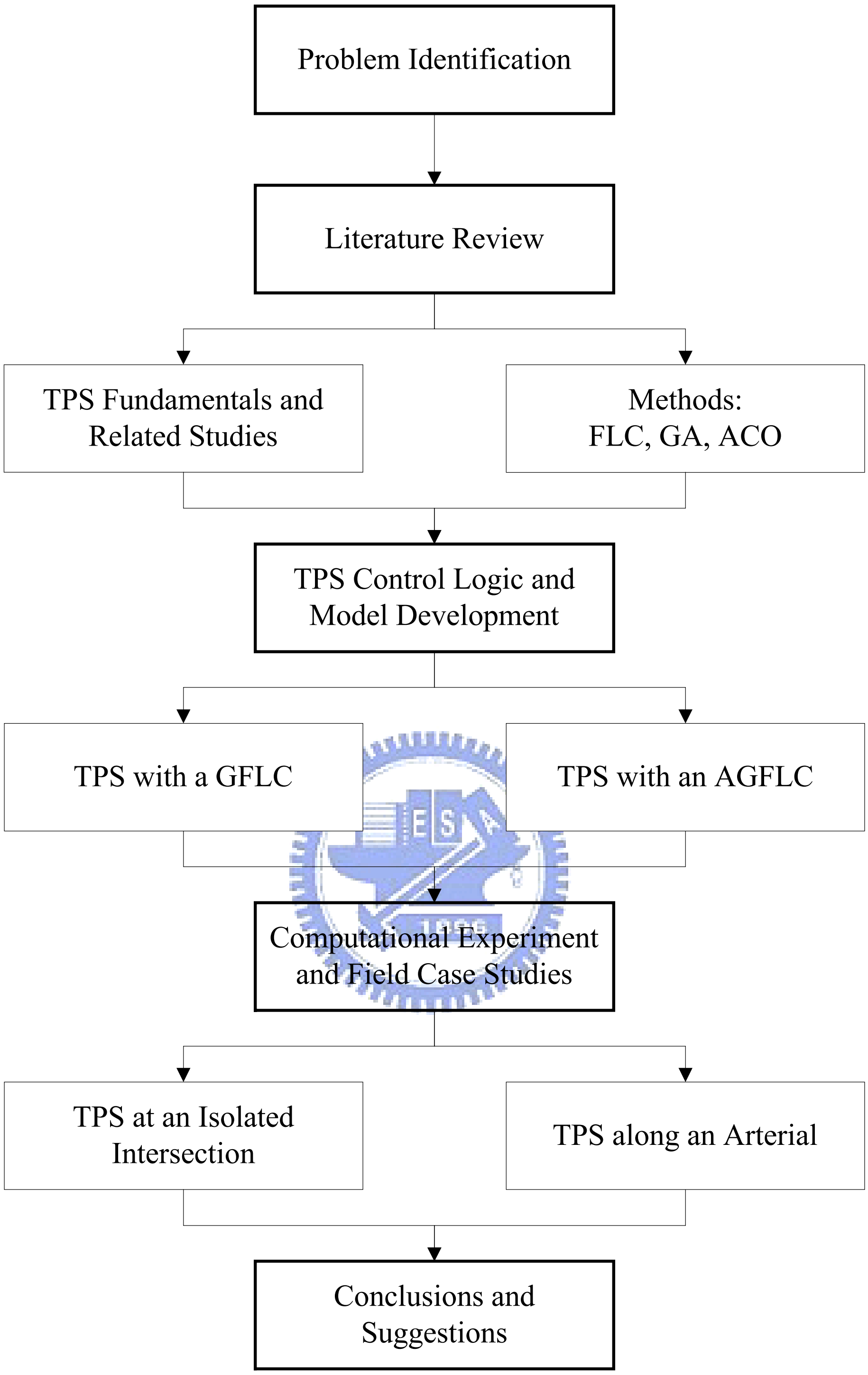

Figure 1-1 Research flowchart

1.4 Chapter Organization

This study is organized as follows. Chapter One explains the background, motivation, purposes and scope of this study. The research procedures are also described. Chapter Two conducts a thorough review of TPS fundamentals and related research. The methodologies, including FLC, GA, and ACO, are also briefly elaborated and reviewed. Chapter Three details the development of the proposed TPS control logic, GFLC, and AGFLC models. Chapter Four conducts the training and validation of TPS models respectively based on GFLC and AGFLC at an isolated intersection. An exemplified example and various sensitivity analyses are conducted to verify the robustness and effectiveness of the proposed models. A field case is also carried out to validate their applicability. Chapter Five further applies the TPS models respectively based on GFLC and AGFLC along an arterial under three different coordinated signal systems. Similarly, an exemplified example and a field case are also conducted. Finally, Chapter Six summarizes the conclusions and addresses issues for further studies.