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Research Article

An Overview of Staged-bus Operation in Cities

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Abstract: In developing countries, demand for passenger travel is higher, due to economic growth. Government policy encourages people to use public transportation instead of their private carsto reduce of traffic congestion and air pollution. In the city areas, bus networks are the major part of the public transportation system because they are easily accessible and cheaper compared to other types of public transportation. In this study revelation of details of bus operation included different agents is studied. Bus operations, during provision of their service, have interaction with three main agents: bus agent, passenger agent and traffic agent. Study of the influence of each agent in bus operation is presented in this study, using the macroscopic way.

Keywords: Bus operation, dwell time, passengers, traffic, travel time

INTRODUCTION

Bus operations, during provision of their service, interact with three main agents: bus agent, passenger agent and traffic agent (Meignan *et al*., 2007; Hafezi and Ismail, 2011a). Bus networks characteristics include several components: system performance and level of service (Vuchic, 1981; Hafezi and Ismail, 2011b). Bus service may be of one type or a combination of them, such as: local, express, feeder and commuter (Wirasinghe and Ghoneim, 1981; Hafezi and Ismail, 2011c). Bus service performance measurement is based on unit departures per hour (Vuchic, 1981). This is achieved through the valuationof the following parameters (Hafezi and Ismail, 2011d).

Service frequency: is the period buses are in motion during their mission, throughout the day (Sinclair and Van Oudheusden, 1997). It is the main issue in increasing reliability. Proper headway of buses along the route can reduce delays in arrivals of buses at each stop (Chua, 1984; Lin and Ruan, 2009). Operating speed: is defined as average speed in total traveling time. Reliability: is expressed as a percentage of vehicle arrivals with less than a fixed time deviation from the schedule. This depends on traffic conditions along the route. Safety: is measured by the number of fatalities, injuries and accidents. Line capacity: is the maximum number of spaces (seats and standing space). Productive capacity: is the product of operating speed and capacity of the line. Productivity and utilization: are the quantity of output per unit of resource space-km and ratio of output to input person-km/space-km. The main purpose of this study is to describe the influence of each agent against three benchmarks, namely, terminal, bus stop and bus route (between bus stops), together with in-bus services. For each benchmark in bus operations, behaviour of these three main agents will be studied, using the macroscopic method.

DETAILS OF BUS OPERATION

In this section revelation of details of bus operation obtained by data collection that in fact it is different between actual and virtual operation is presented. Bus operations, during provision of their service, have interaction with three main agents: bus agent, passenger agent and traffic agent. Study of the influence of each agent in bus operation is presented in this section, using the macroscopic way.

Bus agent: Buses have an important role in bus operation. Behaviour of buses can be effective in helping proper implementation of the bus scheduling model and vice versa (Hafezi and Ismail, 2012). Bus agents are influential in headway, frequency, dwell time, running time, etc., (Ismail and Hafezi, 2011). The details of the bus agent in total bus operation are as shown in Fig. 1.

Origin and destination terminals for buses are off-street areas with stops for several bus routes and where there is palace for recovery time. Recovery time is one part of the bus operation schedule. There are two main issues in recovery time: first is the crew rest. The

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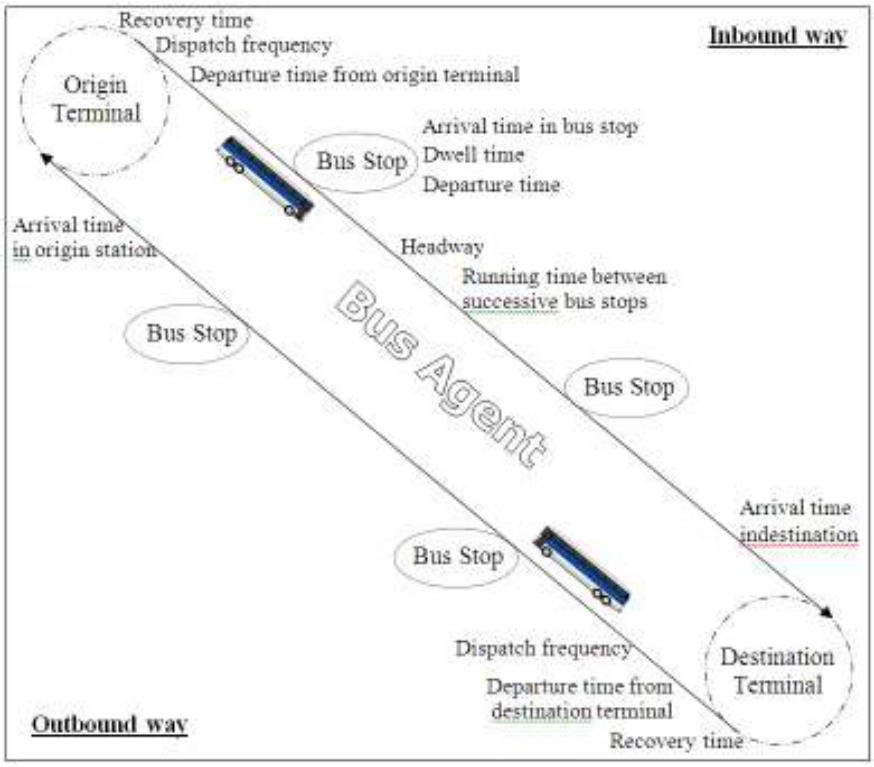

Fig. 1: Interaction of bus agent in bus operation

drivers need to take a rest break between missions during the day (usually there is a "swing" room for drivers in the central terminal). And second is schedule adjustment. The rule of thumb for the total recovery time is about 10% of the round-trip time.

Dispatch frequency is obtained by several general parameters: total trip-time in both directions, demand of passengers and recovery time (Ismail *et al*., 2012a). Trip-time includes the journey time between bus stops and dwell time in each bus stop along the bus routes. Journey time is dependent on average velocity of the bus during operation in the whole of the bus route. This time includes running time and stop time during traffic lights and on interaction with other vehicle traffic. Dwell time is slack time for boarding and alighting passengers at bus stops (Ismail *et al*., 2012b).

Departure time from origin terminal is the first step in bus scheduling for start of neo-mission. Actually, this time is calculated by total time between bus arrivals after completing their mission in the origin terminal and recovery time. It is better to consider the time between rest room and buses parking. Furthermore, it includes waiting time in origin or destination terminal for boarding passengers and fare collection. Because, in real implementation of the bus schedule, the departure time is a fixed time that buses begin their mission and move to the bus route, without any other stop in the main terminal.

Arrival time in the main terminal is the time after alighting all passengers from the bus and arrival in a parking space. Usually, buses alight passengers in the last bus stop and come to the terminal with no passengers. Generally, arrival time in the main terminal is calculated by the difference between time departure time and recovery time. Arrival time at the bus stop is equal to arrival of buses at the station and making a complete stop there. Usually, between entry of buses into the station and complete stop, there is a time lag. It occurs due to different factors, namely, higher demand of passengers, or blocked stop space with other vehicles or buses.

Dwell time is the stop time of buses at the station for boarding new passengers and alighting passengers who want to leave buses because they have reached their destination. Furthermore, bus drivers use this time for fare collection. Fare paying is possible in three ways: cash, touch-n-go card and ticket. Cash payment compared to other payment ways takes more time and around 10 to 15 sec. With this method, passengers can pay the fare on two occasions: when they board the bus and when they alight from the bus. In comparison, Touch-n-go card takes less time and around 4 sec. This way is the best way for decreasing dwell time in the stations. For shorter routes that include only one zone, passengers use touch-n-go card once only, but, in longer routes where calculated fare amount is based on

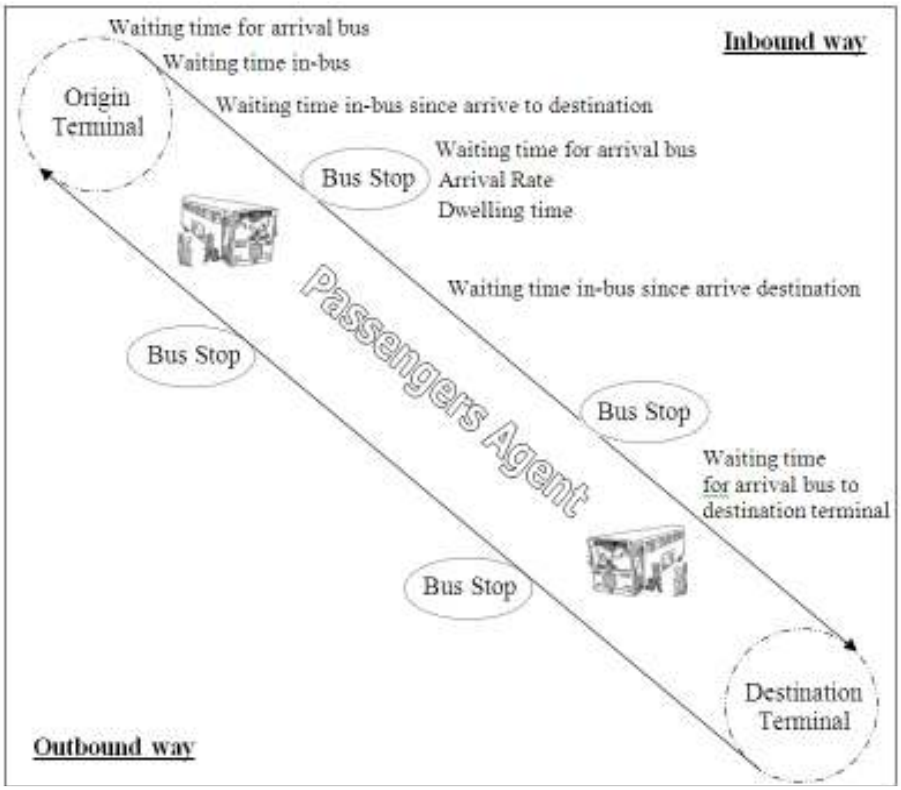

Fig. 2: Interaction of passengers agent in bus operation

zone, passengers use the touch-n-go card twice: when boarding the bus and when they alight from the bus. The last way for fare payment is use of a ticket. Usually, passengers can obtain the ticket in the main station. And in some cases, they can obtain one inside the bus from the bus driver, but in this situation it takes longer. Also, the ticket sold is based on bus route zones. Departure time from the bus stop begins after closing the bus doors and entering the bus route. The process happens after finishing alighting and boarding passengers, fare collection and time lag duration prior to exit of the bus from the bus stop.

Headway of buses along the bus route is obtained by the difference between arrival times of two consecutive buses at the bus stop. The time is not uniform, but varies in line with bus frequency. The most variability of bus headway occurs during rush traffic period, where buses cannot keep the optimum frequency due to traffic congestion and higher demand of passengers. Normally, headway of buses is considered as a fixed time for passengers. Running time between successive bus stops is the difference between departure time of bus from the previous station and arrival time at the next station. It includes time to move and stop along the bus route due to traffic congestion and traffic lights. Instantaneous speeds and acceleration rates are the main parameters in running time, because, their variability directly affects average velocity of buses and subsequently results in increased or decreased running time.

Passenger agent: Passenger agent is effective in two situations in bus operation: in-station and in-bus. Behaviour of passengers in-station includes waiting time for bus arrival and boarding. Behaviour of passengers in-bus includes wait time since arrival at destination and fare payment. Figure 2 represents the details of passengers agent in total bus operation.

In some places, the buses parking space is near to the main passenger station, where passengers are waiting to board the first bus that it is ready to start its journey and join the bus route. In this situation, there is only fare collection time before starting neo-mission. Passengers wait in-bus prior to arrival at their destination. It is possible they may alight between bus stops, or continue traveling until destination terminal. In this situation, the load factor is always high due to crowding of buses. Furthermore, operation with full capacity will take more time and passenger satisfaction is low.

Passengers' waiting time at bus stop is divided into two levels: waiting time for alighting passengers who wish to leave the bus and waiting time for boarding the bus and paying the fare. To organize passengers, a

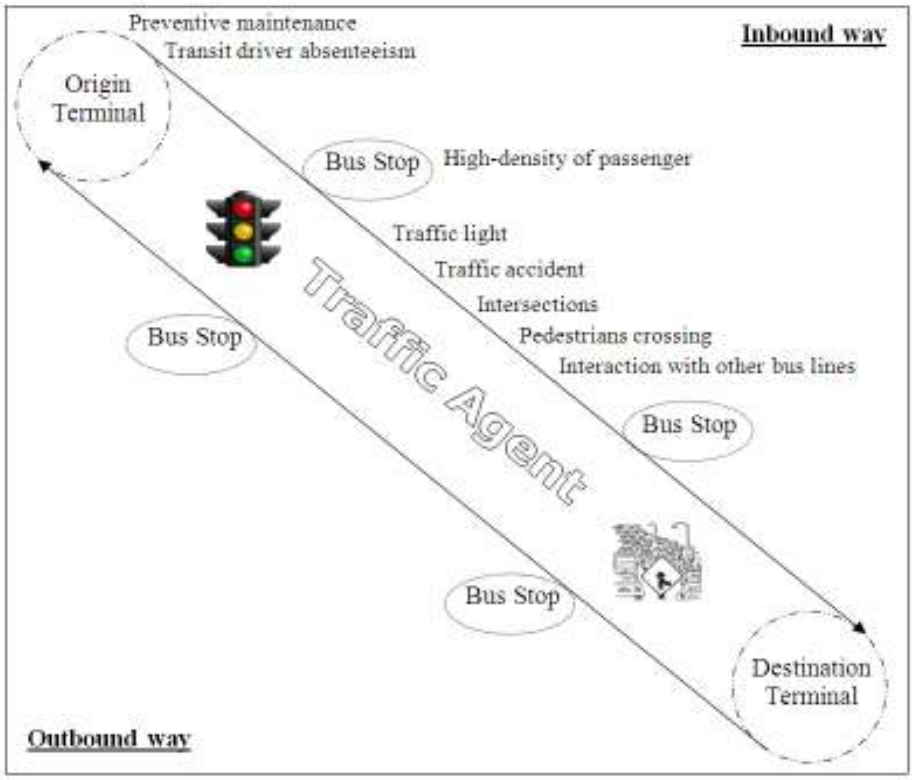

Fig. 3: Interaction of traffic agent in bus operation

metal framework in each bus stop is used. Some bus stops are shared stops with other lines. These stations are larger compared to the non-shared ones. In a new system of bus operation called Bus Rapid Transit (BRT), there is a place for paying fares (touch-n-go card or cash) before boarding to buses. This method can minimize dwell time in-station. Furthermore, separate channels for boarding and alighting passengers can decrease dwell time in-station.

Arrival rate of passengers is obtained by dividing total number of boarding passengers by headway. Arrival rate of passengers is a coefficient parameter that is obtained by considering some factors such as: geographic coverage of station, single or share station and time of operation. Overall, by increasing value of headway, demand of passengers will be increased. Indeed, demand patterns of passengers are dependent on operation time. This value is variable in line with different operation times in the day. It is higher in the morning when travelers want to go to their office and also it is higher in the afternoon when travelers come back to their domicile. In this situation, the Transport Company is forced to add extra buses to bus services for improving bus headway.

Traffic agent: Interaction of traffic agent in bus operation depends on operation time. During rush traffic hour it plays an important role in variability of instantaneous speeds and acceleration rates of bus speed that subsequently causes disruption of the bus schedule. The details of traffic agent in total bus operation are as shown in Fig. 3. Lack of fleet size during creation of the implementation schedule is a major problem in disruption of the bus schedule, due to preventive maintenance or transit driver absenteeism. Furthermore, vehicles under maintenance take up bus parking space. Usually, Bus Companies keep several spare buses or additional bus drivers as one area of their services, covering several bus lines. In addition, they can add spare buses to crowded bus lines during rush traffic period, for improving reliability.

There is a high-density of passengers in the bus stations during rush traffic period. This issue can cause dwell time. Furthermore, in the shared bus stops, where they are shared with other bus lines, density of passengers is high. Design of these bus stops should be such that there is enough space for passengers, in order to decrease time lag for entry and exit of buses from bus stops. Traffic lights can also cause disorganization of the bus schedule, where, timing of red lights and arrival time of buses at traffic light do not coincide. Also, location of bus stops has an effect on passing or stopping of buses at the traffic lights. In the routes, where there are two traffic lines, accidents can cause heavy traffic. Subsequently, this has a bad effect on bus operation. Main and subsidiary intersections along the bus route will increase bus stoppages and eventually velocity of buses will be reduced due to decreased average bus speed. Lack of pedestrian bridges for

passengers crossing the width of the street can also cause stopping of the bus. It is better that buses use side streets, due to existing bus stops in side streets and lower average velocity of buses compared to other vehicles.

CONCLUSION

In this study, three agents of bus operation, namely, passenger agent, bus agent and traffic agent have been presented. We have shown that the influencing parameters in bus operation in three different benchmarks such as: demand of passengers, traffic flow and dwell time. Study of the influence of each agent in bus operation is presented in this study, using the macroscopic way. It was detected that bus agents are influential in headway, frequency, dwell time, running time; passenger agentis influential in waiting time for bus arrival and boarding; and traffic agent is influential in travel time, running time and recovery time in the bus operation.

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