ESTIMATING AVERAGE TRAVEL TIMES FROM BUS TRAVEL TIMES

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Abstract—This paper is to estimate the average travel times of roads from bus travel times and to examine the possibility of using buses as probe cars for collecting the average travel times. Several estimation methods of average travel times from those of buses are examined and developed. From field data, those models are calibrated and the average travel times are estimated. Through a statistical comparison between the estimated travel times and the observed travel times of average cars, these estimation methods and the possibility of using buses for probe cars for collecting the average travel times are evaluated. It turned out that estimating average travel times from bus travel times is quite reliable and, therefore, using buses as probe cars for collecting average travel times can be practical.

Keywords—Bus, Probe car, Travel time, BIS (Bus Information System), AVI

1. INTRODUCTION

The purpose of this paper is to estimate the average travel times of roads, which are the most necessary information for many travelers, from the bus travel times on the same roads. Recently, as the ITS technologies including traffic data collection technologies have been improved and the people's desire for the information of traffic situations, the necessity for collecting average link travel times has increased. Also, these link travel times are effective measures for traffic control.

The most typical way of collecting travel time data is to run probe cars. In several cities in the world, this way of travel time collection is being used such as EURO-SCOUT, SOCRATES, Traffic Master, ADVANCE, etc. However, it is very difficult as well as costly to collect link travel time data by running privately-owned passenger cars as probe cars.

In many cities in the world, Bus Information System (BIS) is under operation. Alternatively, if average travel time data can be collected from these buses in BIS, which run on most arterials with certain frequencies, the cost of running probe cars can be saved a lot.

However, the bus travel times are different from the average travel times of traffic flows because of many factors. Bus vehicles have different maneuverability from average cars and they should stop for unloading and loading for passengers at bus stops. In addition, buses operate on bus preferential right-of-ways in many cities.

If we can estimate the link travel times of average vehicles from the bus travel times considering these differences, no additional system for collecting link travel times will be necessary. In other words, buses of BIS can be utilized as effective probe cars.

This paper is to estimate the average travel times of roads from the bus travel times on the same roads and to examine the possibility of using buses for probe cars for collecting the average travel times. Several estimation methods of average travel times from those of buses are examined and developed. From the data collected from a field study, those models are calibrated and the average travel times are estimated. Through a statistical comparison between the estimated travel times and the observed travel times of average cars, these methods of estimation and the possibility of using buses for probe cars for collecting the average travel times are evaluated.

2. TRAVEL TIME COLLECTING SYSTEMS

Link travel times are difficult to collect by conventional point-based vehicle detectors such as inductive-loop detectors, supersonic detectors, etc. Several methods are available for collecting these data. However, they can be grouped into two methods by-and-large. One is to estimate average link travel times from the data collected by point-based vehicle detectors, which are the traffic flows, occupancies, and speeds at the points of detectors installed.

The other is to run probe vehicles. Automatic vehicle locating (AVL) is necessary here with GPS receivers, beacons or others. Link travel times can be calculated either in probe vehicles or at the center. Locations of probe cars with their times allow to calculate travel times (or travel speeds) between two points along roads. Location data of probe vehicles with their times can be sent to the center and link travel times can be calculated at the traffic information center (central computing). The center can extract travel times from these data. Or link travel times can be calculated in probe vehicles and these can be sent to the center (local computing). Sending these travel times to the center via communications, the travel times of the probe vehicles can be obtained.

Basically, there are two kinds of AVL technologies. One is beacon technology and the other is GPS technology. Beacon technology is to communicate between probe cars and roadside beacons. Beacons can send their locations to the probe cars, which communicate with the center for either local or central computing of travel times. Alternatively, probe cars have their own identifications and send these to roadside beacons, which communicate with the center for either local or central computing of travel times. For the central computing, the beacons send location data of probe vehicles with their identifications in real-time basis to the center. For the local computing, the beacons calculate travel times of probe vehicles and send these travel times to the center. Communicating technologies between probe cars and center or between beacons and center can be either wired or wireless.

GPS technology is to locate probe cars with GPS receivers installed in probe cars. These location data (for the central computing) or calculated travel time (for the local computing) can be sent the center with wireless communication directly or via beacons on roads sides indirectly. The wireless data communication technology is widely used for the communication between probe cars and the center. In case of the through-beacon communication, communication between beacons and the center can be either wired or wireless, but wired communication is widely used.

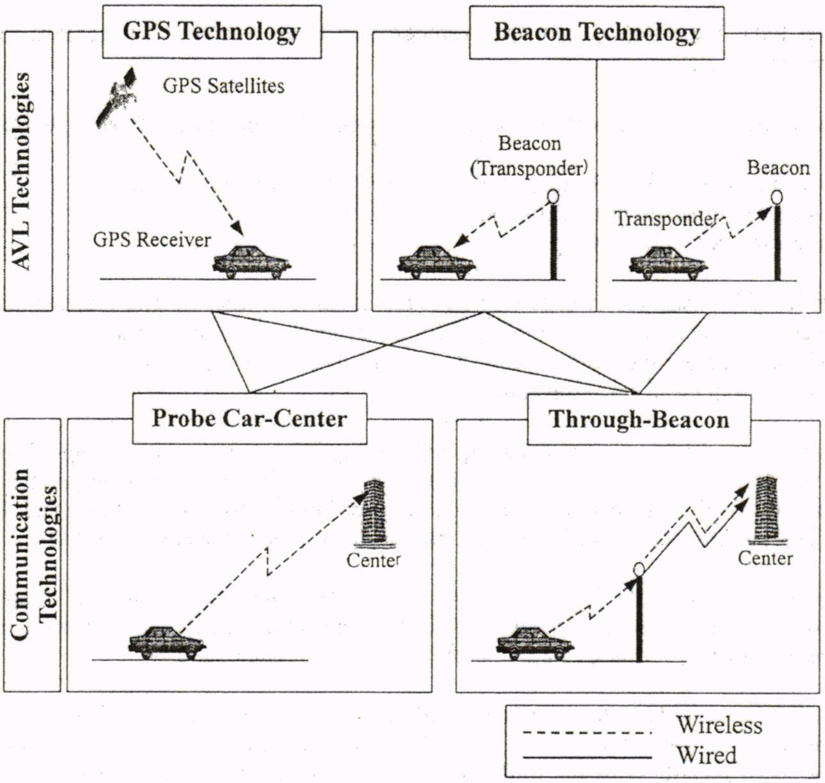


Figure 1. Technologies of BIS system

However, these two methods for collecting link travel time data costly in general. Running many probe cars necessary to collect reliable travel time data is very costly. An alternative way to collect link travel time data is estimating link travel time data from bus travel time data. In many cities in the world, including Seoul, Korea, "BIS (Bus Information System)" is facilitated, which is a part of APTS (Advanced Public Transportation Systems) in ITS. Most of these systems have automatic vehicle locating function in real-time basis and bus travel times can be obtained easily, which are different from the link travel times of average vehicles. If we can estimate the link travel times of average vehicles from the bus travel times, no additional system for collecting link travel times will be necessary. In other words, buses of BIS can be utilized as effective probe cars.

In this paper, several estimation methods of average travel times from those of buses are examined and developed. These include a regression model and neural network model. In order to verify these methods, a field study was performed to collect the travel time data of buses and average vehicles (mostly passenger cars) in the same sections of roads. Parameters are calibrated with these data and the results of estimation are compared statistically.

3. BUS TRAVEL TIMES

Bus travel times are different from the average travel times of roads. The reasons for the difference are as follows

- Bus vehicles have different maneuverability from the average cars, typically passenger cars.
- Buses should stop for unloading and loading for passengers at bus stops.
- Buses operate on bus preferential right-of-ways in many cities.
- Buses have schedules to keep.

Bus vehicles differ from the average cars on roads in terms of size, weight, propulsion, fuel, etc. These cause different maneuverability from the average cars, such as speed, deceleration and acceleration capabilities, turning trajectories, etc. Therefore, bus travel times are subject to be different from the average travel times.

In addition, buses should stop for unloading and loading for passengers at bus stops. The time required for these processes is called "dwell time". This includes door opening and closing times, passenger unloading and loading times, acceleration and deceleration times, etc. Dwell times of buses at bus stops make bus travel times different from the average travel times.

In many cities of the world, buses operate on bus preferential right-of-ways. With any bus preferential treatment, buses are able to operate faster than other vehicles. For example, on the exclusive right-of-way for buses, buses can travel faster than other vehicles.

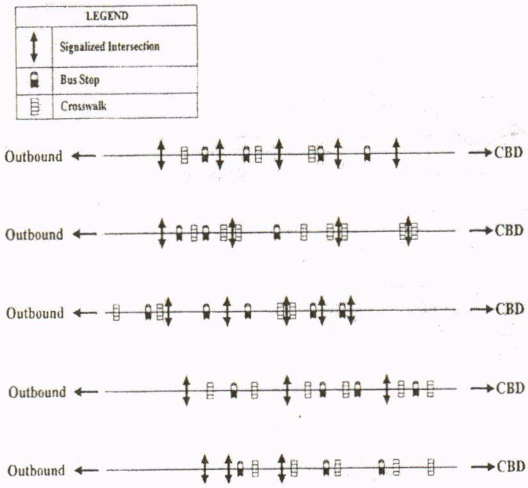
Some buses run according to a certain schedule. Buses may have scheduled arrival and departure times to keep at each bus stop. Then, bus drivers will try to control the bus operating speed regardless of the traffic situation. However, in case of delayed operation, speeding up to keep the scheduled operation times may not be possible due to the traffic congestion.

Many other factors including the above factors cause bus travel times to differ from the average travel times of roads. Therefore, due to this difference between buses and average cars, bus travel times cannot be used to determine average travel times directly and some estimation processes to get average travel times are required.

4. DATA

In order to get a data set of bus and average travel times, sections of 5 streets are selected. These streets are Mangwooro (St. #1), Youngdeungporo (St. #2), Daebangro (St. #3), Hanchunro (St. #4) and Chungparo (St. #5). Among these, St. #1~3 are provided with bus exclusive lanes.

A field study was performed by videotaping license plate numbers of vehicles at the starting and ending points towards CBD direction. Also, traffic volumes by vehicle type are counted. Observation times were morning and afternoon except for St. # 3 (morning only). Observed data was manipulated into a format of 5-minute average values (travel times, traffic volumes, etc.)



St. #	Length (Km)	Bus Exclusive Lane	No. of Bus Stops	No. of Signalized Intersections	No. of Crosswalks
1	2.5	O	4	4	3
2	2.0	O	3	4	8
3	2.0	O	5	5	4
4	2.0	X	4	3	6
5	1.7	X	3	3	5

Figure 2. Field Study Summary

The average travel times and bus travel times in terms of 5-minute-averages are plotted in Figure 3. Table 1 shows some statistical values of travel times such as average and standard deviation.

In general, buses travel faster than average cars with bus exclusive lanes. However, from this initial summary of travel time data, any certain pattern of the bus travel times and average travel times cannot be identified. For example, on some sections of roads buses run faster than the average cars and on some other sections the reverse pattern is observation regardless of bus exclusive lane. In the section of St. # 3 with bus exclusive lane, buses travel slower than the average cars. This implies that some other factors than the existence of bus exclusive lane affect bus travel times.

■ St. # 1: <Morning>

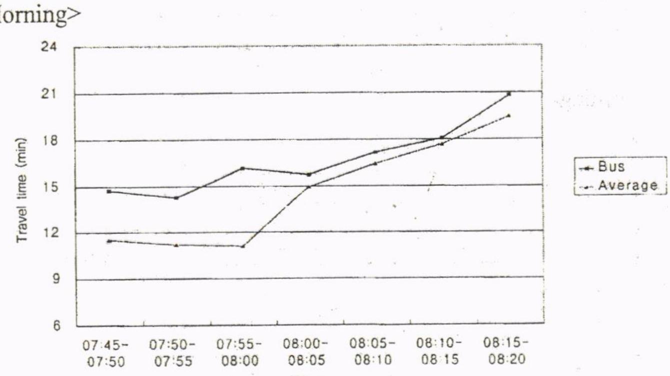
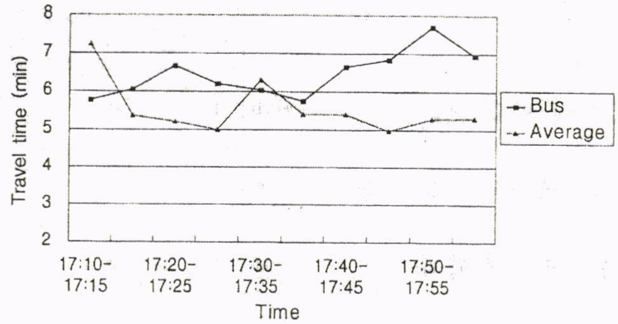
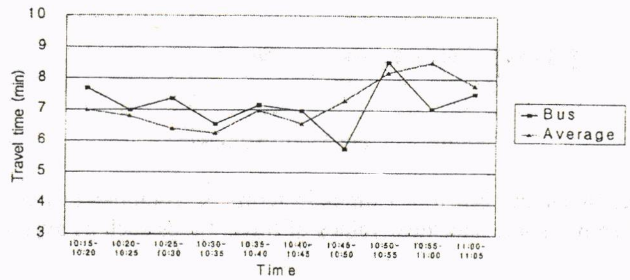


Figure 3. Bus Travel Times and Average Travel Times

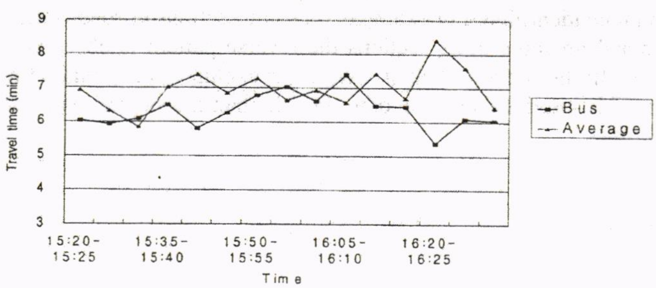
■ St. # 1: <Afternoon>



■ St. # 2: <Morning>



■ St. # 2: <Afternoon>



■ St. # 3: <Morning>

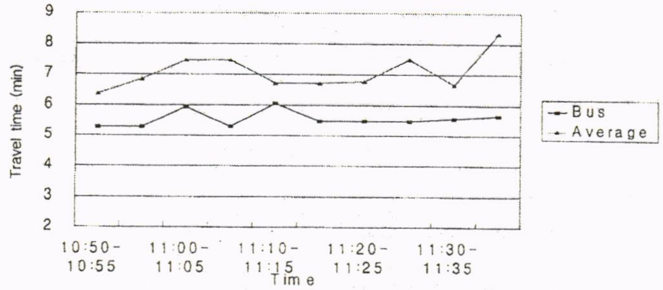
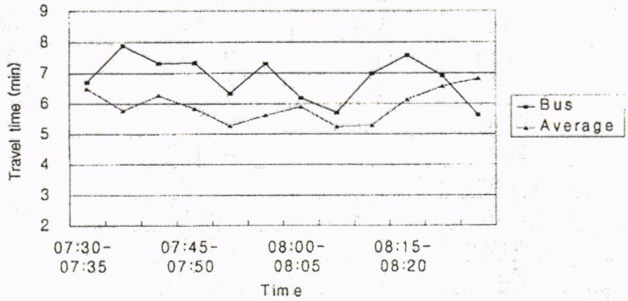
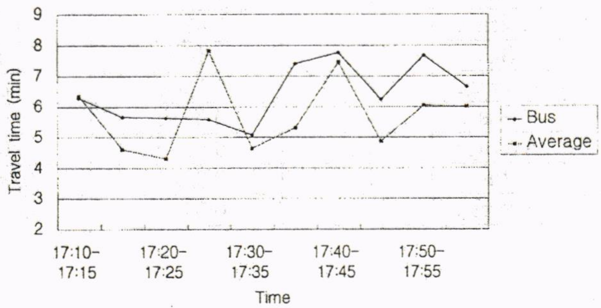


Figure 3. Bus Travel Times and Average Travel Times (*Continued*)

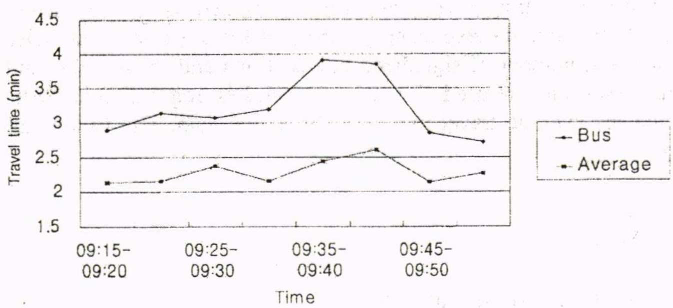
■ St. # 4: <Morning>



■ St. # 4: <Afternoon>



■ St. # 5: <Morning>



■ St. # 5: <Afternoon>

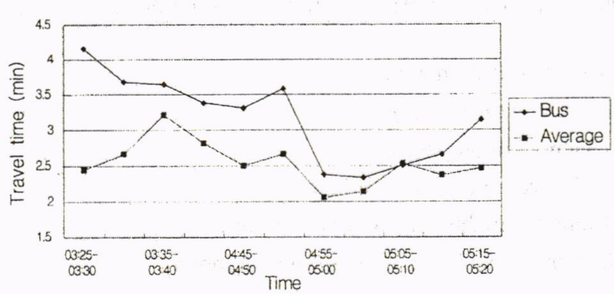


Figure 3. Bus Travel Times and Average Travel Times (*Continued*)

Table 1. Summary of Field Data

Street	Time	Vehicle	No. of Observations	Average Travel time(hrs)	Standard Deviation
St. # 1	Morning	Bus	364	0.2546	0.004048
		Average	1164	0.2437	0.004905
	Afternoon	Bus	281	0.1076	0.000094
		Average	877	0.0924	0.000122
St. # 2	Morning	Bus	114	0.1192	0.000147
		Average	1448	0.1196	0.000166
	Afternoon	Bus	154	0.1053	0.000071
		Average	2044	0.1158	0.000105
St. # 3	Morning	Bus	172	0.0926	0.000020
		Average	1117	0.118	0.000097
St. # 4	Morning	Bus	95	0.1137	0.000146
		Average	1116	0.0988	0.000079
	Afternoon	Bus	34	0.1091	0.068770
		Average	482	0.1063	0.000923
St. # 5	Morning	Bus	42	0.0532	0.000044
		Average	832	0.0369	0.000009
	Afternoon	Bus	25	0.0527	0.0001031
		Average	1042	0.0422	0.0000278

5. ESTIMATIONS

Many methods for estimating travel times can be applied to estimate average travel times from bus travel times. For the explanatory variables for developing models, traffic volume, number of bus stops, number of signalized intersections and crosswalks, and time of day in addition to bus travel time are used. Two types of models, regression and neural network, are used to estimate the average travel times for the above data. The followings describe these models briefly.

5.1 Regression Model

The regression model developed is as follows.

$$T_a = -0.082 + 0.927\, T_b + 0.018\, N_{bs} + 0.0003\, Q - 0.0045\, d_e + 0.038626\, d_t \qquad (1)$$

where T_a = Average travel time (min.)

T_b = Bus travel time (min.)

N_{bs} = Number of bus stops

Q = Traffic volume (veh/5min-lane)

d_e = Dummy variable for exclusive bus lane

d_t = Dummy variable for morning and afternoon

5.2 Neural Network Model

Among various Neural network models, the best one was chosen, which estimates the average travel times most closely. The input variables of the model are bus travel time, traffic volume, number of bus stops and dummy of morning-and-afternoon. The number of hidden layers is 2. The back-propagation algorithm is used for learning and the number of learning times is 30,000. The following table shows the model structure.

Table 2. Structure of Neural Network Model

Input Variables	Output
$T(B, l_{AB})$ = Bus Travel Time $Q(C, l_{AB})$ = Traffic Volume S_B = Number of Bus Stops $D(1/0)$ = Dummy of Morning-and-Afternoon	$T(C, l_{AB})$ = Average Travel Time
α = 0.7 β = 0.1 Hidden Layer 1 = 4 Units Hidden Layer 2 = 3 Units N = 30,000	

5.3 Results

The following figure shows the result of the estimation through the calibration of models. Also the observed travel times are shown in the figure. The figure shows that the estimation results are quite reasonable.

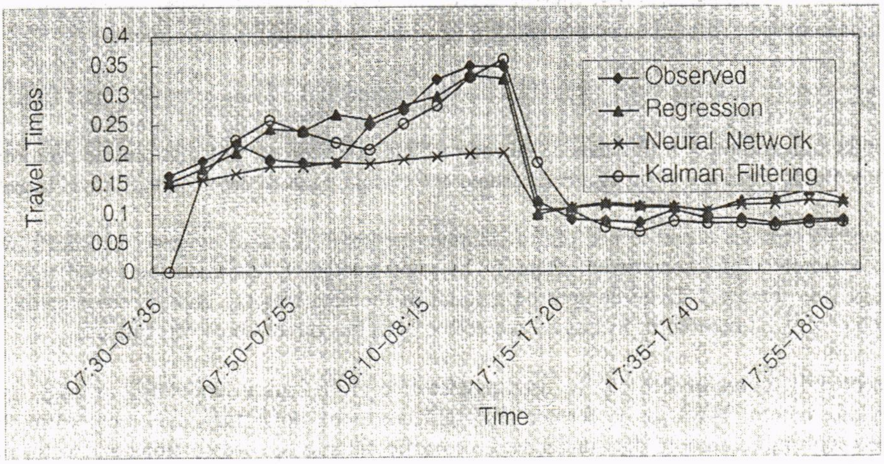


Figure 4. Observed and Estimated Travel Times

6. EVALUATION

Table 3 show the results of statistical comparison between models in terms of MARE (Mean Absolute Relative Error), MAE (Mean Absolute Error), RMS (Root Mean Square), and R^2. The results show that all models estimate the average travels times statistically well.

Table 3. Statistical Comparison of Models

Model	MARE	MAE	RMS	R-square	T
Regression	0.217567	0.027876	0.03365	0.86023	0.061444
Neural Network	0.233514	0.043505	0.06211	0.52395	0.102435

Especially, the multiple regression model turns out to be more powerful than the neural network model. In the regression model, the most influential variables in estimating the average travel times from the bus travel times turn out to be the traffic volume and number of bus stops as well as the bus travel time.

The neural network model is less powerful than the multiple regression model. But, this model results in good estimation of the average travel times. The result shows that the neural network model is estimating the average travel times fairly well under low traffic volumes.

7. CONCLUSIONS

Many buses are operated in most cities of the world, including Seoul, Korea. If these buses are equipped for BIS and can be used as probe cars, it will be a very effective way of collecting traffic information such as link travel times. BIS is a system for bus management and information with AVL equipment package. Bus travel times for links or some sections of roads can be collected with BIS easily. Buses can be easily managed and are economically efficient probe cars because they operate according to their schedules regardless of collecting traffic information without an additional cost or with a very minimal investment.

The key feature of using buses as probe cars is to estimate the average travel times from bus travel times. However, this task is turned out to be a manageable job practically. Several methods are examined in this paper. Through a field study of travel times and calibration of models, the average travel times are estimated and compared with the observed travel times.

Most of the models tested turned out to estimate the travel times of average cars fairly well. Even a simple regression model seems to be good enough to estimate the travel times of average cars precisely. Even though the amount of the data was not enough statistically, the potentiality of estimating the average travel times from bus travel times was proved.

Consequently, buses of BIS can be used as effective probe cars in collecting average travel time information. However, a further research has to be done for developing estimation models with more amount data under various traffic situations, road sections and with more detailed explanatory variables.

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