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A STUDY TO ANALYZE LANE-BY-LANE TRAVEL TIME CHARACTERISTICS

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ABSTRACT

This study aims to develop a tool equipped in a vehicle for observing the lane-wise travel time and to analyze the lane-by-lane travel time using the data from the developed tool. For this purpose we developed a vehicle-attachable lane-wise traffic observing device, named TTMon which is capable of recording the vehicle trajectories as well as the video data of driving environment. Two probe vehicles equipped with TTMon drove the Gangbyun highway from Sungsan-bridge to Dongho-bridge keeping each lane, one for the median lane and the other for the center lane. With the vehicle trajectories and video data collected by TTMon, the lane-by-lane travel time feature was analyzed using TTMonAnalyzer specially developed for handling data from TTMon. The result shows that the space mean speed of the median lane is lower than the center lane because of the higher number of connected ramps on the median lane causing many conflicts in the weaving sections and also the travel time difference between lanes is inclined to increase as the congestion goes higher.

Keywords: *Lane-by-lane travel time, Traffic Observation, Vehicle Trajectory, Probe Vehicle*

I. INTRODUCTION

Since the appearance of smartphones, the ATIS (Advanced Traveler Information Systems) market has been rapidly expanding, but the precision and accuracy of traffic information, which is most important in using the ATIS, has not satisfactorily enhanced. In particular, traffic information (speed, travel time, and congestion) has long been provided for one of the properties of links, based on a road network consisting of links and nodes. In other words, linear road has been segmented based on a specific facility on the road, the segmented section has been defined as a link, and the static and dynamic properties of the link are used for the management of traffic information. The problem is that the method does not take consideration of the number of lanes on the road and is based on the assumption that traffic conditions of all lanes are homogeneous. In fact, a lane is a carriageway with an independent right-of-way, divided by lane marking in the same road section, and accordingly, every lane has different traffic flow features such as speed, traffic volume, and density (Carter et al., 1999; Daganzo, 2002; Amin and Banks, 2005). If a lane is considered an independent object, the complexity of road networks will substantially increase, and therefore, instead, road has been simply assumed to be an object (link) with homogeneous features. As a result, tremendous progress has been made in technology of observing traffic information at the road level, but with no success at the lane level. In this regard, this research developed a device to obtain data on lane travel time, which is the most easily accessible traffic flow feature observed in a lane, and analyzed the lane-by-lane travel time on the continuous traffic road by utilizing the device.

II. DEVELOPMENT OF OBSERVATION TOOL

In this research, TTMon (Travel Time Monitoring Tool) was developed to analyze lane-by-lane travel time characteristics. TTMon is a mobile terminal-based lane-by-lane traffic information observation tool easy to attach to and detach from the vehicle. The device was developed in a form of mobile terminal app and designed to work on the GPS-receivable iOS-based terminal. Its basic features include trajectory tracing, video recording, and replay of the stored trajectory and driving information. In addition, TTMon provides other features such as display of vehicle speed, driving direction, video-recording/replay of events, indication of the location (coordinates) on the map, and current time. Figure 1 shows the main screens of TTMon.

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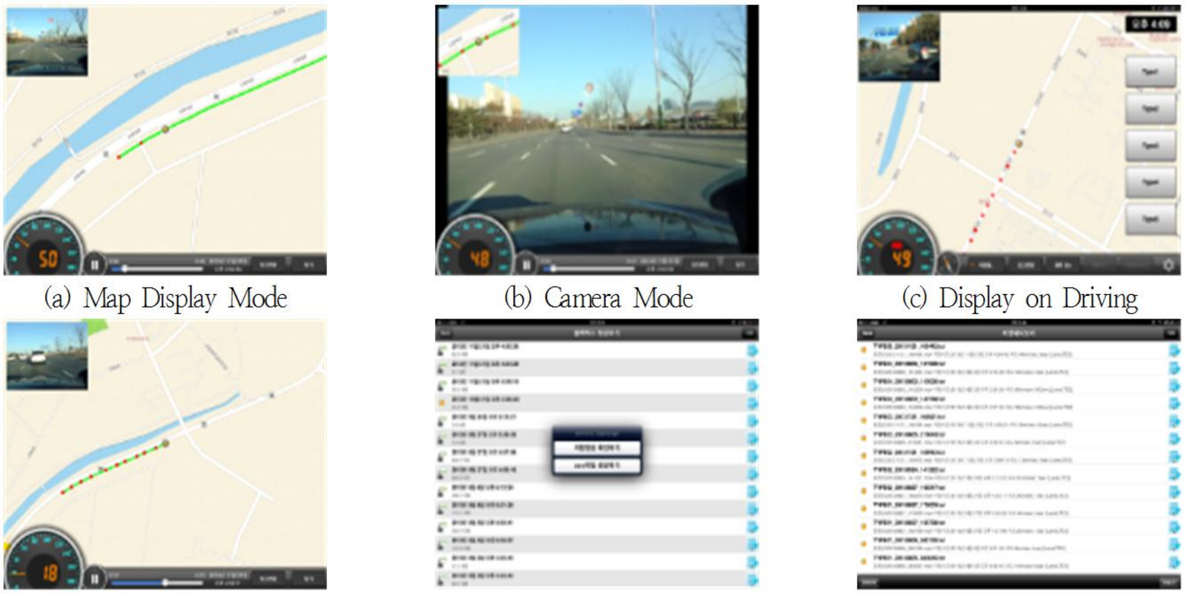

(a) Map Display Mode (b) Camera Mode (c) Display on Driving
(d) Trajectories in Play Mode (e) List of Stored Location (f) List of Coordinates

Figure 1 TTMon Display

When a vehicle with TTMon travels on a lane, the GPS coordinates are stored every second and video images of the lane ahead is recorded. At that time, trajectory, the stored GPS coordinates, is synchronized with video images temporally. The stored trajectory can be utilized for vehicle speed, deceleration changes, and location tracing and the driving video can be used for the monitoring of the traffic conditions according to the location and time of the trajectory. Stored information (such as trajectory and video) can be checked through the relevant list and replayed by selecting desired information from the list (Fig. 1-e).

To observe lane-by-lane traffic information, TTM supports two modes depending on the selected main screen. One is the map mode (Fig. 1-a), and the other is the camera mode (Fig. 1-b). In the map mode, map screen is the primary one and the camera screen is the secondary one, while in the camera mode, the other way around. Stored contents are the same in both modes. Users only can decide which one they see on the larger screen between map and camera. Besides the two modes, the device supports the black box mode to reduce the consumption of 3G'LTE data, and in the mode, as the map is not displayed, communications data is not consumed.

TTMon works on equipment with a GPS receiver, and it is because the main function of TTMon is to store trajectory of vehicles. Location information of vehicles received through a GPS receiver is stores in DB in real time, and it is expressed in trajectory (Fig. 1-d) at the time of replay. The vehicle is always located at the center of the map screen and when the vehicle moves, the previous locations of the vehicle are displayed in red dots. Through the sequential connecting of the dots, the trajectory of the vehicle is completed (Fig. 1-c). Camera continues to record the lane condition ahead, and the trajectory and video images are synchronized with driving time. Through the synchronization information, the location and video images of the vehicle is displayed at the time of replaying vehicle driving information.

TTM provides the user with an event key feature, which enables the use to save a specific event at the desired point. For example, when the user witnesses a traffic accident, the device can be used to save the location of the accident or the location of the diverging or merging area. Event information can be checked through the list and when the event is selected, the location, time, and relevant video images of the corresponding location can be checked (Fig. 1-f). Furthermore, the screen long-touch feature allows the user to acquire coordinates on the map.

III. ANALYSIS OF LANE-BY-LANE TRAVEL TIME CHARACTERISTICS

1. Collection of materials

When observing lane-by-lane travel time using TTMon, particular attention shall be paid in relation to the following. First, vehicles shall be assigned to each lane so as to observe all lanes. In other words, for the N-lane road, the number of vehicles with TTMon required is N. Before driving, the drivers must share information on the entire driving route. Unless the drivers fully understand the driving route, it is difficult to make accurate observation. In addition, the driver of each vehicle shall make sure about the starting and end points of the driving route and check the points through TTMon in advance. If there is any driver who is not clear about the starting and end points, or there is lack of sufficient information sharing among drivers, it may result in incorrect observation, which leads to the missing of information on the important section at the time of analysis. The actual driving route shall be set extensively to include both the starting and end points of the section very safely so that the driver can enter the road with a sufficient distance from the starting point and all the vehicles will be travelling on the assigned lane at the starting point. In case of an accident or other event, the event key stores the relevant information, which enables identifying the cause of the unexpected congestion.

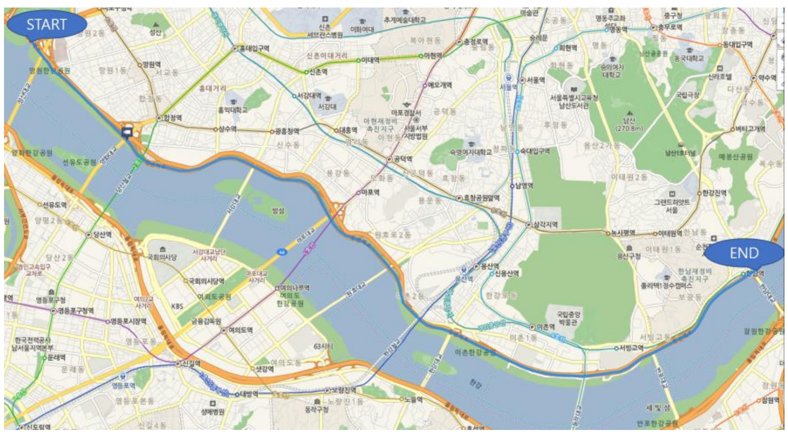

Figure 2 Target Road Section (source: Naver)

This research analyzed the travel time characteristics of the median lane and center lane of Gangbyun highway by using two vehicles. Target section was the eastern part of the highway, and starting and end points were Sungsan Bridge and Dongho Bridge, respectively. Observation starting time was 2:30 pm. Figure 2 shows the target road section. Since most of the bridges connected to the road section has access ramp linked to the median lane, the road section was suitable for analyzing changes of lane travel time depending on incoming and outgoing vehicles. The median lane was assumed to be affected by incoming and outgoing vehicles, and the center lane to be less affected, at the time of analysis.

2. Analysis of information

To analyze the information collected through TTMon, TTMONAnalyzer was developed as a separate analysis program. This program sets the anchor point file and vehicle trajectory file as input values and displays profiles of velocity for each section defined in the anchor file. TTMon saves the vehicle trajectory information as XML (Extensible Markup Language) file, and when selecting the trajectory information from the list, the information can be saved as a CSV file. Table 1 shows the name, example value, and description of each column of the vehicle trajectory information.

The target road section includes ten bridges, based on which, the entire road section (Gangbyun highway) was divided into nine sub-sections. Then, the coordinates of the starting and end points of each section were acquired through TTMon (Table 2), and the coordinates were saved in an anchor point file format to transfer to

TTMonAnalyzer. The driving trajectory information files for the median and central lanes were extracted through TTMon and the files were designated as input files for TTMonAnalyzer for analysis. As the result of analysis, section-by-section travel time, travel distance, and velocity were calculated.

Table 1Vehicle Trajectory File Format of TTMon

No	Name	Description
1	time	20130615_173222
2	longitude	127.1096261312506
3	lattitude	37.33164916749795
4	altitude	113
5	Location Accuracy	Accurate if the value is less than 80
6	velocity	10m/s unit
7	angle	360 degree azimuth

Table 2 Anchor Points

Sect No.	Section		Start Location		End Location	
	Start	End	Longitude	Lattitude	Longitude	Lattitude
1	Sungsan	Yanghwa	37.5570	126.8942	37.5464	126.9079
2	Yanghwa	Seogang	37.5464	126.9079	37.5429	126.9290
3	Seogang	Mapo	37.5429	126.9290	37.5366	126.9414
4	Mapo	Wonhyo	37.5366	126.9414	37.5298	126.9513
5	Wonhyo	Hangang	37.5298	126.9513	37.5216	126.9615
6	Hangang	Dongjak	37.5216	126.9615	37.5160	126.9833
7	Dongjak	Banpo	37.5160	126.9833	37.5191	126.9944
8	Banpo	Hannam	37.5191	126.9944	37.5296	127.0108
9	Hannam	Dongho	37.5296	127.0108	37.5398	127.0186

3. Analysis of travel time

Figure 3 shows the changes in the travel time and speed depending on driving distance on the median and central lanes by road section. The space mean speed of the median lane was 55.9kph, and that of the central lane was 58.9kph. Section-by-section travel time was higher on the central lane in all the sections except for 2^{nd}, 8^{th}, and 9^{th} sections. It is deemed to be because most of the ramps approaching or escaping the target road (eastern part of Gangbyun highway) are connected to the median lane. Vehicles that change lane to the median lane to use an exit ramp linked to the median lane and vehicles approaching the main line through an approaching ramp are gathered on the median lane and at the same time, weaving occurs, and therefore, congestion increases.

As for Sections 6 and 7 (Hangang Bridge – Banpo Bridge), difference of travel time by lane is at least 25%, the highest among the section. It is because a bottleneck state on the median lane caused by high traffic volume entered from the north of Hangang Bridge to Gangbyun highway. This proves that as road congestion increases, the difference of travel speed is higher. To reduce the difference of travel speed between lanes at peak hours, a strategic traffic management method is required, for example, inducing drivers to use the outer lane in advance through the lane use guide (KICT, 2003).

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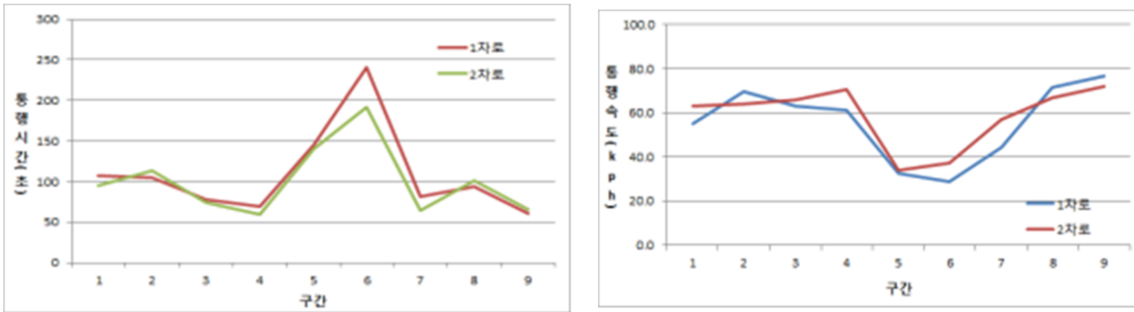

(a) Travel time (b) Speed

Figure 3 Sectional Travel Time and Speed

IV. CONCLUSION

At this point in time when road-based traffic information is provided, an effective method to collect lane-based traffic information is required to reflect different traffic characteristics of each lane comprising the road, and therefore enhance the quality of traffic information. To achieve the objective, this research developed a method of observing lane-by-lane travel time and speed by driving the target road section in the average traffic flow using probe vehicles, and analyzed lane-by-lane travel time characteristics based on the observation materials. In this research, TTMon, a device easy to attach to and detach from probe vehicles was developed, and lane travel time for Gangbyun highway was analyzed by using the device. Travel time of the median lane connected to many approaching and exit ramps was higher than that of the central lane, and the difference of travel time between lanes increased as congestion is aggravated.

TTMon can collect information on a single lane by using one vehicle. Therefore, when collecting information on the multi-lane road, vehicles and drivers are needed as many as the number of lanes, and therefore, a considerable amount of budget and manpower is required. In this regard, it is deemed that further research is required regarding the development of the TTMon capabilities enabling a single vehicle to observe traffic conditions of at least two lanes

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