AN APPLICATION OF LOW-COST RFID SYSTEM TO LINK TRABEL TIME ESTIMATION THROUGH WIDE AREA DETECTION

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ABSTRACT: the development and implementation of low-cost and high-efficiency detection system based on AVI technology for link travel time estimation are presented in this paper. It includes the hardware implementation of the system utilizing RFID(Radio Frequency IDentification) technology and a field test where approximately 500 probe-equipped vehicles are deployed to evaluate performance of the system. The system hardware consists of two types of road-side beacons and in-vehicle units. The first type of beacons broadcasts an inherent identification number referring to its location to the probe-equipped vehicles. And the other type of beacons collects the identification numbers and passage times from in-vehicle units. The in-vehicle units record the identification numbers with passage time from the first type of the beacons. The probe data via RF from the probe vehicles are obtained for a five-minute period and accumulated in the traffic information center through the beacons.

1. INTRODUCTION

Advanced Vehicle detection systems utilizing AVI technologies such as RFID(Radio Frequency IDdentification), Image Processing GPS(Global Positioning System) on the traffic networks is useful for a variety of traffic engineering applications from traffic flow managements to transportation planning. Traditional detection methods have relied on mechanical or electrical devices on the top of, or embedded in the pavements. These systems are relatively expensive to install and hard to maintain, and are limited in their capabilities, especially for Wide Area Detections Systems(WADS).

Among those AVI technologies, RFID-based Wide Area Detection Systems(WADS) have received considerable attention since the RFID-based systems can be implemented at the lowest-cost compared with other AVI technologies. Table 1 illustrates a comparison of the proposed RFID systems and GPS systems for infrastructure built and maintenance cost.

table 1 A comparison of GPS and the proposed RFID system (unit : $)

	GPS+Wireless data networks	GPS+Beacon	This Proposal
Infrastructure-built cost	-	83,333,333	11,416,666
In-vehicle unit cost	597,500,000	341,416,666	85,333,333
communication fee (for three years)	5,310,250,000	150,000,000	15,000,000
Total	5,907,750,000	574,750,000	111,750,000

< Assumption >

- # of nodes in korea (1 node/Km) : 50,000 probe vehicles (1%) : 1,024,363
- ID Beacon : $62.5 ID Beacon installation cost : $20.83 In-vehicle unit : $50
- IDs collector beacon : $ 833.3 its installation cost : $833.3,
  # of IDs collector beacon : 10% of ID-beacons
- wireless communication fee : 0.6cent/packet × 86,400packet/month = $144;
  wired ommunication fee = $83.3

For high efficiency of the proposed system, it uses two different types of beacons mounted on an overpass or an utility pole or traffic signal lights to communicate with the probe-equipped vehicles passing on the roads. the first type of beacons called a ID beacon broadcasts an inherent identification number referring to its location to the probe-equipped vehicles, and the identification numbers are recorded in-vehicle units with passage time. And the other type of beacons called a IDs collector beacon collects the identification numbers and passage times from the in-vehicle units. The probe data via RF from the probe vehicles is obtained for a five-minute period and accumulated in the traffic information center through the IDs collector beacons. These data are converted into average probe travel times for each interval. Figure 1 shows the system configuration.

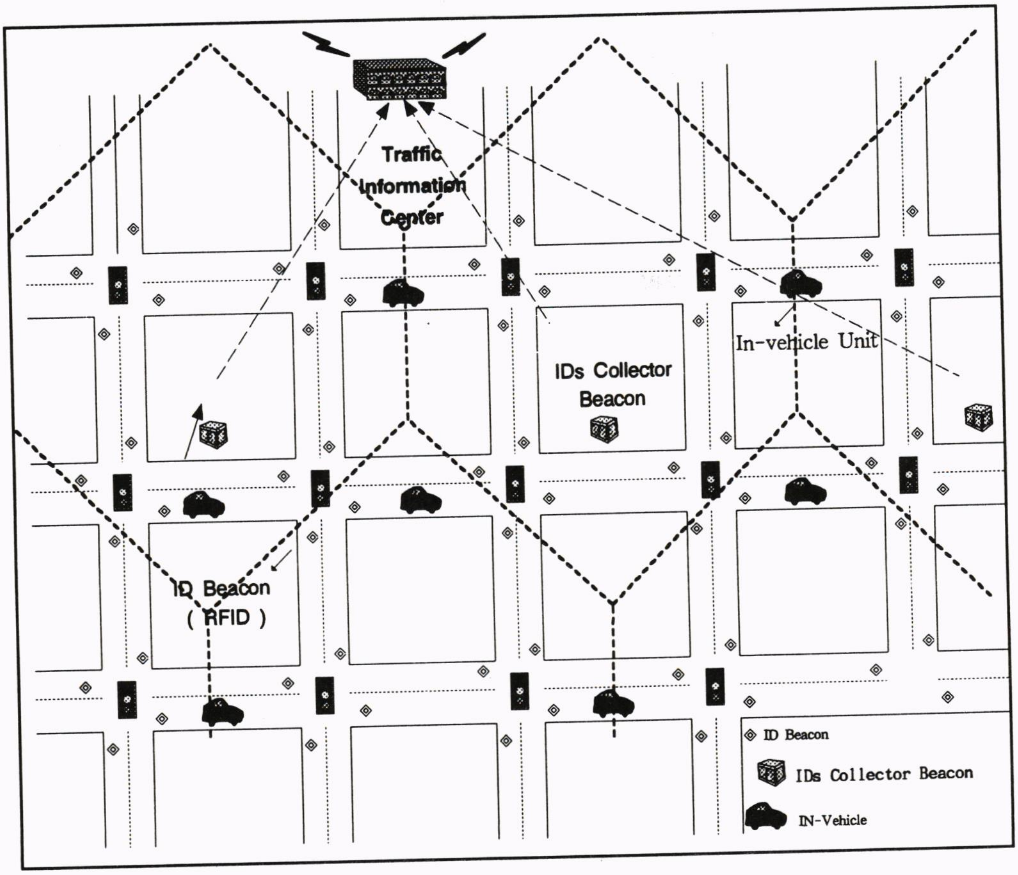


figure 1 Proposed system configuration

The paper is organized as follows: the following section contains descriptions of basic operations of the systems in details. The next two sections are devoted to hardware implementation and experimental validation of the system. The last section summarizes the results and draws conclusions about the system.

2. DETECTION MODEL

These systems are composed of four major components: ID beacons, In-vehicle units, IDs collector beacons, Analyzer. The ID beacons installed in the intersections of a traffic network transmit signals to In-vehicle units, i.e. broadcasts a location ID number to the probe vehicles. And then In-vehicle units only receives and accumulates location ID numbers from the ID beacons with the passage times when a equipped vehicle drives through about 40-50 meters of the ID beacons. The IDs collector beacons are designated to catch signals short periods of time from In-vehicle units, i.e. collects information on driving history from the probe vehicles, when equipped vehicles drive through the IDs collector beacons mounted on the roadside in 1 to 2km interval. The IDs collector beacons are also connected to a Traffic information Center. The probe data via RF from the probe vehicles are obtained for a five-minute period and accumulated in the traffic information center through the IDs collector beacons.

2.1 System Components

This section describes the schematic diagrams of major components of the systems and their characteristics.

2.1.1 ID beacon

ID beacons broadcast their own location IDs in order to locate vehicles' positions. It includes(specifications included)

- wireless antenna and transmitter
- 224Mhz operating frequency(5 channel, 0-10mW)
- 4-bit micro computer to store an ID and to control transmitter,
- Data bit rate of 4800bps
- rechargeable back-up battery
- Operating temperature: -20~70C

Its schematic diagram is shown in Figure 2.

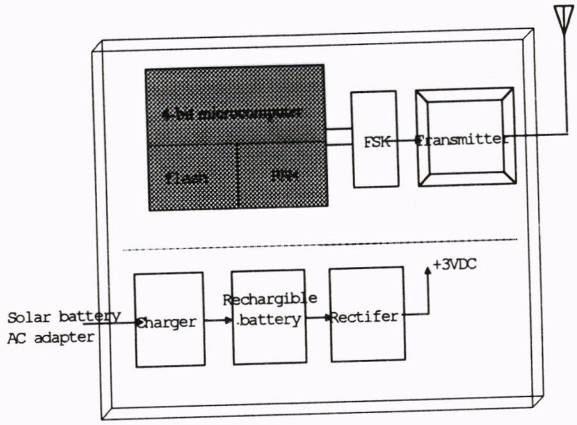


figure 2 schematic diagram for ID beacon

The reading area must be considered when the ID beacons are installed, especially in the signalized intersections since a link travel time is calculated by connecting these two reading areas. The position of the reading area is recommended in the back of each links insead of the stop line of each links since it is less affected by the traffic lights.

2.1.2 In-vehicle units

In-vehicle units receive IDs from the ID beacons and accumulate them with the passage times in their internal memory.

It includes(specifications included)

- wireless antenna and modem for two-way communication
- 224Mhz operating frequency(5 channel, 10mW)
- 8-bit microcomputer to control wireless modem
- Data bit rate of 4800bps
- a memory for a driving history
- electric clock
- Operating temperature: -20~70C

Its schematic diagram is shown in Figure 3.

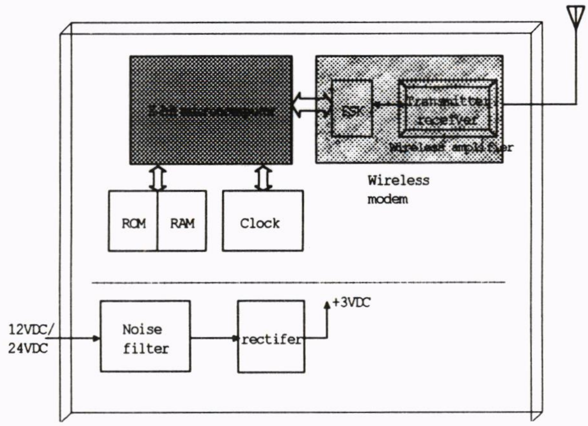


figure 3 schematic diagram for in-vehicle unit

2.1.3 IDs collector beacons

As the probe-equipped vehicle approaches the IDs collector beacon, the beacon generates a signal and the internal antenna module broadcasts the signal into reading area. The reading area is tuned such that only one tag at a time is read. The beacon can collect real time data on driving histories with passage times and stores the data in an internal storage buffer and transmits information to traffic information center.

It includes(specifications included)

- wireless antenna and modem for two-way communication
- wired modem for two-way communication with traffic info. center
- Data bit rate of 2400bps(wired modem)
- 16-bit microcomputer to control wireless and wired modem
- a memory for a driving history
- rechargeable back-up battery
- Operating temperature: -20~70C

Its schematic diagram is shown in Figure 4.

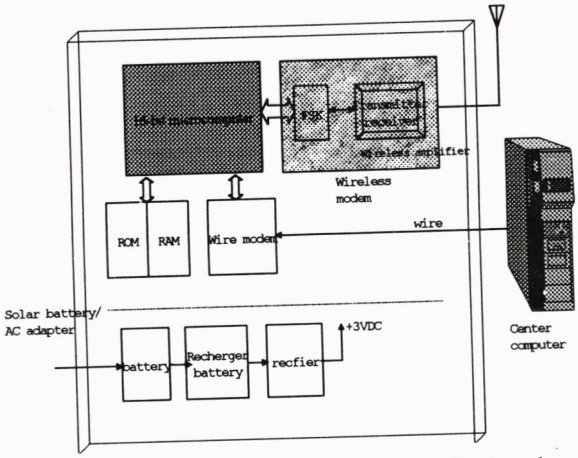
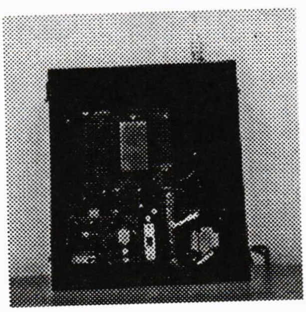


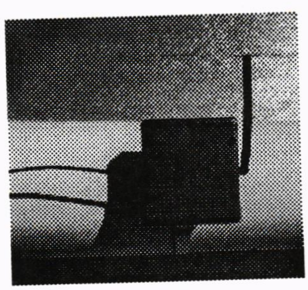
figure 4 schematic diagram for IDs collector beacon

Figure 5 shows the prototype products for the proposed RFID system components



a. IDs collector beacon

b. In-vehicle unit



c. ID unit

figure 5 Major components of the system

3. EXPERIMENTAL VALIDATION

A preliminary field test for the system components have been conducted in the small traffic networks shown in Figure 6. In figure 6, seven ID beacons in the three intersections are mounted on the utility poles, and two IDs collector beacons are installed 700m apart to collect real time information on driving histories. The in-vehicle units are mounted in the upper central inside windshield. Fifty probe-equipped vehicles are deployed for 20 days to evaluate the performance of the proposed system components.

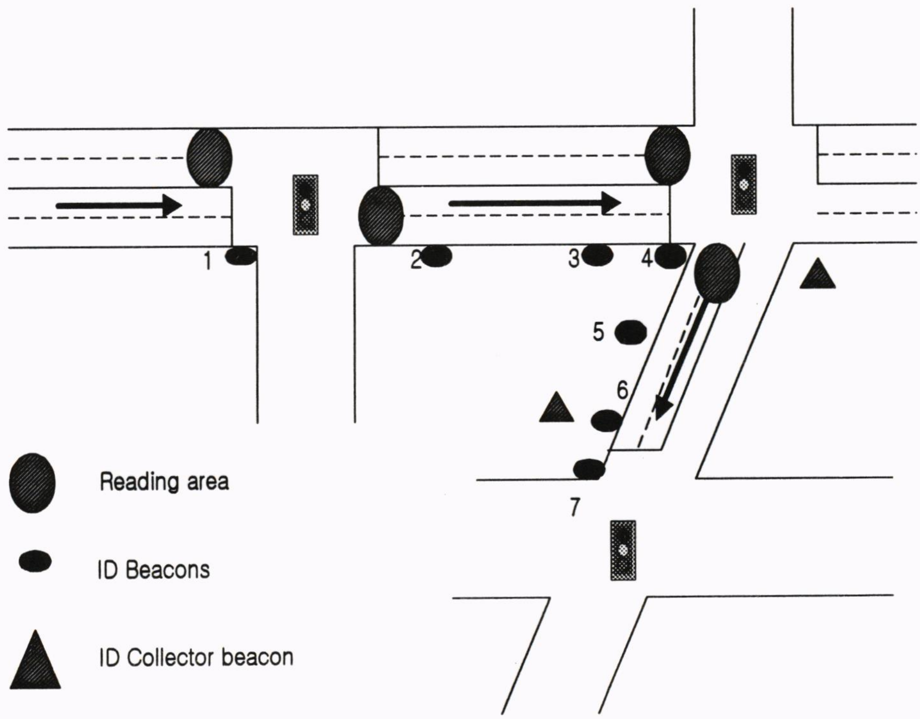


figure 6 Geometry for preliminary field test

3.1 Criteria for performance evaluation and experimental results

Several quantitative measures have been examined to determine the accuracy of the systems when the probe vehicles' speed varies between 5 - 120(kph) in different traffic conditions. Table 2 summarizes the results of the preliminary field tests.

Table 2 Experimental results

Tests	Vehicle speed(kph)	Accuracy
1 vehicle travels alone	5 30 60 120	100%
3 vehicles travel in parallel	5 30 60	100%
3 vehicles travel bumper to bumper	5 30 50	100%
harsh weather(rainy day)	5 30 60 90	100%
Distance between tag and beacon		up to 50m

3.2 Probe data collection and evaluation

A major field test has been conducted in Seoul City area shown in Figure 7. During the summer of 1998 approximately 12000 vehicles included taxi, passenger vehicles and commercial vehicles were driven seven days a week over a week period(June 1- June 7). During this time almost 3,000,000 km were driven to produce over 6,000,000 link reports within Kangnam-ku and Kangbuk-ku area.

The probe reports include raw traffic data for each link: a location ID and its passage time. Once the data from probes were assembled into usable formats, the algorithms are run. Then average probe travel times for each interval are developed. The number of the probe reports are utilized to compute the average travel times for a given link that five-minute interval. A study route shown in Figure 7(darker line) was selected among several study routes to provide mean travel-time which would be used for dynamic route guidance. This study route consists of seven links, and total the length of the route is 3.7km. Mean probe travel-time for a north-south(south-north) bound of the study route during a 24 hours in a week are shown in Figure 8(Figure 9.) Figure 10(Figure 11) shows mean probe speeds for a north-south(south-north) bound of the study route during a week for some specific time periods.

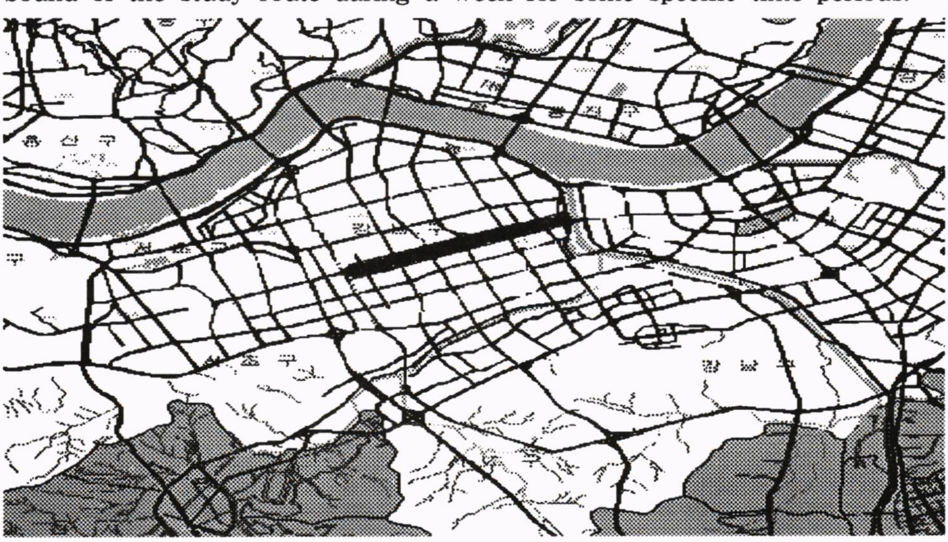


Figure 7 Proposed wide detection area

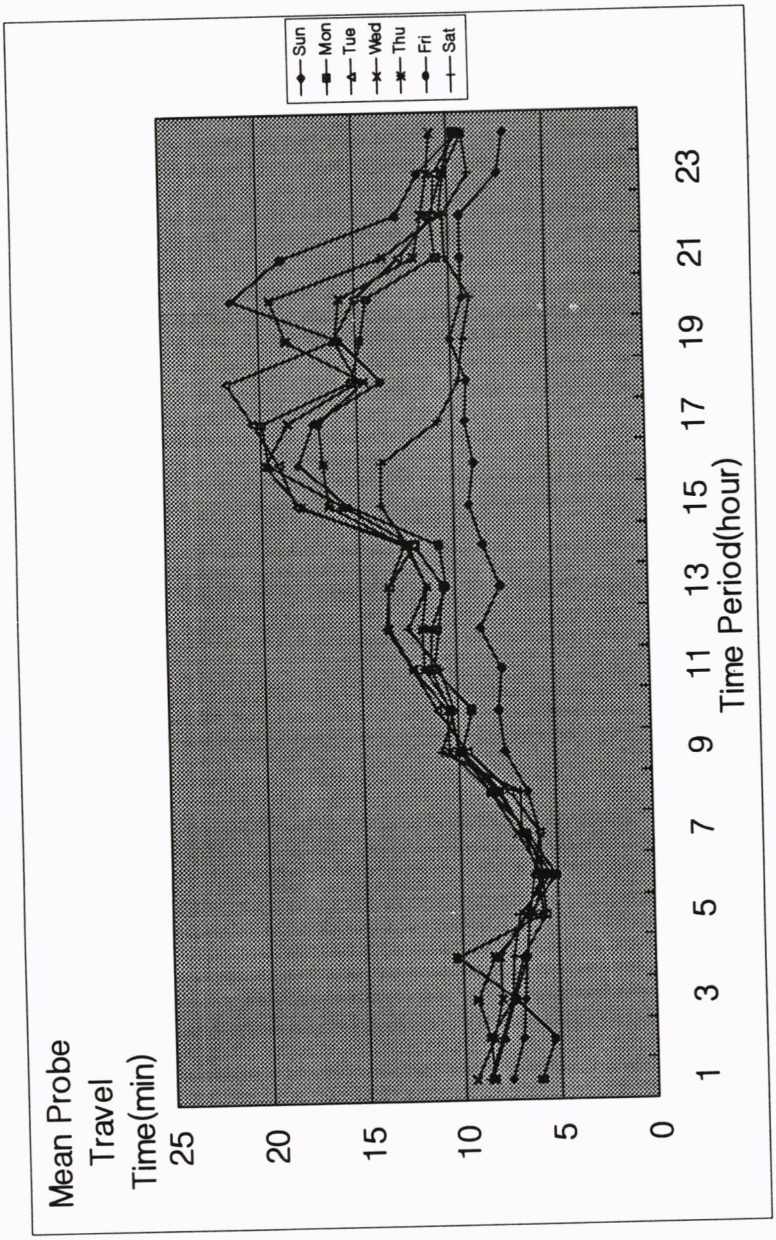


Figure 9 Mean probe travel times for a N-S bound of the study route

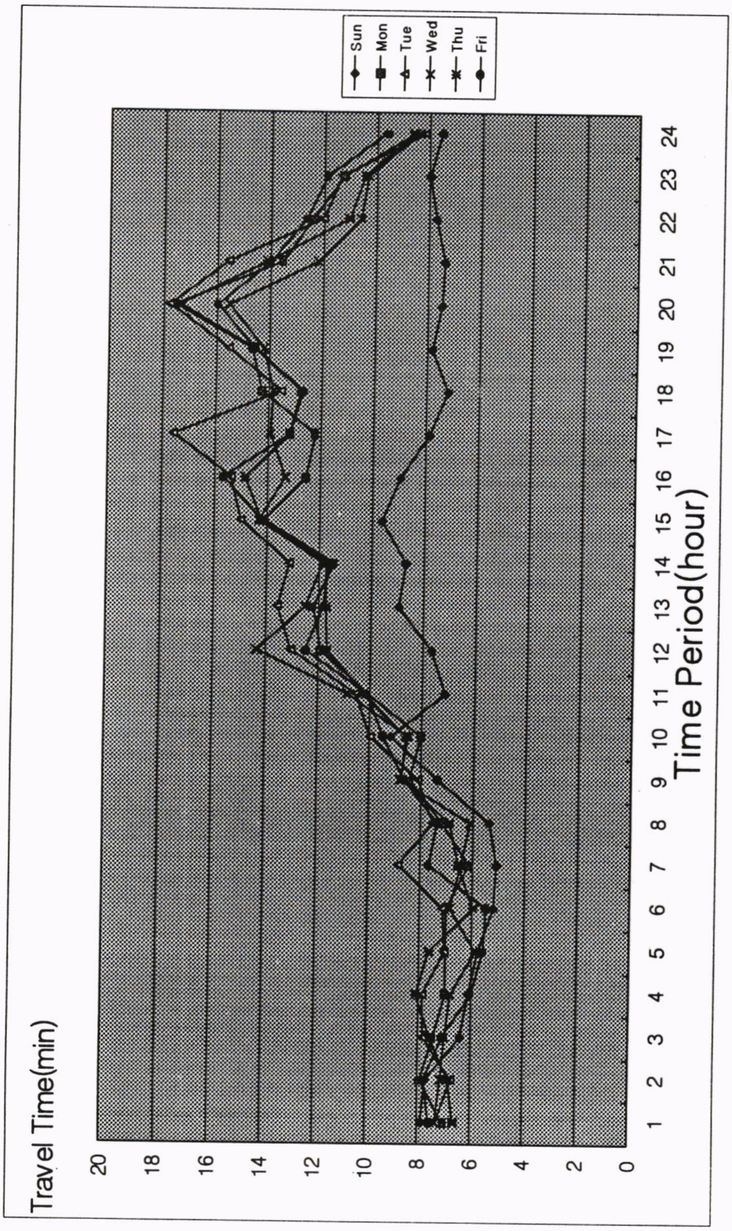


Figure 10 Mean probe travel times for a S-N bound of the study route

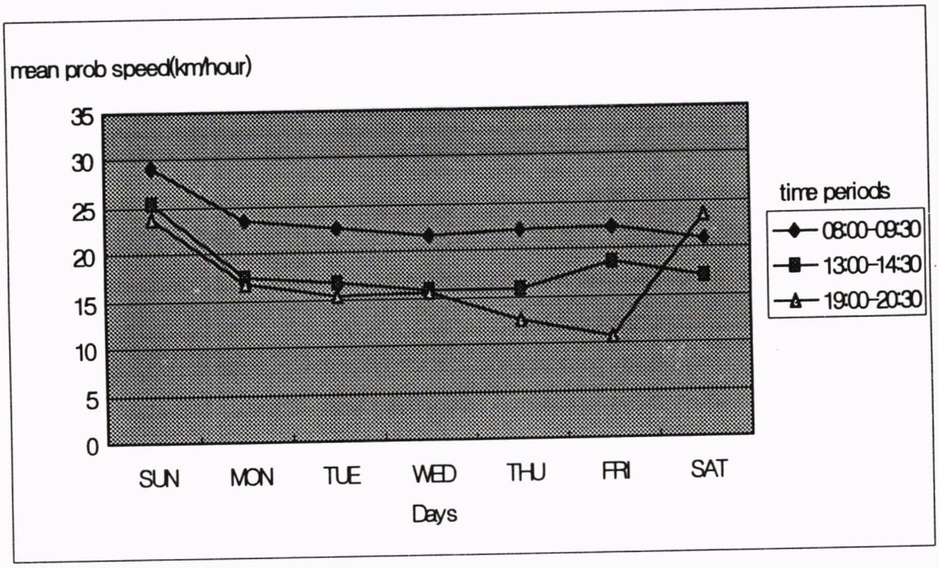


Figure 11 Mean probe-vehicle speeds for a N-S bound of the study route

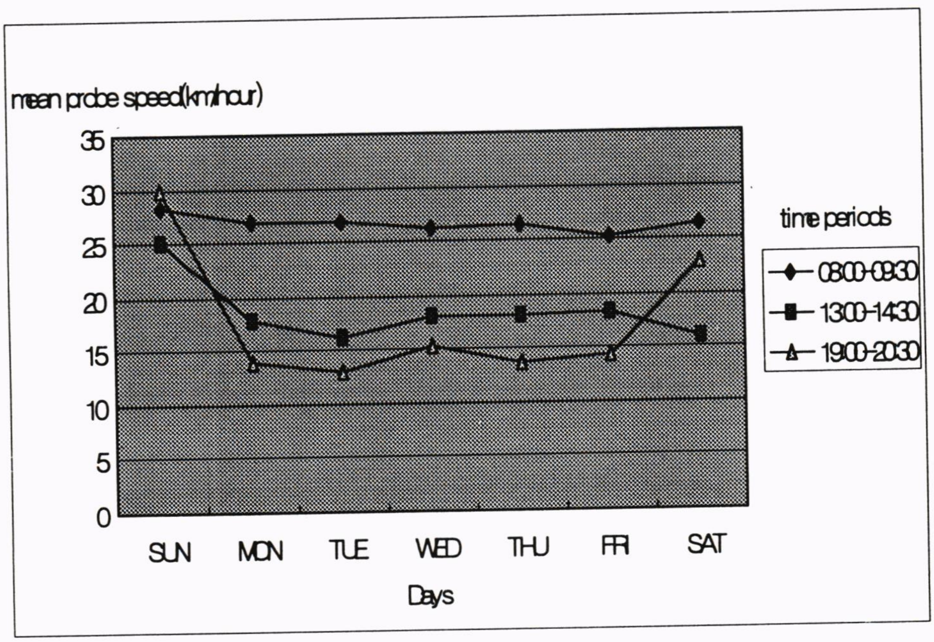


Figure 12 Mean probe-vehicle speeds for a S-N bound of the study route

4. Conclusions and Remarks

This paper described lower-cost and high-efficiency systems based on RFID technologies for link travel time estimations, and presented some results that demonstrated efficiency of the proposed systems. The results offer the following benefits

- Ability to decode data from the system's signal is virtually 100%c
- The same location referencing system using ID beacons without suffering from positioning errors.
- The most economical solution for Wide Area Detection system
- Robustness even where dirt, vibration and harsh weather conditions would degrade the other systems.
- Quick installation and requires no routine maintenance

5. Referance

a)Papers

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b)Books

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