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# Exploring the use of advanced traffic information system to manage traffic congestion in developing countries

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ABSTRACT

Presently, advanced traveler information system (ATIS) is extensively used elsewhere and is regarded as an important component for road traffic control and management. ATIS uses information and communication technology to broadcast traveler information to commuters to help them in scheduling their trips and also offer directions on the way. Information provided by ATIS may include: traffic condition (which may be presented in queue length, travel time, or delay), incidents such as road traffic crash and their geographical locations, events such as road construction and demonstrations, optimal routes, and inclement weather which may disrupt traffic. The traffic information may be transmitted via mechanisms such as radio and television, dynamic navigation systems (in-vehicle or mounted), internet services, smart phone services (e.g. specially designed application) and variable speed limit or changeable message signs systems. Providing commuters with accurate, timely and reliable traffic information will influence travel behavior and ultimately result in reduced travel time and traffic congestion along with reduced vehicle emissions and fuel consumption. Notwithstanding the benefits which can be derived from using intelligent transport systems to manage traffic, its use can be described as being in the basic stage in most developing countries. This paper discusses how ATIS can play a vital role of efforts to reduce traffic congestion in emerging nations.

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## Introduction

Road traffic congestion in most cities in developing countries keeps on increasing because the number of people owning cars keep increasing. Congestion may occur when there are more vehicles than the road can accommodate (demand > supply). It may also be caused by a bottleneck (e.g., merging or weaving areas, on-ramps, road traffic crashes, and construction works) on a section of the roadway. Congestion is undesirable and may cause delay, environmental pollution, noise and even frustrate motorists and commuters which also have health implications. It may also lead to road traffic crashes and degradation of the road infrastructure.

Whereas congestion caused by bottlenecks can be resolved by simply removing the bottleneck, congestion resulting from capacity problem are more challenging to deal with. Traditional attempts to deal with the issue have focused on building new roads and expanding existing ones. Meanwhile, the ceaseless increase in demand for mobility has also meant that traf-

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fic keeps on increasing. Budgetary constraints and space make it practically unfeasible to expand the road infrastructure every time to cater for the growing traffic demand, and it is now not considered as a viable option. Expansion of existing or construction of new roads does not have only financial burden on the government, but also social impact on the community. Displacement and resettlement of the affected residents, relocation of businesses and community services (e.g., parks and churches) may have social and psychological impacts due to the disruption of social relationship, and establishing relationships in a new social environment [1,2]. Studies have established that road expansions spur new travel, known as induced demand, and thus may fail to relieve traffic congestion [3,4,5]. Consequently, a more practical means of handling the existing infrastructure to optimize its use has become necessary.

Presently, advanced traveler information system (ATIS) is extensively used in the developed countries and is regarded as an important component for road traffic control and management. It uses information and communication technology (ICT) to broadcast traveler information to commuters to help them in scheduling their trips and also offer directions on the road. Information provided by ATIS may include:

- incidents such as road traffic crash and their geographical location,
- events such as road construction and demonstrations,
- the traffic condition (which may be presented in queue length, delay or travel time) and
- inclement weather which may disrupt traffic.

ATIS may generally be grouped into two, namely pre-trip and en-route. Pre-trip ATIS (e.g., internet services, radio, and television broadcast) may broadcast real-time traffic information to commuters to assist them in taking decision prior to the trip on their departure time, mode of transport, route and destination.

En-route ATIS such as the variable speed limit or changeable message signs system provides real-time information to assist motorists make informed judgments when on the way. Pre-trip ATIS are usually used to manage traffic on a network scale whiles en-route ATIS are mainly used to control traffic on a segment (i.e., link control strategy). Providing commuters with accurate, timely and reliable traffic information will influence travel behavior and ultimately result in reduced journey time and traffic congestion along with reduced vehicle emissions and fuel consumption [6,7,8,9,10]. Many studies (e.g. [6,10,11]) have established significant improvements in network performance after the introduction of ATIS. Consequently, real-time traffic information (RTTI) results in an optimal use of the existing road infrastructure. The advantages of ATIS to users are not only limited in terms of time and financial savings, but also improves emotional and psychological well-being as it removes uncertainty and anxiety which has health implications [9,12].

Until now, the use of intelligent transport system (ITS) to manage traffic in most developing countries is minimal. A Technical Note of the World Bank titled "ITS for Developing Countries" examined three major developing regions (i.e., East Asia, Eastern Europe, and Latin America) and found that all three regions have introduced basic systems to manage road traffic [13]. The system included traffic signals, traffic surveillance systems using closed-circuit television (CCTV), and traveler information systems based on variable message signs (VMS). Financial constraint, lack of qualified personnel and technology may be the reason why ITS is still at the rudimentary stage in most developing economies.

This study explores the possibility of using ATIS to manage traffic congestion in cities of developing countries.

## Media for advanced traveler information system

ATIS presents real-time traveler information to commuters to help them in organization of their journeys and also provide assistance when on the way. Various media are used to transmit traffic information. Examples of the mechanisms for ATIS are described below.

### *Variable speed limit (VSL) systems*

VSL systems, also referred to as dynamic speed limit systems, dynamic message signs, changeable message signs, etc. in the literature use dynamic speed limits to control traffic based on the prevailing traffic condition [2,14,15,16]. Further to the speed limits, some VSL systems may display information signs which provide warning on potentially dangerous conditions on the way. Other information such as construction works, delay, travel time, and route guidance could also be shown by a VSL system. The VSL control device, which is mostly installed on overhead gantries across the carriageway, may also implement dynamic truck restrictions which require heavy goods vehicles not to overtake or use designated lanes during peak periods. Fig. 1 shows an example of variable speed limit or changeable message signs system in Germany.

### *Dynamic navigation systems*

In-vehicle or mounted navigation devices are also used to provide motorists static or dynamic route guidance. Static route guidance is concerned with providing navigational assistance to motorists who may be unfamiliar with a road network. A geographical database of the road network and its characteristics such as speed limits, distances, and road class is required. Here, the traffic situation is not taken into consideration. Routing is mainly dependent on the shortest or direct travel time path to the destination. Dynamic navigational systems, on the other hand, take into consideration, the traffic situation in deciding the minimal time route. Information on the prevailing traffic condition is updated in real-time. Dynamic route guidance system is seen as efficient way of managing network traffic.

**Fig. 1.** Example of variable speed limit or changeable message signs system in Germany.

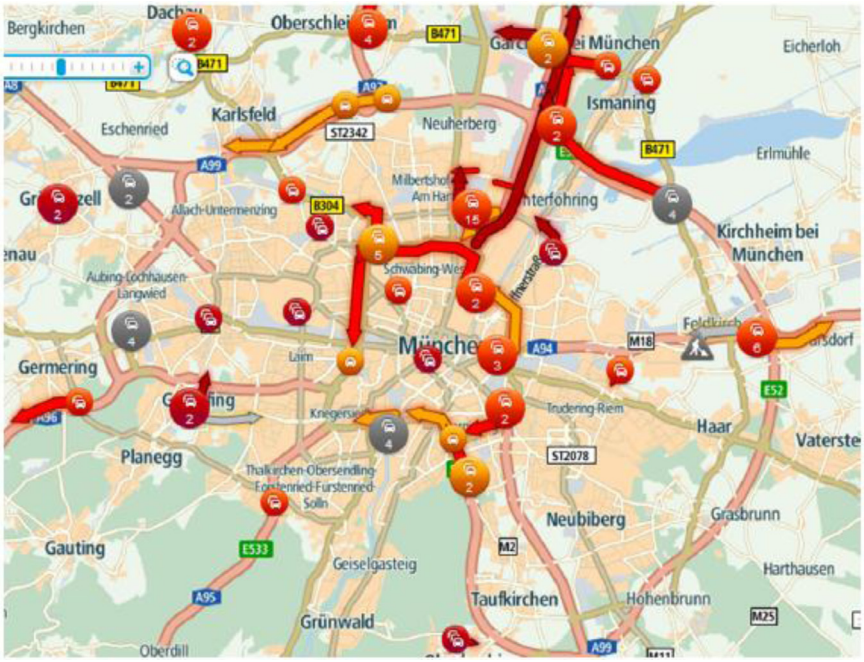


**Fig. 2.** Real-time traffic information in Munich, Germany [Source: [19]].

*Radio and television broadcasts*

Traditionally, this has been the source of traffic information. The radio and television stations, after obtaining the traffic information from their sources, broadcast it to their listeners or viewers.

The limitation of radio and television traffic information broadcast is that it is not available at all times [17,18]. Again, radio and television based traffic information are limited in the frequency of broadcast and the exact spatial extent of traffic management information that they provide.

*Internet services*

Real-Time Traffic Information (RTTI) is also presented to users on the internet. This may be in the form of congestion maps. An example is shown in Fig. 2 for Munich, Germany. The website color codes segments according to the degree of travel time delay with links marked red indicating more delays than segments colored orange. The exact delay time and queue length could be obtained by pointing on the colored link. Information such as road closures and road works may also

be illustrated on the map. The advantage of presenting traffic information on the internet is that it is highly effective and versatile [17,18]. It is also relatively easy and cost-effective to maintain and update.

*Mobile phone services*

Traffic information users can subscribe to a service from a provider where they receive information in the form of short messaging service (SMS) alerts. Fast development in the mobile phone technology and wireless internet connectivity has also ensured that RTTI can be accessed via the internet or through a specially designed application downloaded onto the smart phone.

Telephone information service has also been part of traffic information. Under this circumstance, travelers call a center for real-time traveler information. The information is, mostly, automated. Callers could choose a specific link or route from the computer's menu to obtain an up-to-date report on traffic situation [17,18,20].

## Advanced traffic information systems' architecture

ATIS presents real-time traffic information to motorists and commuters. The information broadcast or shown by the service providers is expected to represent the actual traffic condition (i.e., reality or the ground truth). A flawless data collection practice, processing, and transmission is needed. The subsequent sections describe the procedures used by the providers of traffic information from the data acquisition stage to the time the information is transferred to the user.

ATIS providers can use the stationary inductive loop detectors, which are mostly owned by the government, for collecting traffic variables for broadcasting of traffic information. However, because of the high cost of installation and maintenance of these loop detectors, it makes it practically impossible to have them installed on the entire road network. But, new techniques for gathering road traffic data, for example, the floating car data (FCD) and floating phone data (FPD) presently allow the mobility service providers to determine traffic condition and provide their services without automatically depending on the primary stationary detector data.

*Floating car data*

GPS devices, installed in vehicles, are able to obtain the geographical locations and velocities with a high degree of accuracy. Automatic vehicle location (AVL) technology has also been employed in this direction [21]. AVL determines the positions of vehicles and transmits it to a vehicle tracking system at regular intervals. Another source of FCD is personal navigation devices (e.g., in-built or mounted vehicle navigation devices) with embedded augmented global navigation satellite system (GNSS) receivers. The navigation device receives traffic information from the control and concurrently transmits information from its current position to the control.

Alternatively to devices in the vehicle, FCD can be collected by short-range communication when the vehicle passes the location of a roadside unit [22]. The main disadvantage of FCD method is its penetration rate as getting representative number of vehicles fitted with the GPS or AVL gadget is difficult to achieve on a network level. Notwithstanding, some providers have used taxis, buses, fleet, and service vehicles (e.g., DHL and FedEx) which are constantly on the road for FCD collection to increase coverage. As the number of vehicles with in-built navigator increase and with the availability of mounted navigation devices on the market, the penetration rate of FCD will further increase.

*Floating phone data*

The position of mobile phone, of person(s) in vehicles is, on regular basis, transmitted to the network provider usually by means of triangulation or other techniques such as handover [23]. With handover, movement of a cellular phone is detected and recorded when the phone is moving away from the area covered by one cell (i.e., the base station from where the call is being made or currently is) and entering the area covered by another cell. The positions and times of the handover are then used to estimate the travel times between phone cells. The mobile phone does not need to be in use, but must be turned on. FPD works precisely, particularly, in urban areas where there are lower distances between cellular phone antennas. Some specially designed mobile applications, such as Google Maps, any time we use them and allow them to access our location, also send travel information back to their servers and are also sources of traffic data. FPD is perceived to be a cheaper alternative to the conventional "in situ" detectors, and even the FCD as no additional gadgets are required to be fixed. However, there are concerns about the extent to which irrelevant data can be filtered. Pedestrians walking along a road can be mistakenly sampled as vehicles, and buses with more than one person using a phone can be sampled as multiple vehicles [24].

## Data fusion

Data fusion brings together data from several sources, available to a provider, on a single platform. The advantages of fusing data are that gaps within the data are closed and thus become complete. Data ambiguity is also reduced while extending spatial and temporal coverage [25]. Eventually, accuracy is improved than could be attained by the use of only

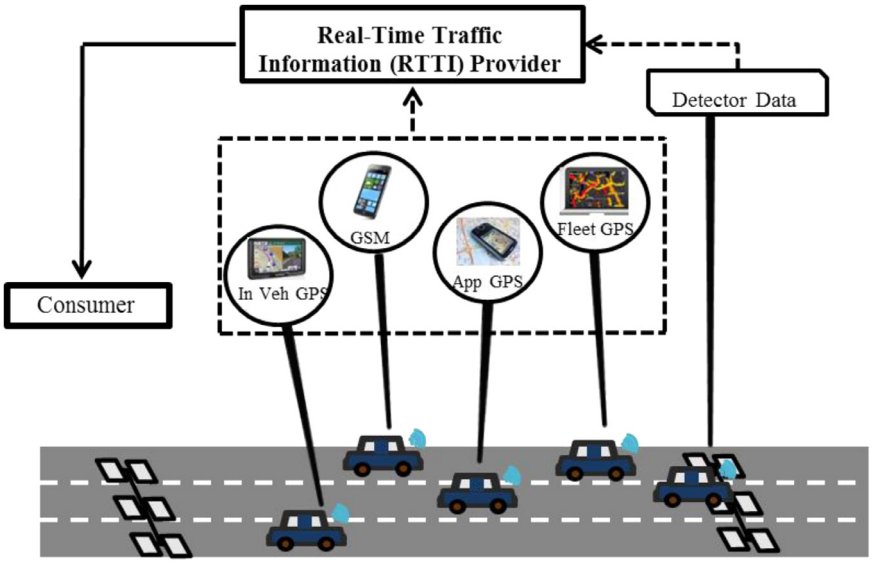


**Fig. 3.** Process chain for real-time traffic information.

one data source. Methods for data fusion have been pulled from areas including artificial intelligence, pattern recognition, statistical estimation and inferences, signal processing, and other areas [25,26]. Several frameworks for fusing data for ATIS have been developed and can be found in the literature. Faouzi et al. [26], grouped these techniques into three categories:

(1) Statistical approaches - e.g., multivariate statistical analysis and arithmetic mean approach,
(2) Probabilistic approaches - e.g., Bayesian approach, maximum likelihood method, and Kalman filter based data fusion, and
(3) Artificial intelligence - e.g., neural networks.

Imperfection and diversity of technologies used in data gathering and the nature of the application environment, however, make data fusion a challenging task [26].

*Transmission of data*

The traffic information service providers prepare the data gathered, assimilate, and transmit the messages to the automobiles, cellular phones and so on of the information users by means of traffic message channel (TMC) technology. The prepared information is then digitally coded into radio data system (RDS). It is then communicated through conventional FM radio broadcast. The processed information can also be communicated on digital audio broadcasting (DAB) or satellite radio [27]. The problem with RDS-TMC is that it cannot embed a large quantity of digital messages. To eliminate this limitation, a recent technology of conveying traffic information to users, referred to as TPEG (transport protocol expert group), has been used. TPEG transmits traffic information through digital broadcast formats such as digital audio broadcasting (DAB) or the internet [27]. TPEG has several advantages over RDS-TMC. It is able to present information on travel time, delay, incidents and their locations, inclement weather, parking locations and rest stops, fuel filling stations in addition to the real-time traffic congestion information. The information can be presented in the form of color-coded map, text message or an icon. The speeds displayed on a route are done per links or segments (between two nodes) only if conveyed by RDS-TMC technology. Therefore, if only a small portion of the segment is congested, the whole link is indicated as congested. However, with TPEG, it is possible to indicate only the problematic area as congested. The schematic representation of the processes for RTTI is as shown in Fig. 3.

## Possibilities of using ATIS in solving congestion in emerging nations

The use of intelligent transport systems (ITS) to control traffic can be described as being in the basic stage in most developing countries as indicated in Yokota [13]. The most visible form is traffic signal system though coordination of some close signals can still be improved upon. As mentioned, ATIS holds a huge potential to help solve the congestion problem in cities. However, implementation of some of the methods, particularly for data collection, will present a challenge in developing nations.

The use of traditional on-road sensors (e.g. inductive loops), though durable for collecting data, is possible but are limited in terms of their coverage. It is virtually impossible to install detectors at representative sections on the road network. Loop

detectors are also expensive in their initial costs and maintenance. According to Yokota [13], innovative approaches to the planning and development of ITS in developing countries, including affordable ITS, should be adopted.

There is also a challenge in using floating phone data in traffic data gathering. Mostly, road infrastructure in developing countries do not provide for pedestrians and are therefore forced to use the same road space with vehicles. Again, even at locations with pedestrian facilities, it is common to find pedestrians jaywalking. Therefore, it will be more challenging to filter pedestrian walking along the road from people using phones in vehicles. Again, tracking the locations of mobile phone users has been a topic of concern as it affects privacy. Therefore, telecommunication companies are, ordinarily, reluctant to give out such data unless it is for their own use. Notwithstanding, companies such as Google with more data input because of the widespread use of their applications are able to predict traffic congestion with a high degree of accuracy in cities, including cities of some developing countries.

One of the most probable method will be the floating car data, where GPS devices, installed in vehicles, are used to collect traffic speed data along road segments. The challenge here will be to acquire a representative sample of the devices and install them in vehicles. To get the most use of the devices, they can be installed in taxis which are constantly on the road during greater part of the day. There is also the possibility of developing a mobile phone application (i.e., an app) which is able to collect speed data as the person with the application on his/her phone travels on a roadway. Commuters could be encouraged to download the application on their smart phones to participate in the data gathering. At the same time, these persons will be able to receive traffic information from the control on the mobile application. The more people use the application, the more accurate the information will be. The usage of the mobile phone application in the data collection will come with a minimal cost as compared with the acquisition of the GPS devices.

The information gathered from this can be presented in the form of a color-coded map on the internet or as an application for users on mobile phones. When traffic information is presented to drivers and commuters in this manner, it enables them to decide their:

- departure time (e.g., change of travel plans to when the road is free from congestion),
- route (use an alternative road with less traffic),
- mode (e.g., use bicycle instead of vehicle if the road is jammed), and
- destination (e.g., shop at target “B” if your preferred shopping location is “A,” but there is a heavy traffic on the way to “A”).

Consequently, RTTI results in an optimal use of the existing road infrastructure.

Although the provision of the traffic information is necessary, it cannot help solve the problem if some prerequisite, which must be met are not put in place. Currently, due to financial constraint in the emerging nations, development of road infrastructure in the cities have focused on expanding major arterials and junction improvement. Little attention is given to other alternative routes. For ATIS to function optimally, there is the need to develop a network of roads. This will make it possible for drivers to choose other alternative good roads if the major arterial is congested to minimize delay.

## Conclusions and recommendations

This paper examined the possibility of using advanced traveler information system to manage traffic congestion in cities of developing countries. Firstly, the different types of ATIS available, the information they provide and the processes from the data acquisition stage to the time the information is transmitted to the user was explained. ATIS hold a huge potential to help us deal with congestion problem in cities. When traffic information is presented to drivers and commuters, it allows them to choose their departure time, route, mode of transport and even their destination. Consequently, ATIS results in an optimal use of the existing road infrastructure. Approaches to the planning and development of ATIS should consider and adopt affordable systems. However, some requirement must be met to make the implementation of ATIS a success. There is the need to develop a network of roads instead of the continual expansion of major arterials. In this way, drivers can utilize the traffic information in deciding on other alternative good roads when the main road is congested to avoid delay.

## Conflict of interest

The author has no conflict of interest to declare.

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