ITS Impact On Traffic Congestion And Environmental Quality
In Large Cities In Developing Countries

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Abstract: Intelligent Transportation Systems (ITS) are advanced technologies that have been used in large cities in developing countries to reduce traffic congestion and then increase environmental quality. Congestion causing poor traffic performance has negative impacts on environmental quality. The aim of this paper is to evaluate the impact of ITS implementation on reducing traffic congestion and increasing environmental quality, in term of fuel consumptions and pollution emissions (CO, NO_x, HC) in large cities in developing countries with specific geometric and traffic behaviour. A number of ITS implementation in many large cities in developing countries is presented in this study. The results found that the impact of ITS implementation on reducing traffic congestion and increasing environmental quality is not always good especially during peak periods that usually have high traffic congestion. In conclusion, ITS implementation in these cities in developing countries is not effective to reduce traffic congestion and increase environmental quality.

Key words: Intelligent Transportation Systems, Traffic Congestion, Environmental Quality, Large Cities, Developing Countries.

1. INTRODUCTION

Intelligent Transportation Systems (ITS) are advanced technologies that have been used in large cities in developed and developing countries to reduce traffic congestion. These systems involve the application of advance technologies, including computers, information processing, communications and control systems to improve the efficiency and capacity of existing roads infrastructure, reduce traffic congestion, increase road safety and contribute to ease and convenience of travel. These Systems collect, store, process, and distribute information relating to the movement of people and goods. ITS can be classified into five categories, including Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), Advanced Vehicle Control Systems (AVCS), Advanced Public Transportation Systems (APTS), and Commercial Vehicle Operations (CVO) (Sutandi, 2006a). Because of limited financial support for implementation and maintenance of ITS tools, limited experts to operate ITS, and low awareness of road authorities of importance of using ITS tools, implementation of ITS in developing countries usually only Advanced Traffic Management Systems (ATMS) as a part of ITS. However, it is unknown how the impact of ITS on reducing traffic congestion and increasing environmental quality in large cities in developing countries.
Congestion causing poor traffic performance has negative impacts on economic productivity, environmental quality and safety through higher fuel consumption, increased costs of goods and service, increased air pollution, and worsened safety conditions. Vehicles are responsible for 25% of the carbon dioxide (CO₂) emissions, as well as 90% of the carbon oxide (CO) and 50% of the nitrogen oxides (NOₓ) emissions generated worldwide (Button, K., 1990). And, CO₂ from the transportation sector in developing countries was estimated to be more than double in the next two decades by an increase rate of 3.5% per year (Browne et al. 2005). Furthermore, these cities face more severe congestion problems because of specific geometric and traffic conditions and also unique driver behavior, for examples: low road network densities with narrow lane width, poor lane discipline, and high level of side friction in connection with on street parking and street vendor activities (Sutandi, 2006b). Road authorities have now recognised that building additional road capacity alone does not help to solve traffic congestion.

The aim of this study is to evaluate the impact of ITS implementation on reducing traffic congestion and increasing environmental quality, in term of fuel consumptions and pollution emissions (CO, NOₓ, HC), in large cities in developing countries with specific geometric and traffic behaviour. A number of ITS implementation in many large cities in developing countries is presented in this study.

2. TRAFFIC CONGESTION IN LARGE CITIES IN DEVELOPING COUNTRIES

Traffic congestion in large cities in developing countries is a severe problem. As was mention earlier, these cities experience more traffic congestion problems in term of specific geometric and traffic conditions, lack of adherence to traffic regulation, and unique driver behavior. Driver behavior in these cities causing traffic congestion and furthermore poor quality of environment. Poor lane discipline of drivers cause vehicles in left lane not only will turn left but also straight through or even turn right. The condition is similar to other lanes and cause high traffic congestion. Moreover, drivers will also use the other direction of the road both to drive straight ahead and on occasions as an extra right turn lane. Drivers usually also pass an intersection during amber period. At intersection with very congested traffic condition, the tail of previous platoon (a group of vehicles (or pedestrian) traveling together as a group, either voluntarily or involuntarily because of signal control, geometrics, or other factors) will block the following platoon from entering the intersection.

Give way priority is often ignored. While the traffic regulation stipulate the standard priority rules, there does not appear to be any fixed Give Way priority rules actually applied on street by drivers. Drivers making turns force their way across opposing through movements with the result that both movements are severely disrupted. In a number of places this will be overcome by installation of leading right turn arrows, which will clear the right turners and leave the way clear for through traffic to move unimpeded (AWA Plessey, 1996b). At a number of intersections, left turn on red is used where there is no separate exit lane for the left turning traffic to use. They merge with the opposing through traffic as best they can. Normally it would suggest that is not acceptable, but to remove it would severely limit capacity. It may be worth considering leaving these movements as they are, or alternatively to install a Give Way or Left Turn With Care sign.

Another specific condition is major interference of public transport vehicle. Bus or local public transportations (angkot) usually stop and park along the street, and also use area near
intersection as a public transportation terminal. This condition will increase traffic conflicts and reduce road user’s safety. They stop on request and cause a number of problems both at and between intersections.

A number of studies regarding this specific geometric and traffic conditions and driver behaviour have been done, for example (Sutandi, 2008):

- A lack of capacity at many intersections because of on street parking, street vendor activities, and driver behavior;
- Problems for public transport resulting in delays and interference with other road based vehicles;
- Difficulties associated with the mix of traffic;
- Problems in establishing a road hierarchy, in developing a strategy for managing the road network and establishing priorities at roundabouts and intersections;
- Poor driver behavior and poor adherence to road rules;
- Growth in infrastructure and development of a traffic signal network to cope with future projected development;
- Development of a suitable road hierarchy and management plan;
- Impact of traffic congestion to environmental quality.

3. IMPLEMENTATION OF ITS IN LARGE CITIES IN DEVELOPING COUNTRIES

3.1 ITS Tools

Many kinds of ITS tools have been implemented in large cities in developing countries. A number of these implementations are presented in this section. In developing countries implementation of Advanced Traffic Management Systems (ATMS) as a part of ITS are well known. ATMS is used to solve transportation problem. ATMS will integrate the management of various roadway functions. These systems will predict traffic congestion, optimisation the traffic flow, and provide alternative routing instructions to vehicles over regional areas to improve traffic safety and comfort and enhances the environment (Sutandi and Dia, 2005a). The technology is applied to traffic signalling systems, traffic-safety and route and congestion management.

In large cities in developing countries, ATMS applications include:

- Adaptive Traffic Control Systems (ATCS);
- Ramp Metering;
- Lane Control Systems (LCS);
- Incident Management;
- Congestion Pricing.

3.2 ITS in Developing Countries

ITS have been implemented in Suvarnabhumi International Airport, Bangkok Thailand. Busways (Bus Rapid Transit - BRT), Chiang May Busway, and Bangkok Subways. Furthermore, The Bangkok Metropolitan Administration (BMA) has announced plans to build a second Bus Rapid Transit (BRT) route, from Nonthaburi's Pak Kret to Bangkok's Mor Chit, and Mass Rapid Transit of Thailand.
In Thailand, there are Thai ITS Stack and Technology Road Map, Thai ITS Master Plan, Thai ITS Forum, Existing ITS Development & Deployment, ITS Researches, and 10 years ITS Plan regarding traveler information, traffic management, vehicle commercial, public transport, safety and security, and electronic payment. Bangkok Metropolitan Administration (BMA) has already implemented Smart Traffic Sign (in operation), Smart Taxi Stand (in operation but not fully utilized), Smart Parking Building (review), Area Traffic Control, RTPI for Bus Rapid Transit, and CCTV (online for Internet and mobile phone) (Prathombutr, Passakon, 2008).

Nazri, Ai’d’a Fazirah (2007) said that many major cities in Malaysia such as Kuala Lumpur, Penang, Johor Bahru, and many others are currently facing serious transport problems as other big cities of the world. The benefit of implementing MITS reduce lag and congestion, fair and efficient treatment of traffic, increased safety, improved planning capability and maintenance for municipalities and overall improved traffic flow. Furthermore, reducing the effects of pollution from vehicles by better traffic management and reducing number of accidents by providing drivers with more information about conditions on the roads they are using.

Implementation of Adaptive Traffic Control Systems (ATCS) especially Sydney Coordinated Adaptive Traffic Systems (SCATS) in large cities in Asian countries is presented in Table 1. SCATS has gain popularity in Australia, Asia, and more recently in North America (PATH, ITS, 2005). SCATS is applied in many large cities in Asia, including Singapore, Cebu and Manila in the Philippines, Sandakan and Serembam in Malaysia, Sha Tin, Hongkong, and Guangzhou in China, Bandung and Jakarta in Indonesia, Brunei Darussalam, Suva in Fiji (AWA Plessey, 2006a, AWA Plessey, 2006b). In addition, SCATS is installed in 36 cities worldwide and controls around 7,000 traffic lights (ITS Australia, 2005, Ogden and Taylor, 1999).

<table>
<thead>
<tr>
<th>City, Country</th>
<th>Number of intersections connected to SCATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong, China</td>
<td>605</td>
</tr>
<tr>
<td>Shenyang, China</td>
<td>50</td>
</tr>
<tr>
<td>Shanghai, China</td>
<td>160</td>
</tr>
<tr>
<td>Guangzhou, China</td>
<td>40</td>
</tr>
<tr>
<td>Singapore</td>
<td>1020</td>
</tr>
<tr>
<td>Manila, Philippines</td>
<td>450</td>
</tr>
<tr>
<td>Cebu, Philippines</td>
<td>80</td>
</tr>
<tr>
<td>Sandakan, Sabah, Malaysia</td>
<td>10</td>
</tr>
<tr>
<td>Bandung, Indonesia</td>
<td>117</td>
</tr>
<tr>
<td>Jakarta, Indonesia</td>
<td>45</td>
</tr>
</tbody>
</table>

4. STUDIES REGARDING ITS IMPLEMENTATION IN DEVELOPING COUNTRIES

A few researches regarding the impact of ITS application in large cities in developing countries on traffic congestion and environmental quality are presented in this section. Nevertheless, this kind of research in developing countries is very limited. Various results were produced based on local conditions.
Sutandi, 2007 evaluated advanced traffic control systems SCATS (Sydney Co-ordinated Adaptive Traffic Systems) impacts on traffic congestion and environmental quality in Bandung, Indonesia. Using the validated microscopic traffic simulation models of all (90) intersections connected to SCATS as a part of ITS tools, in Bandung (TSS, 2004a, TSS, 2004b), the impact of SCATS on traffic congestion and environmental quality (fuel consumptions and pollution emissions) in this city were evaluated at network-wide level.

Two data sets were collected for use in this research. The first data set was used to develop and calibrate the models and the second data set was used for validation. The throughput data from each loop detector at each signalised intersection, in addition to queue length data from a number of signalised intersections with CCTV surveillance, travel time data of selected streams, and also the traffic control data, are believed to make up one of the largest sets of “real world” data available for the development, calibration, and validation of microscopic traffic simulation models (Sutandi, 2006). GETRAM (The Generic Environment for Traffic Analysis and Modelling) was used to develop the models. Therefore, the models were clearly accepted as significant valid replication of “the real world” (Sutandi and Dia, 2005a, 2005b).

The validated models in the Bandung North and the South Regions during peak and off peak periods were also run under the Fixed Time control. In large cities in Indonesia, include Bandung, the Fixed Time system at signalised intersections is based on the Indonesian Highway Capacity Manual (IHCM) – 1997 (Indonesian Highway Capacity Manual, 1997). In this manual, the methodology for analysing the signalised intersections is derived from the real geometric and traffic conditions in large cities in Indonesia.

Based on the same traffic demand and motorist behaviour, the distinguish traffic conditions as the impact of using SCATS and without SCATS can be explained through traffic performance measures differences that presented in Table 2. Table 2 shows that in average traffic performance measures under SCATS was not as good as expected. More detail discussion regarding fuel consumption and pollution emissions are presented using Figures 1 and 2.

| Table 2 Traffic performance differences between with and without SCATS in Bandung road network |
|-----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                   | Flow (veh/h)    | Queue Length (veh) | Density (veh/km) | Speed (kn/h) | Travel Time (h:mm:ss) | Delay Time (h:mm:ss) | Stop Time (h:mm:ss) | Stops(no.stops/km) |
| SCATS                            | 1,916           | 37              | 16.5            | 38.7          | 0:04:55           | 0:03:11           | 0:03:01           | 2.5               |
| FIXED                            | 1,950           | 31              | 15.6            | 39.5          | 0:04:33           | 0:02:49           | 0:02:39           | 2.5               |
| DIFF (%)                         | -1.77           | 16.22           | 5.31            | -2.01         | 7.36              | 11.45             | 11.98             | -0.19             |

The fuel consumption and pollution emissions as the results of comparative evaluation of the models with SCATS as a part of ITS and without the application of SCATS (under fixed time traffic control system) are presented in Figures 1 and 2. In large cities in Indonesia, include Bandung, the fixed time system at signalized intersections is based on the Indonesian Highway Capacity Manual (IHCM, 1997).
Figure 1 Fuel consumptions in Bandung road network

Figure 1 shows that the impact of advanced traffic control systems SCATS on reducing fuel consumption in Bandung road network is not good. Fuel consumption under SCATS seems similar to those under fixed time traffic control system. This condition can happen because of geometric conditions and traffic behavior of driver in Bandung. The low road network densities, only 3 percent of the whole city area, has to serve more than two million city resident with high population density and has also to serve more than 500,000 vehicles with high annual vehicle growth rate (6%) (AWAPlessey, 1996a, 1996b). Furthermore, poor lane discipline causes more traffic congestion. Vehicles in any lane at intersections, especially in direction with more than two lanes, may turn to the left, turn to the right, or straight through. Therefore, in these conditions advanced traffic control system cannot help to enhance traffic performance and reduce fuel consumption. In more detail, fuel consumption during peak periods especially during morning peak period is higher than during off peak period because activities and traffic congestion during morning peak period is the highest (Sutandi and Dia, 2005b).

Figure 2 Pollution emissions in Bandung Road Network with and without the application of SCATS during peak and off peak periods
Figures 2 shows that the impact of advanced traffic control system SCATS in Bandung road network on reducing pollution emission is not good, especially during morning peak and afternoon peak periods. Whereas during off peak period, the pollution emission of vehicles under SCATS traffic control system seems similar to under Fixed time traffic control system. This result consistent with the previous result that the impact of SCATS on reducing fuel consumption is worse during peak periods that usually has high traffic congestion.

Facing severe traffic congestion problems and then air quality deteriorations, in 2005, local government of Jakarta, Indonesia issued a bylaw on air pollution controls from mobile sources, which took effect since February 2006. All private car owners must get their vehicles’ emission tested twice a year. The vehicle owners will be given a certificate, as a requirement to extend the vehicle’s registration. This paper describes an initial analysis of vehicle characteristics which influence to emission testing results. Analysis was done by using On-road emission measurements at nine major roads in Jakarta city and its surrounding cities. Nugroho, et al (2007) apply bivariate probit model for the likelihood of CO and HC emission violations given a set of vehicle characteristics. The vehicle age, non-sedan, fuel type, carburetor and lambda all play a significant role in determining the probability of emission test failure.

A joint study by Japan International Cooperation Agency (JICA) and Environmental Impact Management Agency (1997) revealed that private motor vehicles and motorcycles contribute for 50% and 20% of CO emissions in Jakarta respectively. Looking at the mobile sources, comparing among several types of vehicle category, passenger car emit CO and HC dominantly.

Table 3 Jakarta’ in-use gasoline vehicles emission standards (Nugroho, et all,2007)

<table>
<thead>
<tr>
<th>Model year</th>
<th>CO (%)</th>
<th>HC (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carburetor car</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre - 1985</td>
<td>4.0</td>
<td>1000</td>
</tr>
<tr>
<td>1986 - 1995</td>
<td>3.5</td>
<td>800</td>
</tr>
<tr>
<td>1996 and newer</td>
<td>3.0</td>
<td>700</td>
</tr>
<tr>
<td>Injection car</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986 - 1995</td>
<td>3.0</td>
<td>600</td>
</tr>
<tr>
<td>1996 and newer</td>
<td>2.5</td>
<td>500</td>
</tr>
</tbody>
</table>

Source: Governor Decree of Jakarta No. 95/2000

Table 4 Variable definitions: means and standard deviations of measured parameters (Nugroho, et all, 2007)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Results of Emission test</th>
<th>Whole samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of samples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO (% of total volume of emission gas)</td>
<td>Failure of CO 6.086 (2.286)</td>
<td>Failure of HC 6.059 (2.286)</td>
</tr>
<tr>
<td>HC (ppm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>539.6 (366.0)</td>
<td>1047.5 (457.0)</td>
</tr>
<tr>
<td>Lambda (air to fuel ratio)</td>
<td>0.9041 (0.206)</td>
<td>0.9516 (0.351)</td>
</tr>
</tbody>
</table>
Total sample size obtained from on-site emissions measurements is 787 vehicles. Table 3 and Table 4 present gasoline vehicles emission standards in-use in Jakarta and Variable definitions, means and standard deviations of measured parameters, respectively. As regards vehicle characteristics, about 76.49% of all vehicles are non-sedan cars, and about 64.55% of all are carburetor cars. About 81.45% of vehicles use regular gasoline and the average air-to-fuel ratio is about 1.0067. The vehicles tested are more than 51% below or equal to six years old. The engine size capacity of vehicles concentrated in the range between 1000 cc to 2000 cc respectively (more than 88%).

Figure 3 shows that vehicle age positively affects CO emission test failure. These results are based on emission test. In Figure 4 emission test failures of Co and HC by vehicle engine size.

5. EVALUATION OF ITS IMPACTS ON TRAFFIC CONGESTION AND ENVIRONMENTAL QUALITY

Results study by Sutandi found that the impact of advanced traffic control system on traffic congestion and environmental quality in Bandung, Indonesia, is not good, especially during peak periods, because the application of this system in road network with limited road infrastructure, high population density, high number of vehicles, high traffic congestion, and specific traffic behavior cannot help to increase environmental quality (Sutandi, 2007). This result consistent with the other result that the impact of SCATS on enhancing environmental quality is worse during peak periods that usually has high traffic congestion.

In conclusion, it was found that the impact of advanced traffic control system on traffic congestion and environmental quality is not good, especially during peak periods, because the application of this system in road network with limited road infrastructure, high population density, high number of vehicles, high traffic congestion, and poor lane discipline cannot help to increase environmental quality.

The results obtained in the study by Nugroho, 2007 using bivariate probit regression model on I/M vehicles emission checking at several major roads in Jakarta city has successfully identified the characteristic of vehicles that are significantly associated with emission test which consist of Carbon Monoxide and Hydrocarbon emission test failure. Information from
this study can be used as the initial review results based on the actual conditions at the several major roads in Jakarta and its neighborhood.

In the context of urban air quality management and the social capacity, it can further classify the actor’s responsibility in order to reduce the emission from passenger car. The government should be take part into the variables of fuel quality and vehicle age. Government also can take part in the determining the minimum criteria of emission control equipment which should be installed for non-sedan car. Citizen or car user should be fully responsible to do regular and routine vehicle maintenance and repair in order to reduce their car emissions. The local government mention about the selective car which allowed register in Jakarta city based on their age or banned the old vehicle register in Jakarta city.

In case of urban air quality management, Nugroho, 2007 support the local government in order to reduce the mobile emission source especially from passenger car in Jakarta city. The results of study can be used as a preliminary review of the implementation of new regulation in Jakarta city, Indonesia.

6. CONCLUSIONS

Intelligent Transportation Systems (ITS) are advanced technologies that have been used in large cities in developing countries to reduce traffic congestion problems. In developing countries implementation of Advanced Traffic Management Systems (ATMS) as a part of ITS are well known. ATMS is used to solve traffic congestion problem. ATMS will integrate the management of various roadway functions. Researches regarding the impact if ITS in increasing traffic performance and then enhance the quality of environment in large cities in developing countries are very limited. However, it can be summarized that to produce a good results of implementation of ITS tools in increasing traffic performance and enhancing the quality of environment, specific local geometric and traffic conditions such as limited road infrastructure, high population density, high number of vehicles, high traffic congestion should be concerned. Moreover, road user should change their traffic behaviour and adhere to the traffic regulation in order to support government’s efforts.

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