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Technology Transfer and Project Implementation Information

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Effectiveness of the Borman Expressway ITS Program on Local Air Quality

Introduction

The Borman Expressway in Northwestern Indiana is one of the most heavily traveled freeways in the United States especially among heavy duty diesel vehicles such as semi tractor trailers. Heavy duty diesel vehicles are a major source of fine particulate matter, or $PM_{2.5}$, and with the recent revisions in the National Ambient Air Quality Standards focusing on $PM_{2.5}$, vehicles with diesel engines as well as other mobile sources will be targets for significant $PM_{2.5}$ emissions reductions. Intelligent Transportation Systems (ITS) present one method of reducing emissions from all vehicles including those that are diesel powered. By smoothing out traffic flow, reducing traffic congestion, and minimizing accident response and clearance times ITS could reduce vehicle acceleration and deceleration cycles which are associated with increased pollutant emissions.

An environmental monitoring station adjacent to the Borman Expressway in Northwestern Indiana has been collecting data on $PM_{2.5}$, Carbon Monoxide (CO), and meteorological parameters since September of 1999. Monitoring began prior to the installation of ITS technology and is continuing, as of this draft, while the last components of the ITS system are being put in place. Data was collected at a 10 second averaging interval to resolve short term events associated with the rapidly changing conditions on the Borman expressway. Limited traffic data, averaged at 5 minute intervals, became available in June of 2001. The general objective of this study was to correlate the local air quality to events on the Borman and determine the overall effect of the ITS on the local air quality. An “event” on the Borman is defined as anything that impairs traffic conditions on the Expressway. Construction delays, lane restrictions, accidents, weather, and excessive demand are all capable of creating congestion and impairing the utility of the expressway.

Findings

Correlating local air quality to vehicle operating conditions is a complicated process. Individual vehicle emissions vary considerably with both speed and acceleration. Moving from the individual vehicle level to the roadway level complicates matters further because vehicles travel at a variety of speeds at varying densities. However if you step back from the details and consider the road as a means of conveyance for people and goods and consider the energy (fuel) required to move those people and goods, logical correlations begin to present themselves.

Pollution, (fine particulate matter, carbon monoxide, and others) is a by-product from the conversion of stored energy (gasoline and diesel fuel) to kinetic energy (vehicular motion). As a vehicle travels from point “A” to point “B”, it encounters friction from the roadway, friction from internal moving parts, and drag (total drag is the sum of form drag and skin friction drag) from the air (wind resistance). All of these require energy to overcome and therefore produce pollution. If the vehicle is required to slow down during its trip, energy is dissipated via the brakes and/or engine (in the case of compression braking) as heat energy. To return to its prior speed, the vehicle must not only overcome the resistance previously described but accelerate as well, thereby requiring more energy and thus producing more pollution. In work previously demonstrated by Dr. Robert B. Jacko, acceleration has a pronounced effect on vehicular emissions.

Three general statements can be made at this point.

1.) At constant speed and all other factors equal, the more vehicles operating in a mile of roadway, the more pollution that will emanate from that roadway.

2.) Acceleration requires additional energy (fuel) input to vehicles beyond cruising and therefore produces additional pollution beyond that produced by cruising vehicles.

3.) Deceleration converts kinetic energy (vehicular motion) into heat that must eventually be replaced with more energy (via acceleration) if the vehicle is to return to its prior speed.

Therefore, the most efficient, and thus least polluting means of traveling between two points is one that minimizes acceleration.

How is this theory put into practice? Consider your own driving experience. When density (vehicles per mile) is very low and you are essentially the only individual on the road, you are free to drive at any speed you wish without having to change lanes or accelerate to pass individuals. Your vehicle is operating about as efficiently as it can given the average speed you have chosen to drive. Better fuel mileage may be achieved at a different speed, but you could do much worse if you had to accelerate and decelerate frequently to accommodate other vehicles.

Now consider a road where you're driving "at the speed of traffic". You may still be traveling at the same speed you were when the road was yours alone but you no longer have the option to travel any faster, and you can not decelerate without affecting traffic behind you. In this scenario, emissions from each individual vehicle are the same as they would have been if each of them were on the roadway alone. But because of the greater density of traffic on the roadway, the emissions from *roadway* into the local air are much greater than they were before when you were the only vehicle on the road.

As more vehicles demand use of the roadway, speeds begin to decline as drivers adjust to reduced vehicle spacing. Acceleration and deceleration increase as drivers must adjust vehicle speeds to accommodate other vehicles. As vehicle density increases, speeds decline and acceleration/deceleration cycles continue until jam density is reached and vehicles are moving very little if at all. Many different factors are in play in these operating conditions. As traffic density increases, velocity decreases therefore frictional energy and form drag demands decrease, so logically, pollutant emissions decrease, however, as traffic density increases acceleration/deceleration cycles increase therefore increasing energy input (and therefore pollution) into the system. Finally, as density increases you have more sources of pollution (vehicles) per mile.

One of the parameters available from the Borman ITS program is roadway occupancy. This is a ratio of the time any vehicle is over a sensor to total time, or the time the sensor is "occupied". This parameter is analogous to traffic density, the parameter discussed at length to this point. Our environmental measurements and measurements of traffic occupancy have shown that, as expected by the vehicle energy requirements just described, pollution flux near the Borman Expressway is well correlated with traffic occupancy.

A telling example of this is in comparing two scenarios varying only in density of traffic. Speed, flow, and density are three interrelated parameters useful in describing the operating conditions on a roadway. Flow is the number of vehicles per hour and is the product of the speed of the vehicles (in miles per hour) and the density of traffic (in vehicles per mile). At a given flow however, you may have more than one set of vehicle speed and density. You can have a high speed and low density or a low speed and high density. In real world terms, this would be a case where traffic might be heavy but moving along at a reasonable speed versus slower very congested traffic moving well below posted limits.

In a similar real world case on the Borman Expressway, our research demonstrated that for the same number of vehicles moving through a segment (1600 veh/lane/hour), higher traffic occupancy (25%) produced 16% to 34% more pollution (carbon monoxide and fine particulate matter) in the area near the roadway than did traffic at lower occupancy (19%). This illustrates the environmental benefit of minimizing oversaturated traffic flow conditions. The same number of vehicles were moving through the segment, the only difference was in the density of them. If this traffic situation can be avoided or minimized, as ITS can do, then the air quality near the Borman will be improved.

In addition to the general relationships between flux and traffic occupancy, specific events (designated by Hoosier Helper responses to accidents), were studied. Local air pollution would frequently increase by a factor of 2 or 3 over pre-event (accident) pollution levels. An additional benefit of ITS is the reduction of accidents, particularly secondary accidents (accidents occurring within or at the end of a traffic queue from a prior accident). Obviously the reduction of accidents and secondary accidents by ITS would reduce the environmental impact of the Borman on local air quality.

One of the real benefits of this study is that for the first time we have quantifiable real-time road parameters that have been correlated to real-time environmental conditions. This will permit the development of traffic management tools that incorporate the environment. This is one of the goals of the implementation phase of this project.

Implementation

Correlations between flux and vehicle occupancy as well as between flux and traffic flow have shown that mitigating oversaturated traffic conditions can significantly reduce PM2.5 and CO in the area adjacent to the Borman Expressway. ITS is the unique tool for accomplishing this improvement in the air we breathe near the expressway. By monitoring real-time traffic conditions, the Borman ITS system will optimize the smooth flow of traffic. Rerouting scenarios including providing information to motorists regarding traffic conditions will allow drivers to make informed travel decisions and thereby avoid congested areas. Consequently, the Borman ITS program should result in improvement of the local air quality, as it will provide information for faster response by the Hoosier Helpers and other emergency vehicles thereby shortening traffic backups and subsequent pollution production. Keep in mind that the while the first phase of this project has shown how ITS can improve air quality near the Borman, the ITS system was not fully operational at the time of the completion of this phase. A follow-up phase will incorporate all of the ITS data and add substantially to the understanding of the environmental benefits of ITS.

The follow-up phase of the project will assess the effects of fleet mix, number and type of lane obstructions (moving lane closure, fixed lane closure, accidents), and duration of closure. A model will be developed and verified based on data from the site. This model and other work associated with the follow-up phase will be incorporated into a set of tables and/or a decision matrix that will assist planners and operators in making environmentally sound decisions regarding not only the Borman expressway but other expressways as well.

The benefits of ITS will be communicated in several ways including; A press release to be developed through the INDOT Office of Communication, talking points for public officials, and information sharing with Gary, Chicago, Milwaukee corridor officials. The information will also be incorporated into Trafficwise.org, a website that will offer information about traffic conditions including information gathered from intelligent traffic systems in the state of Indiana. These educational initiatives will help the public at large understand their role in keeping traffic moving smoothly and the environmental benefit of driving decisions made with the assistance of ITS systems.

Contacts

For more information:

Prof. Robert B. Jacko
Principal Investigator
School of Civil Engineering
Purdue University
West Lafayette IN 47907
Phone: (765) 494-2199
Fax: (765) 496-1988

Indiana Department of Transportation
Division of Research
1205 Montgomery Street
P.O. Box 2279
West Lafayette, IN 47906
Phone: (765) 463-1521
Fax: (765) 497-1665

Purdue University
Joint Transportation Research Program
School of Civil Engineering
West Lafayette, IN 47907-1284
Phone: (765) 494-9310
Fax: (765) 496-1105