Environmental Impacts of
Truck-Only Lanes on Urban Freeways:
A Microsimulation Approach

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An Integrated Microscopic Simulation Approach

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ABSTRACT

Freight transportation, particularly by trucks, plays a key role in the economy at the national, state and local levels. However, increasing truck traffic on urban freeways bring about many truck-related transportation problems such as congestion, traffic accidents and air pollution, especially in urban areas where transportation problems are already regarded as a big concern. Several locations around the country have either modeled or examined the benefits building truck-only lanes where truck traffic is the heaviest. However, in our opinion, the fares charged to use these facilities will not be sufficient to cover their costs. Therefore, if public agencies are going to invest in these facilities they will have to be justified for their regional economic benefits, safety impacts and air quality impacts. Our study examines the potential air quality impacts of developing a truck-only facility on the I-170 freeway leading to and from the busy ports complex of Los Angeles and Long Beach. The ports complex is an Environmental Protection Agency air quality non-attainment area. Our research complements earlier study which estimated potential fares and safety benefits associated with the development of a truck-only facility at this location.

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INTRODUCTION

Freight transportation, particularly by trucks, plays a key role in the economy at the national, state and local levels. However, increasing truck traffic on urban freeways bring about many truck-related transportation problems such as congestion, traffic accidents and air pollution, especially in urban areas where transportation problems are already regarded as a big concern.

This study is motivated by growing concerns about air pollution in Southern California. Despite tremendous strides made by the State of California in controlling emissions from mobile and stationary sources, the current air quality conditions in South Coast Air Basin are getting worse. The rapidly growing population, economic growth and increased imports demand higher freight movements as well as passenger transportation in this region. The high proportion of truck traffic is increasingly becoming a concern in terms of traffic congestion, safety and air pollution. This is partly due to the characteristics of the area where the Ports of Long Beach and Los Angeles are located. As a result, this area is designated as one of the severest non-attainment areas by the U.S. Environmental Protection Agency (EPA). A non-attainment area indicates an area that does not meet the national primary or secondary ambient air quality standards for a set of pollutants.

Freight movements in and out of the port complex involve single mode trucking and railway operations and intermodal operations, which contribute to air pollution in this area. For example, even with the adoption of new truck emission standards, the share of total mobile source NOx emissions in the South Coast Air Basin attributable to trucks is expected to increase from 44% to 53% between 2000 and 2010 (1). In an effort to reduce air pollution as well as mitigating traffic congestion in the area, the establishment of dedicated truck lanes is being considered along the Long Beach Freeway (I-710), which is a main corridor for freight transportation that provides regional access to the Ports of Long Beach and Los Angeles. While many hurdles to the development of these lanes remain, there are several indications that their development could ease many of the safety and environmental problems plaguing the area adjacent to the Ports complex.

The primary objective of this preliminary study is to evaluate the feasibility of establishing truck-only lanes in urban freeway systems in terms of its potential environmental impacts. The evaluation is based on microscopic simulation approach. In order to achieve this goal, an emission model must be integrated with existing microscopic traffic simulation programs such as PARAMICS. For this reason, this study addresses the development of an integrated traffic and emission simulation model at the microscopic level. An approximately 15-mile northbound freeway segment of the I-710 corridor was selected for our case study. The goal of our case study is to test the reasonableness and applicability of the integrated model developed in this study.

The paper is organized as follows. The next section introduces some background information related to truck-only lanes and recent research efforts obtained from relevant literature survey. This is followed by the description of the integration of the emissions model into a traffic simulation framework. In this section some potential emissions models are briefly explained. Then our case study is examined. Finally, the paper concludes by discussing application results and future research directions.
BACKGROUND

Truck-only lanes are lanes designated for the exclusive use of trucks. Normally, other types of vehicles are not allowed to use truck-only lanes. The basic idea of truck-only lanes is to separate slowly moving trucks from other high-speed traffic to enhance safety and/or stabilize traffic flow. While truck-only lanes or truck-only facilities have been considered by several states, few have been constructed. Several benefits associated with truck-only facilities have been identified. These are increased safety, reduced congestion, reduced emissions and under some conditions, faster shipment delivery. The State of California and the Southern California Association of Governments have been considering expanding the number of truck-only facilities beyond the two on the I-5 freeway to several locations in Southern California (2).

A study put out by the Southern California Association of Governments focused on State Route 60 from I-710 to I-15, a distance of approximately 38 miles (3). Three main strategies were considered, including: 1) allowing trucks to share the high occupancy vehicle (HOV) lanes during limited time periods, 2) adding truck lanes to the freeway at grade, and 3) adding lanes above the freeway grade. However, the first HOV lane option was dropped due to a number of barriers, including legal and funding obstacles. As a conclusion, the study recommended combining the two non-HOV strategies, with at-grade truck lanes built where feasible, and above-grade mixed-flow lanes built where right-of-way acquisition would be difficult. However, it was noted that above-grade lane sections should be kept to a minimum due to safety and operational considerations, as well as higher construction costs. To date, these truck-only lanes have not been constructed, due to a variety of complicating factors.

A recent study by Pooe and Samuel identified candidate sites for the development of tolled truck-only lanes (4). That study was primarily concerned with the development of truck-only lanes on portions of the US highway system where longer combination vehicles are permitted. Their study suggests that to be viable, these facilities must include two lanes in each direction so that breakdowns and accidents would not bring traffic to a halt. That study followed their earlier study (3) which focused on proof of concept for truck only lanes. A study by Fischer, Atanu, and Valisiewski (6) also examined the feasibility of developing truck-only lanes on the heavily congested SR-60 and I-710 highways in Southern California. Those lanes would not allow for longer combination vehicles because the length of the potential truck-only portion is insufficient to support using those vehicles. That study did a preliminary analysis of the tolls that could be charged and the safety implications of adding truck-only facilities.

In our opinion, however, the case for truck-only lanes will not likely be made on the basis of cost. Most trucking companies will not be willing to use the facilities if they are required to pay fares that would recover the cost of maintenance and construction. If public agencies decide to invest in such facilities, they must make the case for these investments based on regional economic measures, safety and air quality impacts. Our study aims to complement the earlier research by examining the potential emissions impact of building truck-only lanes. Our study also lends some insight to the question of how much air quality could be improved by shifting some of the port truck traffic to the rail
lines. That too is problematic. Despite the fact that significant improvements have been made in the rail facilities and the on-deck rail lines, much of the freight coming through the port is perceived by shippers to be too time sensitive to wait for rail service. In addition, despite some recent improvements, it is not clear how much additional freight could easily be absorbed by the rail lines.

It should be noted that our simulation study examines restricting trucks to the right most lane only and the conversion of a mixed use lane on an existing facility to a truck-only lane. We see these alternatives as potentially viable inexpensive alternatives to new construction. In addition these can provide us an opportunity to further consider the safety, economic and air quality benefits of segregating truck traffic on certain facilities. In addition to enormously high construction cost, earlier attempts in Southern California to construct truck-only lanes met with significant public resistance because of the need to destroy several hundred homes along the freeway. These homes are occupied by lower income residents who, even if they receive a benefit due to their homes, would not be able to find similar residences in Southern California to purchase.

INTEGRATED EMISSION AND TRAFFIC SIMULATION MODEL

As part of our study, an integrated microscopic traffic and emission simulation model is developed to measure the impacts of truck-only lanes on air quality in urban areas. Microscopic traffic simulation is a software tool to model the real-world traffic phenomenon, resulting from the interactions between different components involved such as the road, drivers, and vehicles in fine details. In a micro-simulation process, the state of an individual vehicle is continuously or discretely simulated and observed based on vehicle-vehicle and vehicle-road interactions. The car-following, lane-changing and gap-acceptance models are the basic elements of a microscopic traffic simulator. Notable instances of micro-simulators include PARAMICS, CORSIM and VISSIM, among others. See Jayakrishnan et al. (7) for more details about microscopic simulators available to transportation studies. With the advancement of computer technology and modeling traffic flow at the microscopic level, microscopic simulation is increasingly becoming a popular and effective tool for many transportation applications such as modeling and evaluating ITS strategies, which are not amenable to study by other means.

Among many candidates, we selected the PARAMICS as our traffic simulation tool for its distinct advantage, i.e., the capability of easy integration with other models through a function of Application Programming Interface (API). To examine the emission impacts of freeway traffic, we now need to select an emission model suitable for the study under consideration and data incorporated into traffic simulation framework of the PARAMICS. The following paragraphs describe some potential emission models collected from relevant literature.

Emission Models

A number of emission models have been developed over the years. Different perspectives lead to different models and data requirements. Hence we first evaluate the characteristics and applicability of each model and then choose one of the models most appropriate for
our study. Emissions models can be classified into macroscopic and microscopic models, depending on the level of details of input data that feed into the model.

- **Macroscopic emissions models** are based on averaged characteristics of a fleet of vehicles such as average speed and/or vehicle-mile traveled. The MOBILE developed by the EPA and the EMFAC by the California Air Resources Board are in this category. The macroscopic models are suitable for planning level study, in which aggregated data is used. The major components in these models include vehicle type and age, average speed, ambient basic emissions rates, fleet characteristics, local conditions such as temperature, fuel characteristics and inspection and maintenance program. Ding (8) and National Research Council (9) present more detailed information on these models.

- **Microscopic emissions models**, on the other hand, are based on instantaneous values of individual vehicles. Instantaneous emission models compute a vehicle’s emission based on instantaneous measurements of explanatory variables such as vehicle speed and acceleration/deceleration, roadway gradient, and vehicle’s power. Thus fuel consumption models commonly used at present can also be classified into the microscopic models, including UC Riverside model (10, 11). Using this methodology, Ahn (12) in the Virginia Polytechnic Institute and State University developed microscopic vehicle emission models in the form of polynomial equations. Taylor and Young (13) developed another instantaneous model called University of South Australia (USA) model. The variables in the model include instantaneous values such as speed and acceleration at a specific time. The model yields the rate of emission/consumption (E/C) of components for: (a) the fuel used or air pollutants generated in maintaining engine operation, estimated by the idle rate, (b) the work done by the vehicle engine to move the vehicle, and (c) the product of energy and acceleration during periods of positive acceleration.

Among various emission models described above, we employ one of the microscopic models since they can well respond to the operating characteristics of individual vehicles generated from traffic simulation at macroscopic level. In this respect, three microscopic models can be considered. However, the Virginia Tech Model does not capture some of key factors that affect emissions generated by each vehicle such as vehicle weight and gradients of road segment, while UC-Riverside model is too difficult to implement under limited data acquisition environment. On the other hand, the USA model considers more factors into measuring emissions compared to the Virginia Tech Model. Furthermore, it is easy to implement. However, we should point out that the parameters identified in the USA model may not fit to the U.S. freeway system since they were originally developed based on the Australian highway conditions. A detailed description of the USA model and its associated parameters may be found in Oh and Cortes (14).

**Integration of Emission Model into Traffic Simulation Program**

In traditional planning practice, emissions rates of various air pollutants are determined in a way that traffic volume is first estimated from demand models and then its estimates are fed into emission model to calculate the rate of each pollutant. Such post-processing methods have a drawback that it does not fully capture the characteristics of each individual vehicle and dynamism of total traffic. To overcome this limitation of existing methods, it seems clear that a combined traffic and emission model should be used to
better measure emissions rates. In the PARAMICS simulation framework, there are two ways that emission models can be integrated with PARAMICS: 1) using emissions look-up table, which can be generated from emission model and implemented in PARAMICS using "PARAMICS Monitor Plug-in", 2) using an embedded set of emission functions, which involves the development of model-specific APIs in PARAMICS. See Barth, et al. (11) and Quadrifonte, Ltd. (13) for more information on these methods.

In this study, the approach of using emissions look-up table is chosen since the look-up table can be readily generated from existing emission models and thus it is easy to implement. Note that the method of using an API function associated with an emission model would generate more accurate results in terms of level of details. This is currently under development and will be considered in the next stage of our study. The approach by emissions look-up table involves creating the following three new files for integrating emissions model into PARAMICS simulation model.

- 'pollution' – a file defining pollutants, factors and emission lookup table
- 'pv-type' – a file matching vehicle types defined in traffic model with polluting vehicle types in emission model
- 'pollution-control' – a file configuring PARAMICS Monitor. To enable this file, the following statement must be added to the network 'configuration' file: read parameters file "pollution-control"

After the simulation has run for the pre-specified time period, the pollution levels are saved to a file called 'link-pollution-HH-MM-SS'. The following diagram describes overall integration process of emissions model into PARAMICS simulation framework.

**FIGURE 1: Integration Process of Emissions Model into PARAMICS Simulation**
APPLICATION TO THE I-710 CORRIDOR

Once the integrated simulation model is developed, the problem at hand is to apply the model to real-world air pollution problems related to transportation, particularly by trucks. Then the model should be evaluated in terms of its reasonableness and applicability. Overall procedure of our application study is illustrated in Figure 1. Each of individual steps is briefly described as follow.

FIGURE 2: Overall Procedure of the Application Study

Study Area and Problem Identification

Air pollution problems currently undergoing in Southern California by increasing truck traffic along the Long Beach Freeway (I-710) provide a good example for our case study. As mentioned earlier, I-710 is a main corridor for freight transportation that provides regional access to the Ports of Long Beach and Los Angeles. It extends from the east side of the port area to downtown Los Angeles and connects along its northbound way with Pacific Coast Highway (SR-1), San Diego Freeway (I-405), Riverside Freeway (SR-91), Century Freeway (I-105), Santa Ana Freeway (I-5) and ends near the intersection with Santa Monica Freeway (I-10).

For our case study, we chose an approximately 15-mile northbound freeway segment of the I-710 corridor where truck traffic is the heaviest. The proportion of truck traffic on I-710 amounts to almost 14 percent over the entire freeway segment, which is comparable with 3-5 percent of other Southern California freeways (76). Figure 3 depicts overview of our study area.
Simulation Network

After defining study area, we developed a simulation network of the area. The network was coded in PARAMICS based on the physical characteristics of each road segment such as number of lanes, length and width, speed limit, and also on its operational features associated with vehicles and drivers. Network information for existing conditions was obtained from relevant data sources such as PeMS (97) and the default values pre-specified in PARAMICS were applied to the parameters related to vehicles and drivers. Proposed truck-lane alternatives were added onto the base network presented in the following figure.
In order to simulate actual traffic phenomenon, the microscopic simulation model requires an origin-destination (O/D) demand that reflects vehicle movements from one place to another. However, O-D demand data specific to our study area are not available. In this study, we obtained a reference O-D demand data generated from the OCTM (Orange County Transportation Model), and then calibrated it to fit to actual traffic flow patterns. The calibration was performed based on an observed traffic data provided by the California Department of Transportation (16). The estimated demand is for AM peak time period, i.e., 5:00-9:00 a.m. since the time period is the most congested. In addition, 8 different vehicle types were considered to reflect the most real-life traffic conditions, in which trucks are classified into 4 types depending on the number of axles and weight, and truck portion is assumed to be 15% of total traffic.

It is important to note that the calibration and validation processes for simulation network and its associated parameters is the most important step in any simulation studies to obtain desirable results. It should be carefully conducted since the level of accuracy of simulation results depends largely on the calibration process. The work by Chu, et al. (18) provides useful information about calibration process in the microscopic traffic simulation contexts.

Scenarios

As a way of improving air quality in our study area, two alternatives to establishing truck-only lanes were considered for our application study. The current condition of simulation network is operating without any restrictions for mixed traffic. This consists of 'Baseline' scenario of this simulation study. To maintain equivalent conditions of simulation network over different alternatives, we assume that the physical and operational characteristics of baseline simulation network including demand are all applied for alternative network simulations except the one associated with restrictions for truck traffic. Each alternative scenario related to truck lanes is described as follows, and these are compared to the baseline scenario.

- **Alternative 1:** The first alternative is to consider a truck lane scenario in which one lane at the right most part of the road is designated for truck use. In this scenario, it is assumed that trucks are restricted to use the designated lane, but other types of vehicles are allowed to use the truck lane. This scenario reflects the current situations that slowly moving trucks have a tendency to use the right most lanes of the road. This scenario is referred to as 'Alternative 1' scenario.

- **Alternative 2:** As the second alternative, we consider an exclusive truck-only lane. This alternative has the same conditions as those of the Alternative 1 except the fact that other types of vehicles are not allowed to use the designated truck lane. This is defined as 'Alternative 2' in our analysis.

Based on the baseline simulation network, each alternative simulation network can be easily coded in PARAMICS by restricting trucks to the rightmost lane and adjusting some parameters that control lane-changing allowance of vehicles. Figure 5 presents graphical representation of each scenario considered in this simulation study.
Simulation Results

PARAMICS is a stochastic simulation model, which relies on randomly generated numbers to release vehicles, assign vehicle types, destination and route, and determine their behavior as the vehicles move over the simulation network. This implies that individual simulation runs using the same assumptions will produce somewhat different results. Therefore, we base our simulation results on the average values obtained over thirty simulation runs for each scenario. Although precise statistical tests were not conducted, it is reasonable to assume that most variables of interest, i.e., changes in speed and emissions rates of each pollutant, are normally distributed. Therefore, we compare the mean values observed under the different alternatives.

To evaluate the effectiveness of each alternative, two measures are used, i.e., average speed and emission rates of each pollutant. Each measure of effectiveness reflects the improvement of traffic conditions and air quality in the overall network, respectively. For the evaluation of the air quality of the study corridor, the four air pollutants most commonly used in practice were selected and estimated in this study. These include Carbon Monoxide (CO), Carbon Dioxide (CO₂), Hydrocarbon (HC) and Nitrogen Oxides (NOx). Note that emission rates of each pollutant were measured in units of grams per vehicle-kilometer traveled since the total number of simulated vehicles differs across runs.

Table 1 provides the summarized results of our simulation study for each alternative scenario. The results show that introducing a truck lane, which other vehicles are permitted to use as needed, produced the most successful results. Emissions generated by mobile sources near the I-710 corridor can be significantly reduced. Rates of reduction seem to range from 2.8% in HC to 7.1% in CO₂ and 10.4% in NOx while CO is expected to be slightly increased by 2.8%. This can be justified by the increase in average speed under this scenario which can be interpreted as the effect of a decrease in truck traffic that disturbs the higher speed traffic in the other lanes. On the other hand, the case of an exclusive truck lane seems less effective in terms of air quality. Under this condition, emissions rates of all pollutants would be increasing from 1.0% in CO₂ to 16.3% in NOx. This can be explained by the fact that the establishment of exclusive truck lane on the I-710 corridor leads to the situation in which traffic congestion of other lanes becomes worse.
by constraining the full utilization of existing capacity while capacity of the truck-only lane is not fully utilized. This implies that truck portion of 15% we employed may be insufficient to support a policy option of exclusive truck lane for our study area.

Finally, based on our preliminary simulation results, we can conclude that alternative 1, that is, restricting truck traffic to a mixed use right lane, is the most effective policy option in terms of improving traffic congestion and air quality.

Table 1: Effectiveness of Potential Truck-Only Lane Strategies

<table>
<thead>
<tr>
<th></th>
<th>Speed (kph)</th>
<th>CO (g/veh-km)</th>
<th>CO₂ (g/veh-km)</th>
<th>HC (g/veh-km)</th>
<th>NOₓ (g/veh-km)</th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
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<td>14.73</td>
<td>206.7</td>
<td>0.20</td>
<td>8.93</td>
</tr>
<tr>
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<td>15.15</td>
<td>192.1</td>
<td>0.19</td>
<td>0.83</td>
</tr>
<tr>
<td>Alternative 2</td>
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<td>15.00</td>
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<td>0.23</td>
<td>1.08</td>
</tr>
<tr>
<td>Percent Change (%)</td>
<td></td>
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<td>-2.8</td>
<td>-2.8</td>
<td>-10.4</td>
</tr>
<tr>
<td></td>
<td>-5.6</td>
<td>1.8</td>
<td>1.6</td>
<td>13.8</td>
<td>16.3</td>
</tr>
</tbody>
</table>

CONCLUSIONS AND RESEARCH CHALLENGES

In this study, we evaluated the environmental impacts of restricting trucks to the right most lane or converting the right lane of traffic to a truck-only lane. An integrated microscopic simulation model that simultaneously measures both traffic behavior and emissions rates of individual vehicles was developed to estimate the emission impacts of restricted truck traffic or track-only lanes in an urban freeway system using the Southern California I-710 corridor. The integrated model was implemented in the PARAMICS simulation framework. Simulation results show that all but one observed pollutants decreased when trucks were restricted to one lane of traffic only. This suggests that this relatively inexpensive alternative should be considered in some urban areas. Alternative 2, which appears to be less successful might be more successful under conditions of additional truck traffic. In addition, successful implementation of the integrated microscopic simulation model developed in this study demonstrates the potential of its applicability to future emission-related transportation projects.

For future research, the impacts of alternative truck lane schemes need to be studied for the development of better policy options for air quality control. For example, network configuration of truck lanes could be a factor that affects overall network-wide performance. Our study assumed that trucks make up 15% of the traffic in the corridor studied. An increase or decrease in that fraction would naturally impact the usefulness of restricting truck traffic or of creating truck-only lanes.
Regarding the integrated model, the method using an emission lookup table employed in this study has limitation that it does not measure detailed emissions of vehicles due to the approximation of the emission rates in the table. Therefore, model-specific APIs that generate more detailed information on emission rates of individual vehicles needs to be developed, and their applications remain as future research arena. Finally, the emissions model embedded into our microscopic traffic simulation model has a limitation that it does not capture the characteristics of individual modes, which means that an advanced emission model should be incorporated in the future. We must acknowledge that we consider our results preliminary. Of key importance for these types of studies is the development and dissemination of reliable origin-destination data for automobiles and trucks. We continue to conduct additional studies in order to gain more confidence in our findings.

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