Emissions Comparison Between Truck and Rail: Case Study of California I-40

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A comprehensive goods movement study of the California Interstate 40 corridor (from Barstow to Needles) has recently been completed. This study attempted to characterize goods movement in the region, perform a corridor emissions analysis, and make recommendations in terms of capacity and improvements, as well as economic feasibility of using rail in conjunction with trucks for goods movement. The emissions analysis of goods movement along the I-40 corridor is examined, specifically emissions of carbon monoxide, hydrocarbons, nitrogen oxides (NO_x), and particulate matter associated with both truck and rail traffic. Heavy-duty diesel truck emissions are estimated using truck activity data recorded along the corridor. A unique methodology is used to calculate these truck emissions, incorporating road grade factors and determining engine load on a link-by-link basis. These emissions are then compared with the emissions associated with freight trains that travel along this I-40 corridor. On the basis of current (1994) truck and rail volumes, it was found that goods moved by rail produces lower emissions, except for NO_x, which is slightly higher for rail. The factor decrease of other pollutants ranges from 2.49 to 8.50, which is consistent with other recent studies. Given the amount of pollutants produced by trucks, shifting some of the freight from trucks to rail with a greater emphasis on intermodal business should reduce the total freight emissions along the I-40 corridor.

The California Interstate 40 freeway from Interstate 15 near Barstow to the California-Arizona state line (approximately 225 km) has been identified as a high-priority corridor in the National Highway System. Because of the North American Free Trade Agreement (NAFTA), there will be a greater need for infrastructure improvements on the California I-40 to reduce future congestion, air pollution, and travel time along this corridor. In addition, California is one of the few states that have severe air quality problems, so the federal Clean Air Act (CAA) has an influence on the way that railroads and trucking companies operate in the state.

During 1994 and 1995, the authors performed a comprehensive study of the California I-40 corridor, a nonattainment area for particulate matter (PM) in California's San Bernardino County (*1*). The purpose of the study was to analyze several issues associated with intermodal goods movement—specifically, to (a) characterize goods movement in the region, (b) perform a corridor emissions analysis, and (c) make recommendations in terms of capacity and air quality improvements, as well as economic feasibility of using rail in conjunction with trucks for goods movement.

This paper focuses on the emissions analysis of goods movement along the I-40 corridor, specifically on emissions associated with both truck and rail. The analysis consists of the emission species carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x), and PM. Heavy-duty diesel truck emissions are estimated using truck activity data recorded along the corridor. A unique methodology is used for calculating these truck emissions, incorporating factors of road grade and determining engine load on a link-by-link basis. These emissions are then compared with the emissions associated with freight trains that travel along this I-40 corridor.

Comparatively little information is available in the literature on the relative emission levels of railroads and trucks. Many studies deal with the aggregate levels of railroad and truck operations, but only a few address their intermodal competition and associated emissions (*2,3*). The study by Blevins analyzed a representative route across Canada on which two types of modes competed for goods movement. Some of the key conclusions of this study were that railways can competitively move freight at a fuel savings typically in the range of 65 to 70 percent compared with trucks. Further, a savings of 30 to 40 percent of NO_x pollutants per net ton kilometer can be achieved (*2*). The Abacus study considered 38 truck and train scenarios (*3*). Computer simulations using actual data of both rail and truck operations were run for the same origins and destinations; it was found that rail achieved a higher ratio of ton miles moved per gallon of fuel than trucks (by a factor of 1.4 to 9). This study, however, did not consider secondary transportation costs, speed of delivery, or quality of service.

In this paper, background on the California I-40 corridor is given, and the data collection process of the study is described briefly. Next, the methodology of estimating truck and rail emissions is provided, which is followed by a set of conclusions and recommendations for further study.

DATA COLLECTION

The California portion of I-40 lies between the towns of Barstow and Needles, as shown in Figure 1. I-40 is a rural freeway with two lanes in each direction, a right-of-way width of 122 m, and truck climbing lanes at two locations. Currently, most of the California I-40 corridor operates at Level-of-Service (LOS) B or better except near Barstow, where it sometimes operates at LOS D (*4*).

Vehicle Classification Counts

As part of this research project, field studies along the corridor were conducted. Detailed vehicle classification counts (VCCs) were performed at numerous locations along the corridor, and truck drivers traversing the route were surveyed. The primary purpose of these field studies was to obtain detailed information on current goods movement patterns and fueling practices. Another key objective was to obtain traffic counts indexed by vehicle type, which were then used as vehicle activity data in the corridor emissions analysis. Bidirectional 24-hr manual VCCs were conducted at seven locations between Barstow and Needles during the week of March 28, 1994.

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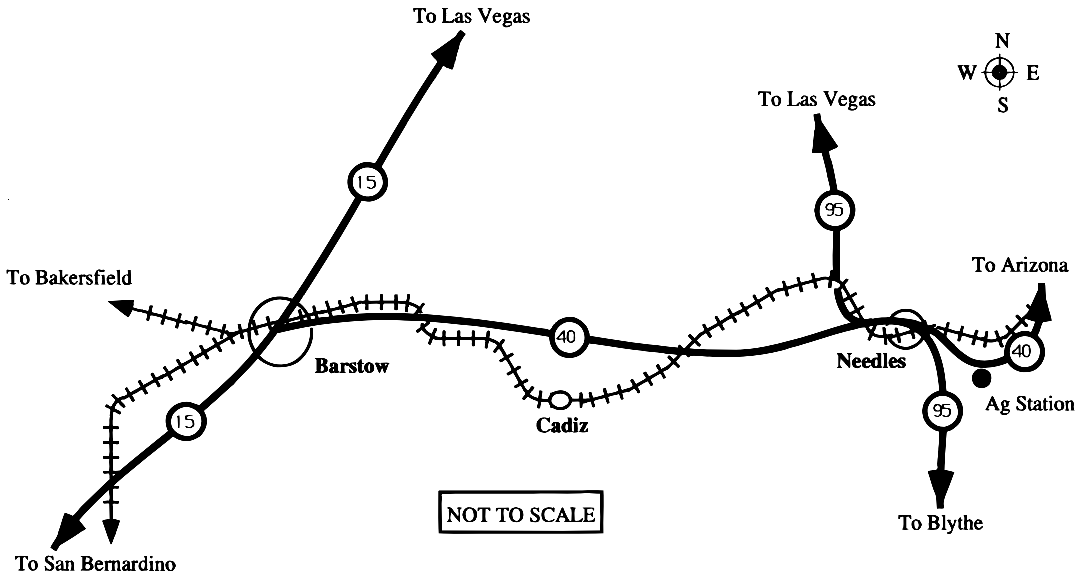

FIGURE 1 I-40 corridor in California.

Vehicles were classified into eight types, with an emphasis on different truck types. It was found overall that approximately 60 percent of all traffic was passenger vehicles, 30 percent was trucks, and 10 percent was miscellaneous vehicles (e.g., recreational vehicles, motorcycles, buses, etc.). The VCC data were transformed into traffic volumes given in origin/destination (O-D) form. The O-D matrix consisted of hourly volumes for a 24-hr period, for each vehicle class.

Truck Survey

In addition to obtaining the VCCs, truck drivers were surveyed to obtain data to characterize intermodal goods movement along the corridor. This survey was conducted on March 31, 1994, over a 12-hr period at two locations (east- and westbound) along I-40 near Needles. The survey consisted of a short but detailed questionnaire that acquired the following information:

- Type of goods being transported;
- Origin and destination of goods;
- Capacity utilization;
- Cargo mix, weight, and value;
- Hauling time and frequency of the trip; and
- Fueling locations and fuel prices along the route.

Approximately 183 westbound and 372 eastbound trucks were interviewed during the 12-hr period. A complete analysis of the survey data is presented in detail in a separate paper (*1*). Pertinent data collected from the survey for the emissions analysis included a distribution of gross vehicle weights and a categorization of the truck types.

Railroad Data

The Atchison, Topeka and Santa Fe Railroad (Santa Fe) is the only company that operates freight trains along the I-40 corridor (Figure 1). The track between Needles and Barstow is approximately 168 mi (270 km), and it takes approximately 3 hr 5 min to cross this distance. The route consists of double track for the entire distance and never exceeds 2 percent grade. The track elevation difference between Barstow and Needles is approximately 1,600 ft (488 m, Barstow being higher). There are two main sections of steep grade (under 2 percent: one at Goffs Road and another near Ludlow. The average speed of a freight train traversing the track is approximately 55 mph (88 km/hr). The number of trains going through Needles in a 24-hr period varies from day to day; there is also a degree of seasonal variation. According to the Santa Fe sources, 40 percent of the I-40 traffic is handled on weekends. Monday is the peak time for outbound trains traveling to their main Chicago hub, whereas Friday and Saturday are peak days for ship arrivals at the Los Angeles/Long Beach ports. Data on train activity for the emissions analysis were obtained directly from Santa Fe.

EMISSIONS ANALYSIS METHODOLOGY

Heavy-Duty Truck Emissions

For estimating heavy-duty truck emissions along the California I-40 corridor, a unique methodology was devised that emphasizes road grade along the route and the corresponding engine load requirements of the trucks that travel the route. A microscopic transportation/emissions model was implemented for the truck emissions analysis (*5*). This model requires detailed network data and emission factor data that are sensitive to engine load requirements. The derivation of these data are given in the following.

Network Data

The network data required for implementing the truck transportation modeling component consist of nodes and links, as is typical for any transportation model. Node points are used to segment road links and provide the connections between links. Nodes are typically given as two-dimensional positions (latitude and longitude), but in this modeling case, nodes are given in three dimensions: latitude, longitude, and elevation. Each roadway link is characterized by its "from" node and "to" node, as well as other parameters such as length, link type, capacity, and grade.

Nodes and links typically are derived from roadway data bases provided by either government agencies or private companies (*6*). However, the reliability of these roadway data bases for nonurban regions (such as the California I-40) is questionable at best. Furthermore, the roadway data bases usually do not contain elevation or grade information, an important parameter when estimating on-road truck emissions. For these reasons, link and node information for the California I-40 has been derived using a research vehicle equipped with global positioning system (GPS) instrumentation.

The instrumented research vehicle uses an on-board vehicle data acquisition system along with a GPS receiver. By using differential GPS techniques and then postprocessing the data off-line, the vehicle's position along specific roadways can be determined on the fly to an accuracy of a few centimeters (*7*). The California I-40 was essentially "mapped" by driving the instrumented vehicle along the route in a single day. The technique required that a base GPS receiver be established at various locations along the route, and then the mobile GPS receiver (i.e., located on the instrumented vehicle) traversed the east- and westbound directions. The average speed of the instrumented vehicle during the data collection was approximately 60 mph (96 km/hr). With a GPS sampling rate of 1 Hz, X, Y, and Z location information (corresponding to latitude, longitude, and altitude) was recorded approximately every 25 m along the route. For the entire mapping of the California I-40, 17,603 location points were recorded, which included not only I-40 itself, but also parts of US-95 and Goffs Road, which parallels I-40 part of the way.

Using the 17,603 location points as node data and then determining links between them provided too much resolution detail for the needs of the model and required an excessive amount of computation when the emissions model was run. For this reason, a unique method of determining nodes and links was derived, based on grade changes in the roadway. In typical roadway network data, nodes are chosen at the key intersection points within the network, and the links usually correspond to "city blocks" (at the arterial level). Because the California I-40 has very few intersecting roads and landmarks, node locations were based on significant changes of grade. Grade changes between consecutive location measurements were examined at different subsampling rates. A subsampling window was used on the consecutive data, and grade changes greater than a specified threshold were used as node points. Using a threshold of 0.25 percent grade and an averaged subsampling of five data points, the number of node points was reduced from 17,603 to 1,227. This number is much easier to deal with in a microscale traffic model while still capturing the important link lengths and the resulting emissions of vehicles traveling over these links. The eastbound and westbound elevation profiles of all links are shown in Figure 2. Note that the westbound and eastbound lanes are separated along most of the route; at some locations the elevations differ by as much as 50 m.

Emission Rate Factors

The California Air Resources Board has developed a mobile source emissions model called EMFAC (*8,9*). It uses a modeling approach in which an emissions inventory is based on two processing steps: the first step consists of determining a set of emission factors that specifies the rate at which emissions are generated, and the second step is producing an estimate of vehicle activity. EMFAC uses emission factors that are based on laboratory-established emission

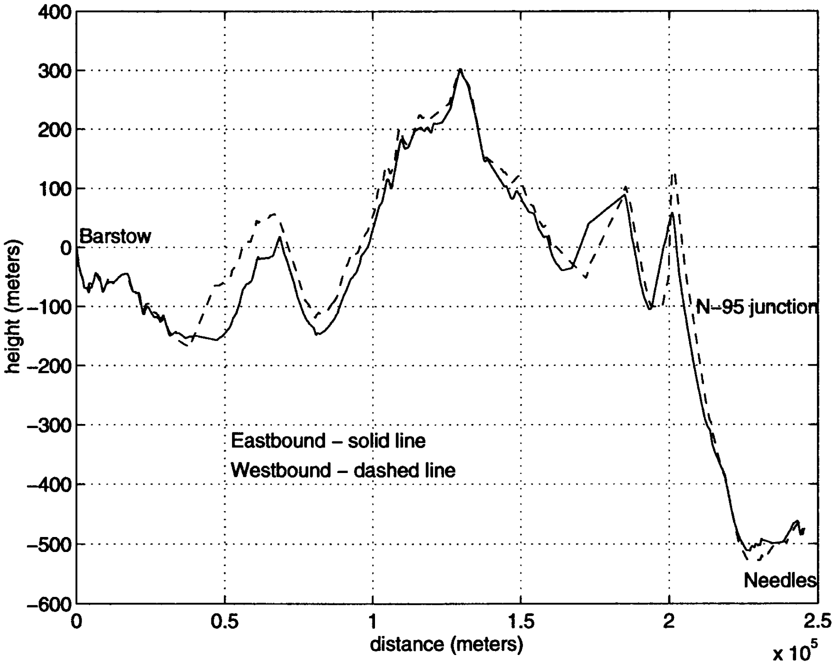

FIGURE 2 East- and westbound elevation profiles of California I-40, normalized to Barstow.

profiles for a wide range of vehicles, including heavy-duty diesel trucks. Base emission rates are determined for specific driving cycles and then adjusted through a set of correction factors. A set of speed correction factors is used to adjust the emission rates for speeds other than the driving cycle's average value.

Unfortunately, EMFAC does not account for factors of road grade. This is a serious deficiency, particularly for truck emissions, since very different rates of emissions are produced under different engine load conditions, even when traveling at the same speed. A more appropriate model to use would be a *modal* emission model, a model that directly relates emissions at high time resolutions (e.g., second by second) to vehicle operating modes such as idle, various levels of acceleration and deceleration, steady-state cruise, and so forth. Such a model implicitly takes into account the various loads placed on the engine during these modes of operation.

For estimating heavy-duty diesel truck emissions with road grade playing a major role in the calculations, the authors have derived a simple load-based modal emissions model from the existing EMFAC model (version EMFAC7F1.1) for a "generalized" heavy-duty diesel truck. This modal model determines the emission rates for steady-state velocities only and does not include transient operations such as accelerations and decelerations. This is a valid assumption in this case since the California I-40 highway almost always operates under free-flow conditions. The current traffic volume is low enough [measured at approximately 15 percent of its rated capacity (*1*)] that there is little intervehicle interaction that would cause the accelerations and decelerations normally associated with stop-and-go traffic.

These emission values for heavy-duty trucks within EMFAC are based on a composite average of heavy-duty diesel trucks. EMFAC classifies these truck categories as light heavy-duty (with weights between 3864 and 6364 kg), medium heavy-duty (with weights between 6364 and 15 000 kg), and heavy heavy-duty (with weights exceeding 15 000 kg). The emissions considered here are for the cases of tailpipe exhaust and running losses and do not take into account evaporative emissions. It is important to note that ongoing studies are attempting to better characterize heavy-duty truck emissions and their relation to different vehicle operating modes (*10*).

In creating a generalized heavy-duty truck modal emissions model, a number of assumptions are made about the truck fleet traveling the California I-40. On the basis of the results of the truck survey and the VCCs along the route, more than 95 percent of the trucks are semitractor-trailer rigs with five or more axles. The average gross vehicle weight for east- and westbound truck traffic was determined to be 19 988 kg, again derived from the truck survey. Other key parameters for this type of truck used in these calculations were derived from the literature (e.g., average rolling resistance, average aerodynamic drag, etc.).

The emissions rates for heavy-duty diesel trucks are then taken as a function of speed from the EMFAC model. These emission rates are converted from grams per mile to grams per second using the corresponding speed value. Knowing that these emission rates reflect testing at zero grade, the required power for each of the speed values from the EMFAC model can be estimated. Power can be estimated using the following equations:

Inertial power requirements (in kilowatts) are given in simplest form as

$$P_{\text{inertial}} = \frac{M}{1{,}000} \cdot V \cdot (a + g \cdot \sin\theta) \qquad (1)$$

where

M = vehicle mass (kg),
V = vehicle velocity (m/sec),
a = vehicle acceleration (m/sec^2),
g = gravitational constant (9.81 m/sec^2), and
θ = road grade angle.

The power requirements due to the drag components are given in simplest form as

$$P_{\text{drag}} = \left(M \cdot g \cdot C_r + \frac{\rho}{2} \cdot V^2 \cdot A \cdot C_a\right) \cdot \frac{V}{1{,}000} \qquad (2)$$

where

C_r = rolling resistance coefficient,
ρ = mass density of air (1.225 kg/m^3, depending on temperature and altitude),
A = cross-sectional area (m^2), and
C_a = aerodynamic drag coefficient.

Thus the total tractive power requirements placed on the vehicle (at the wheels) are given as

$$P_{\text{tract.}} = P_{\text{inertial}} + P_{\text{drag}} \qquad (3)$$

To translate this tractive power requirement to engine power requirements, the following simple relationship is used as a first approximation:

$$P_{\text{engine}} = \frac{P_{\text{tract.}}}{\eta_{tf}} + P_{\text{acc.}} \qquad (4)$$

where η_{tf} is the combined efficiency of the transmission and final drive, and $P_{\text{acc.}}$ is the engine power demand associated with the operation of accessories, such as air conditioning, power steering and brakes, and electrical loads.

For establishing emission rates as a function of engine power demand, the average weight of a heavy-duty diesel truck during the emissions testing was estimated to be 13 636 kg, which was based on the documented weight ranges in the EMFAC model (*8,9*). Other static parameters (i.e., C_r, ρ, A, C_a, and η_{tf}) used within these equations were derived from the literature. $P_{\text{acc.}}$ was set to 0 for this analysis because of a lack of information on accessory operation.

Given the emission rates for the pollutants of CO, HC, NO_x, and PM for different values of approximate engine power, functional line fits were made to the data. For CO and HC, piecewise polynomial line fits of degree 3 were used; for NO_x and PM, single polynomial line fits of degree 3 were used. The overall fit of these curves is quite good.

Train Locomotive Emissions

To calculate locomotive emissions along the route, two types of freight trains were considered. Train Type 1 is an intermodal train with approximately 4,000 trailing tons and 5.0 hp/ton of locomotive power. Train Type 2 is a manifest train with approximately 6,500 trailing tons and 2.5 hp/ton of locomotive power. Type 1 trains basically carry intermodal equipment such as trailers and containers on railroad flatcars; they also transport products such as electronic and household goods. Type 2 trains typically carry the other freight, such as coal.

Using emission rates obtained from a recent Southern California Regional Rail Authority report (*11*) and other recent train locomotive studies (*12–14*), CO, HC, and NO_x are estimated for the two types of trains for eastbound and westbound directions. The emission estimation methodology consists of first determining the time at the different locomotive notch settings (i.e., similar to a throttle) along the route. These accumulated duration values were then multiplied by the emission rates for the corresponding notch setting and summed over all settings. For the I-40 corridor rail line, Santa Fe provided the notch time duration data, which are considered proprietary information and are not presented here.

EMISSION RESULTS

Trucks

Using the generalized truck emission power functions developed in the previous section, instantaneous emission rates for pollutants CO, HC, NO_x, and PM can be calculated for a single truck traveling both directions along California I-40. For these calculations, several assumptions were made:

1. *Vehicle speed and acceleration*. Vehicle velocity and acceleration have a large effect on emissions output. These parameters vary depending on several factors, such as road geometry and infrastructure, behavior of driver, limitations of vehicle performance, and traffic interaction. It is assumed that trucks travel on California I-40 roughly at a constant free speed of 88 km/hr (55 mph) with little or no interaction between all the vehicles on the road. Sections of I-40 have steep enough grades that limit a truck's uphill speed. These lower climbing speeds are calculated in the analysis based on maximum engine power of the generalized truck model.
2. *Road grade*. Road grade is the most dynamic parameter in the emissions calculations along I-40. As described earlier, great care was taken to divide the route into links and nodes that correspond to changes in grade, rather than to network intersections (of which there are ten along the route). It is also important to point out that "engine braking" is considered in this modeling procedure. It may be that when a truck is traveling down a steep grade, the power demand placed on the vehicle is 0 or negative, implying that without engine power, the vehicle would maintain or increase speed due to gravitation. To prevent losing control of a vehicle (especially trucks), drivers often shift to lower gears so as to use engine friction to help brake the vehicle going downhill. For these situations, the appropriate emissions are calculated in this modeling procedure.
3. *Vehicle weights*. The basis of determining the heavy-duty diesel truck weights for this analysis is difficult in that it depends highly on the load that the vehicle is carrying. According to data from the truck survey field study, the average gross vehicle weight for both directions along I-40 was 19 998 kg. This average value was applied to the entire truck volume on I-40.

For each link in the roadway network, road grade was used in the power equations (along with the constant velocity assumption stated earlier), and the emission rates were calculated using the emission power functions. For obtaining cumulative emissions over the roadway link, link length was used to calculate the link trip duration of the vehicle.

Figure 3 shows five parameters plotted against distance for the eastbound direction (westbound plots are similar). The top graph shows the road elevation profile, the second graph shows the engine power demand calculated for each link segment, and the remaining three graphs show the corresponding emissions of CO, HC, and NO_x.

Traveling at 55 mph (88 km/hr) at level grade, a heavy-duty truck operates at approximately 75 percent of its rated capacity (approximately 310 hp). When a truck encounters a slight uphill grade, the required power increases above that operating point. There are several points along the route where the incline induces power requirements that exceed the rated power of the generalized truck. At these points, heavy-duty vehicles cannot maintain the prescribed 55-mph (88-km/hr) velocity, and they slow to the highest possible speed while remaining at maximum power. When operating at these lower speeds on steep grades, the time spent climbing those links increases (compared with the 55-mph case), which is taken into account when calculating cumulative emissions. In only a few cases is engine braking required for a generalized heavy-duty truck: for eastbound truck traffic, it is on the final descent into Needles; for westbound truck traffic it is occurs briefly in the middle of the route.

To calculate a total 24-hr emissions inventory, the traffic volume data for the different segments of I-40 were multiplied with the appropriate cumulative emissions described in the previous section. The resulting total emissions by segment are shown in Figure 4.

Although the volume of traffic is approximately the same for both the east- and westbound directions, the westbound direction produces 244 kg more CO, 36 kg more HC, and 670 kg more NO_x per 24-hr period. This is primarily due to the overall increased grade when traveling to Barstow, which is about 500 m higher than Needles.

A key conclusion from this modeling analysis is that if the overall traffic volume on the corridor increases, the emissions will increase linearly. When the traffic volume approaches capacity, there will be greater interaction between vehicles, leading to an increase in stop-and-go traffic, which in turn leads to greater emissions. Therefore, this linear relationship is applicable for a factor range of 0 to an approximate fourfold increase of average daily traffic (ADT) (during peak periods, the linear relationship will break down sooner).

Rail

The emissions for CO, NO_x, HC, and PM were calculated for the intermodal and the manifest trains, in the east- and westbound directions along the I-40 corridor; they are presented in Table 1. Table 1 indicates that the estimated locomotive emissions for intermodal trains are lower for each pollutant in both directions. Overall, the estimated westbound emissions were higher than the estimated eastbound emissions, with the differences greater on the higher emitting manifest trains than the intermodal trains, as shown in Figure 5.

Emissions Comparison

To compare these train emissions with those of heavy-duty trucks traveling on I-40, east- and westbound truck emissions based on gross vehicle weight are first determined using the 1994 survey data as shown in Figure 4 (daily totals) and Table 1 (per truck). Train

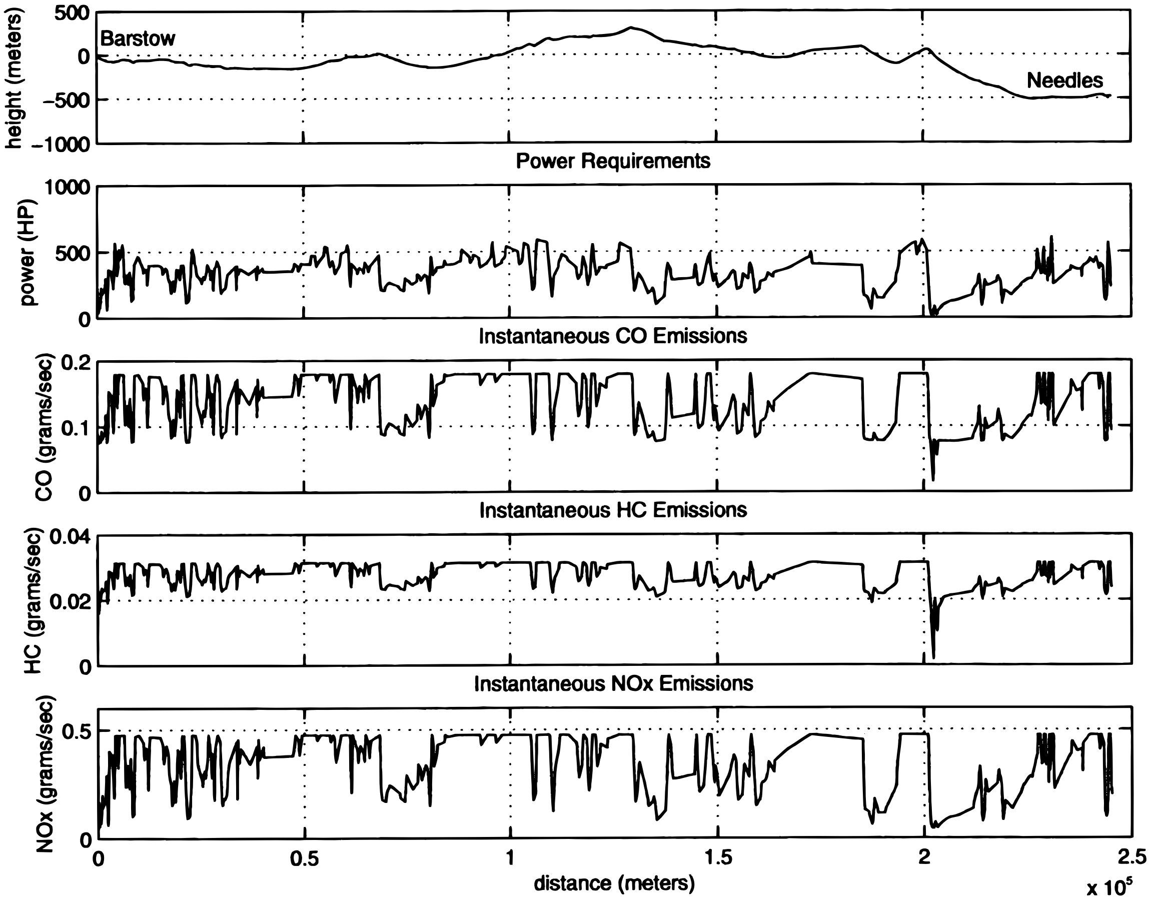

FIGURE 3 Eastbound road profile with corresponding power demand, CO, HC, and NO_x emissions for generalized heavy-duty diesel truck.

emissions in Table 1 were calculated per locomotive. Since each intermodal train is pulled by five engines and each manifest train is pulled by four engines, total train emissions are obtained by multiplying the values in Table 1 by 5 (for an intermodal train) and by 4 (for a manifest train). Comparisons are then made between trains and trucks for different cases of how many "truckloads" a single train replaces. For Train Type 1 (intermodal) carrying the equivalent of 60, 90, and 120 trucks, total emission production for the single trains is less—except for NO_x in the case of the 60-truck-equivalent train. The factor decrease for the equivalent train by pollutant type varies from 1.21 to 8.50 when compared with the same number of trucks; this is also summarized in Table 1.

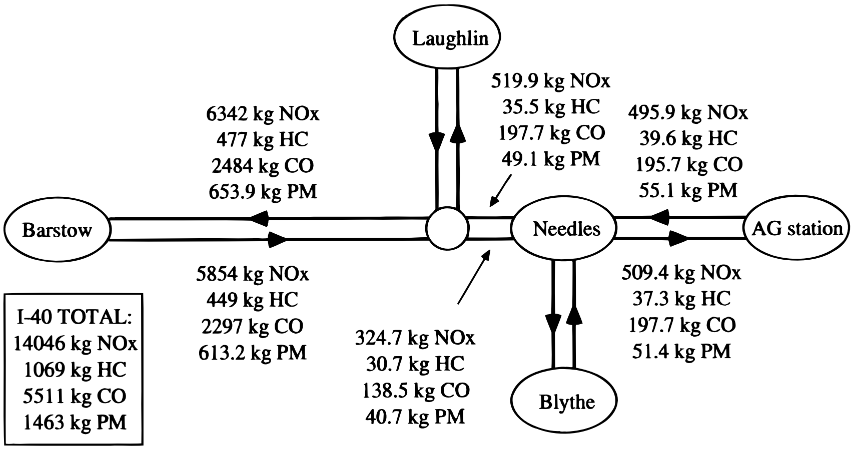

FIGURE 4 Current 24-hr heavy-duty diesel truck emissions along I-40.

TABLE 1 Estimated Emissions per Locomotive for Intermodal and Manifest Trains, and Trucks Along I-40 Corridor and Factor Increase of Truck Emissions over Train (Intermodal) Emissions for Different Train Capacities

	Eastbound Trip Emissions (kg)				Westbound Trip Emissions (kg)			
	CO	NOx	HC	PM	CO	NOx	HC	PM
Intermodal	5.298	46.734	0.804	1.313	7.740	60.977	0.869	1.587
Manifest	8.557	69.329	1.058	1.865	12.887	101.887	1.390	2.627
Truck	1.4475	0.2846	3.675	0.3882	1.6055	0.3075	4.1081	0.422
train = 60 trucks	3.28	4.25	0.94	3.35	2.49	4.24	0.81	3.19
train = 90 trucks	4.92	6.37	1.42	5.32	3.73	6.36	1.21	4.78
train = 120 trucks	6.56	8.50	1.89	7.09	4.98	8.48	1.62	6.38

The number of trains going through Needles in a 24-hr period varies daily and even somewhat seasonally. A late 1994 count indicates that approximately 30 trains run in the easterly direction and 26 trains run in the westerly direction during a 24-hr period. For this analysis, a 50:50 split between intermodal and manifest is assumed and total daily emissions are estimated. These emissions are then compared with the truck emissions in Table 2.

Limitations of Emissions Analysis

Several assumptions were made throughout the emissions analysis. The primary limitation was the breadth of emissions factor data and related functions. In order to best perform the emissions analysis based on grade and power parameters, a more comprehensive, robust modal emission model is required for a wide range of trucks.

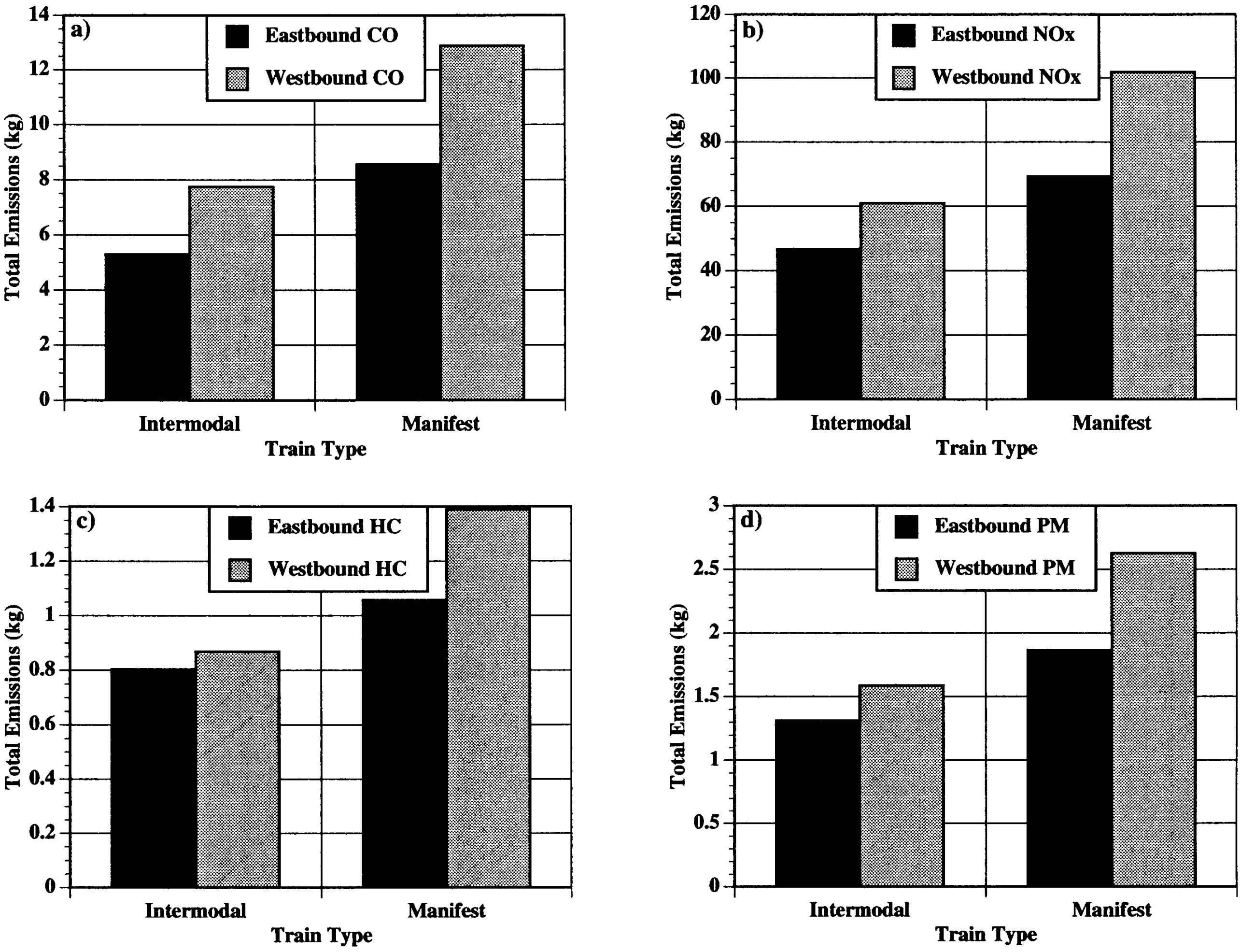

FIGURE 5 Plot of estimated CO, NO_x, HC, and PM emissions of intermodal and manifest trains on I-40 corridor.

TABLE 2 Daily Two-Way Emissions Comparison in Kilograms Between Rail and Truck for I-40

	CO	HC	NOx	PM
Rail	2084	253	16927	45
Truck	5511	1069	14046	1463

The EMFAC emission values used in this analysis were for an average set of trucks that underwent limited testing. More comprehensive testing for a wider range of trucks is under way (*10*). Similarly with rail traffic, additional research is being conducted to better characterize diesel locomotive emissions (*13*).

The VCC and survey data that were used as input to the emissions modeling procedure were collected once during a narrow period of time. Average truck weights and truck volumes may differ significantly during different times of the year. These can be improved with additional data collection throughout the year.

The findings discussed in this paper apply only to the California I-40 corridor and should not be projected to other truck/train scenarios without performing the detailed analysis. Also, this study considered only the line-haul emissions between Barstow and Needles and did not address emissions for access to rail and line-haul truck operations (e.g., local truck deliveries, etc.), which are very important when evaluating the total emissions impact associated with the modes of truck and rail.

CONCLUSIONS AND RECOMMENDATIONS

Using the results described earlier, the following key conclusions can be made about emissions along the I-40 corridor:

Truck Traffic

- NO_x emissions dominate the total emission inventory, with an overall 24-hr heavy-duty diesel truck traffic emissions estimate of 14 046 kg of NO_x, 1069 kg of HC, 5511 kg of CO, and 1463 kg of PM.
- With the traffic volume approximately the same in both directions, the westbound direction produced greater emissions because of the increase in elevation (increased grade).
- The current traffic volume is far less than freeway capacity (approximately 15 percent, so any increase in traffic volume will lead to a linear increase of emissions; this will generally hold true until the volume is approximately four times the current average daily volume, when serious congestion factors set in (during peak periods, the linear relationship will break down sooner). As for future traffic volume along the corridor, year 2015 projections indicate a 10 to 42 percent increase in the overall traffic between Barstow and the Arizona border. The truck traffic will remain at approximately 33 percent of total ADT (*15*).

Rail

When rail emissions are compared with truck emissions (for the corridor), goods moved by rail produce much lower emissions by amount of cargo. The factor decrease of emissions (with the exception of NO_x for a 60-truck-equivalent train) is 1.21 to 8.50 (summarized in Table 1) and is consistent with other studies (*3,16*).

Overall NO_x is the dominant pollutant of trucks and trains even though it is approximately 20 percent higher for trains. PM is negligible for rail, whereas HC and CO are approximately 300 and 165 percent higher, respectively, for truck traffic. Given the amount of pollutants produced by trucks, shifting some of the freight from trucks to rail with a greater emphasis in intermodal business will reduce the total freight emissions along the corridor (some transport companies, such as J. B. Hunt, are already doing this).

It is widely believed that with the implementation of NAFTA, the trade flow and thus traffic between Mexico, Canada, and the United States are expected to increase considerably. However, the exact long-range implications of NAFTA for the U.S. highways are uncertain, particularly in Southern California. The effects of military base closures need to be properly assessed in various long-range traffic forecasts. Two major studies currently under way should provide a better understanding of the trade traffic between the United States and Mexico (*17,18*). Even though there appear to be no immediate capacity problems along I-40, increased traffic due to NAFTA may result in substantial congestion and emission problems.

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