Managing Trucks for Air Quality: Current Work in Progress

CHRIS NELSON, SARAH SIWEK, RANDALL GUENSLER, AND KELLY MICHELSON

In most areas of California, motor vehicles continue to produce significant amounts of emissions that result in photochemical smog. The smog problem is exacerbated in the South Coast Air Basin (which includes Orange County and major portions of Los Angeles, Riverside, and San Bernardino Counties), a result of local topography and weather conditions. The ozone problem of the South Coast Air Basin is so severe that experts estimate emissions of hydrocarbons must be cut by as much as 82 percent to meet the national ambient ozone standards. Although air pollution levels are not as severe in other areas in California, almost every urban area is currently violating, or close to violating, ambient air quality standards for ozone, nitrogen oxides, or particulate matter. Heavy-duty vehicles are significant contributors to the emission inventory in urban areas. The history of truck-related transportation control measures, current transportation control measures under consideration in California, and uncertain effects of proposed measures are reviewed.

In most areas of California, motor vehicles continue to produce significant amounts of emissions that result in photochemical smog (*1*). Local topography and weather conditions exacerbate the problem in the South Coast Air Basin, which includes Orange County and major portions of Los Angeles, Riverside, and San Bernardino counties. The ozone problem is so severe in the South Coast Air Basin that emissions of hydrocarbons may have to be cut by 82 percent to meet the national ambient ozone standards (*2*). Though air pollution levels are not as severe elsewhere in California, almost every urban area is violating or close to violating ambient air quality standards for ozone, nitrogen oxides, or particulate matter. Heavy-duty vehicles contribute significantly to emissions in urban areas. The history of truck-related transportation control measures, current transportation control measures under consideration in California, and uncertain effects of proposed measures are reviewed.

BACKGROUND

1984 Olympics

The 1984 Summer Olympics, held in Los Angeles, presented a unique challenge to transportation and air quality planners. In anticipation of massive traffic jams and unhealthful air pollution levels, numerous transportation control measures (TCMs) were implemented. These measures included increased ridesharing and moving of commuter traffic to off-peak periods. This effort was marketed as a temporary solution through a massive public relations effort (*3*). Neither congestion nor air quality violations were noted (*4*).

One of the strategies that relieved traffic congestion was a voluntary reduction in truck traffic during anticipated peak periods. The truck trip reduction program had several elements. Restrictions on night deliveries were lifted, aided by union cooperation in accepting regular wages for night work. State laws allowing the night delivery of certain commodities were enacted, and a public information campaign to persuade the trucking industry of the need to adjust routes and activities was used (*3*). Some businesses also increased inventory to reduce the need for deliveries during the Olympics period. Visual counts revealed less truck traffic during peak periods. Peak periods, in this case, were those periods before, during, and after Olympic events and did not correlate exactly with normal peak traffic periods. Evening truck traffic increased, leading to the conclusion that truck trips were shifted out of peak periods, rather than that an outright reduction in trips occurred. Figures 1a and 1b compare traffic by time period, during Olympics and non-Olympics periods.

Traffic moved smoothly and efficiently during the 1984 Los Angeles Olympics and air quality during the Olympics surpassed all expectations (*4*). The direct effect of truck strategies is difficult to isolate, because numerous strategies were used to reduce all traffic. A high level of cooperation and public awareness was achieved during this period, including business using trucks, perhaps partially based on the knowledge that the control measures were temporary.

Trucks as a Source of Motor Vehicle Emissions

There are numerous sources of on-road motor vehicle emissions, and their contribution to the emission inventory in California is much higher than in many other states. Sources generally include automobiles (both commute and recreational trips), trucks, and buses. Overall, trucks constitute a small percentage of total traffic volume; however, they still contribute a significant portion to the mobile source emissions inventory (*5*). Table 1 presents their contribution by air basin for California. Note that the truck contribution to the emission inventory is especially pronounced for NO_x.

C. Nelson and S. Siwek, South Coast Air Quality Management District, 9150 Flair Drive, El Monte, Calif. 91731. R. Guensler, California Air Resources Board, 1102 Q Street, P.O. Box 2815, Sacramento, Calif. 95812. K. Michelson, Lockheed Information Management Services Company, 40 North Central Ave., Suite 2250, Phoenix, Ariz. 85004.

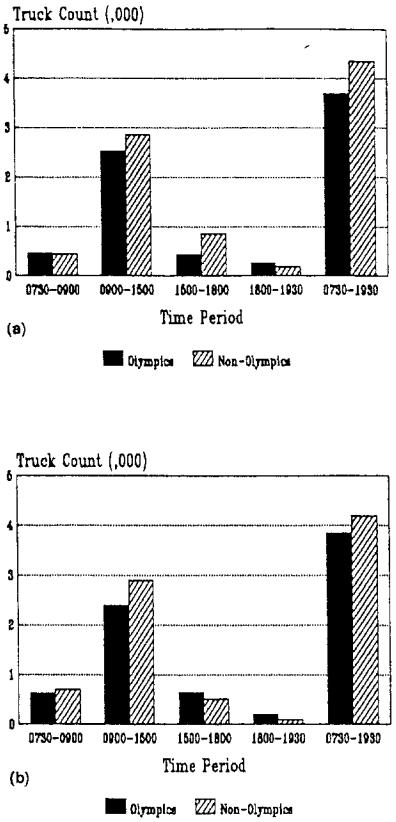

FIGURE 1 Truck traffic on I-10 east of I-110 by day, direction, and time period (3): (a) eastbound, and (b) westbound.

TABLE 1 ESTIMATED EMISSION CONTRIBUTIONS OF HEAVY-DUTY TRUCKS (5,500 lb OR HEAVIER) TO TOTAL 1987 EMISSIONS BY AIR BASIN (IN PERCENT)

Air Basin	ROG	NO_x	CO	PM10[a]
South Coast	4	18	12	3
San Diego	4	15	9	2
Sacramento Valley	4	28	7	2
San Francisco Bay Area	3	17	9	3
San Joaquin Valley	3	24	9	2
Statewide	4	21	8	2

[a]Particulate matter less than 10 μm in diameter. Values do not include PM10 associated with resuspended road dust.

What is a Heavy-Duty Truck?

The definition of a heavy-duty truck is not standard. These vehicles can be defined by gross vehicle weight rating (GVWR), gross vehicle weight (GVW), or unladen weight. The GVWR is the weight rating assigned by the vehicle manufacturer and is used by federal and state agencies to determine the applicability of motor carrier safety and air pollution control regulations. GVW is the estimated hauling weight reported by the vehicle operator to regulating agencies for weight-distance tax purposes. It is possible that GVW is either under- or overreported by the operator, depending on the tax structure. Unladen weight is used by the California Department of Motor Vehicle registration purposes. The unladen weight does not account for the load that the vehicle will be hauling. If desired, any weight criteria can be further disaggregated by number of axles, engine size, and fuel type (gasoline, diesel, methanol, etc.).

A legislative working group established a definition of heavy-duty trucks as "any commercial vehicle with a gross vehicle weight rating (GVWR) or 8,501 pounds or greater" (6).

The City of Los Angeles originally defined trucks as vehicles with GVW greater than 26,000 lb. Later, the definition was modified to include three or more axles. In their latest version (October 1990), the City has dropped the weight classification completely. This is intended to aid in enforcement by police unfamiliar with weight classifications.

For purposes of this discussion, heavy-duty trucks will be divided into two classes: (a) 8,501 lb to 26,000 lb GVW, and (b) greater than 26,000 lb GVW. Class I generally includes trucks with two axles and gasoline-powered engines. Class II vehicles generally have three or more axles and diesel-powered engines. These categories are used because originally, the City of Los Angeles proposed using GVW for their program and because data are available for GVW categories. The GVW categories were also used in the south coast AQMD's survey to determine the potential regulated population for heavy-duty truck regulations. However, it should be noted that the definitions used by the California Air Resources Board for vehicle emission regulatory purposes are in GVWR. Figure 2 shows the number of vehicles in the South Coast Air Basin and their approximate contribution to the emissions inventory.

Regulating Trucks

The California Air Resources Board has the responsibility for regulating tailpipe emissions from motor vehicles, including heavy-duty trucks. Statewide controls include new-vehicle emission certification standards and in-use inspection and maintenance emission standards. Although local agencies may not, under state law, regulate the emission rates of motor vehicles, they were granted authority to regulate vehicle activity in 1988.

In the South Coast Air Basin, the first vehicle use control strategy (transportation control measure) implemented was an employer-based commute trip-reduction regulation. Regulation XV, adopted by the South Coast Air Quality Management District (SCAQMD) in December 1987, required employers of 100 or more individuals to develop a vehicle trip reduction plan applicable to commute hours and to provide employees with incentives to rideshare.

Regulators are now beginning to examine transportation control measures that will affect heavy-duty trucks. Local air quality districts are developing transportation control strategies designed to change driver behavior and the use patterns of heavy-duty vehicles.

Authority to Regulate Trucks

Two legislative acts have impacted the development of strategies to lower truck emissions, SB151 and the California Clean Air Act (CCAA) AB2595.

SB151 (Presley), passed in 1987, authorized the SCAQMD and gave it the authority to regulate the operation of heavy-

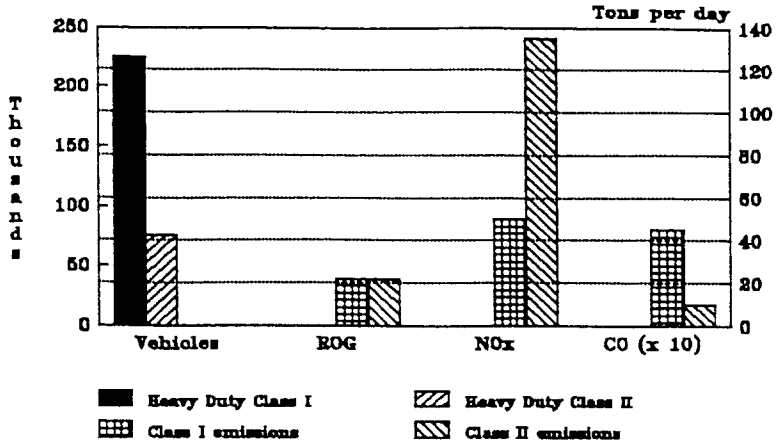

FIGURE 2 Relative contributions of heavy-duty trucks (*1*).

duty trucks during the hours of peak congestion (typically 6 to 9 a.m. and 4 to 7 p.m. in the South Coast Air Basin).

In 1988, the CCAA was passed by the California Legislature and signed by Governor Deukmejian. This comprehensive bill revamped the local agency air quality regulatory authority. The CCAA granted transportation control measure authority, similar to that of the SCAQMD, to all other local air districts in California.

The CCAA also required that a heavy-duty truck technical advisory group, with representatives from industry and regulatory agencies, be established to prepare guidelines for TCMs that would affect heavy-duty truck operations. This group started work in September 1989 and completed its guidelines in August 1990 (*6*). The guidelines, which will be discussed later, present to the districts a discussion of issues surrounding truck operation restrictions and an evaluation of different strategies. All districts other than the SCAQMD must take the AB2595 technical advisory group guidelines into consideration before adopting any TCM that would affect the operations of heavy-duty trucks.

Federal Transportation Law

The 1982 Surface Transportation Assistance Act (STAA) set standards on the size of vehicles using the Interstate highway system and preempted local restrictions on use of or access to the Interstate system by trucks. *New York State Motor Truck Association, Inc. v. City of New York* (S.D.N.Y. 1987, 654 F. Supp.) essentially struck down state laws restricting access to facilities.

In order to restrict truck access, states historically have had to prove that the facility could not safely handle truck traffic, or that the cargoes (hazardous materials, etc.) presented a danger to public health. The federal rulings would seem to limit the scope of truck traffic control measures, because any that were construed to limit access could be challenged in court. Nevertheless, the conflicts between the STAA requirements and local air pollution control regulatory authority have yet to be addressed in the courts, so it is premature to second guess what findings the court will make on these issues.

There are two additional developments that may alter this situation. When the STAA is renewed, the conflict between a cleaner environment and commerce may be resolved by Congress. The 1990 federal Clean Air Act (1990 CAA) appears to have preempted the STAA requirements for nonattainment areas classified as extreme, such that peak-period heavy-duty truck TCMs might be easily implemented. Section 182(e)(4) of the 1990 CAA, Traffic Control Measures During Heavy Traffic Hours, states that transportation control measures applicable during heavy traffic hours to high polluting vehicles or heavy-duty vehicles may be implemented ". . . notwithstanding any other provisions of law. For areas not classified as extreme, the conflict between the STAA requirements and local air pollution control regulatory authority are still to be resolved." The "extreme" nonattainment classification, according to Section 181 of the 1990 CAA, applies to areas with ozone design values of 0.280 ppm and above, with attainment of the primary standard set at 20 years.

Trucks and the Economy

Truck operations affect every part of our economy. Trucks are not only used for goods movement, but also to assist in the provision of needed services (J. Reynolds, unpublished research, City of Los Angeles Transportation Management Program, 1989). A large portion of truck traffic serves the wholesale and retail segments of the economy. Other industries with a high volume of truck vehicle miles traveled (VMT) include construction, chemical and petroleum refining, metal products, lumber, wood products, and furniture (*7*). Any transportation control measure restricting truck movement will have an effect on the economy.

In preparation for the possible implementation of transportation control measures impacting heavy-duty truck operations, the SCAQMD conducted a pilot survey of businesses using large trucks to ship and receive goods. This pilot survey was designed to gain additional baseline information for future survey efforts and to determine the most effective data-gathering methodology. In February 1990, Lockheed Information Management Services was obtained to conduct the pilot survey.

The pilot survey universe consisted of licensed businesses within the city of Los Angeles. Response to the survey was not mandatory. In order to conduct the survey, a stratified sample of businesses was randomly selected from the various business license categories in the city's file (wholesale, resale,

transportation, etc.). A 4.5 percent random sample was taken. A resulting 10,125 businesses of the city's 224,000 licensed businesses were mailed survey questionnaires. The survey effort was promoted in the district newsletter and through outreach groups. A telephone support unit was also established to conduct follow-up calls to both encourage response and answer survey-related questions. A total of 1,587 were initially returned. After quality assurance review, 1,563 records (15.83 percent of the original 10,125 surveys) were retained for data analysis, representing only 0.7 percent of the 224,048 licensed businesses in Los Angeles. However, the survey sample was found to be generally representative of the survey population.

The survey questionnaire asked each business to provide general information concerning their business (business type, square footage, number of employees, etc.), and to log and report the shipments they received or sent using heavy-duty trucks over a 1-week period. Businesses were also asked to provide the number of large trucks they owned and leased and how many of these were used to ship goods. The survey instrument identified two types of trucks. This delineation was based on gross vehicle weight (GVW) and included those trucks between 8,501 and 26,000 lb GVW (Class I), and those over 26,000 lb GVW (Class II). These categories were represented on the survey instrument using pictorial examples of trucks falling within each category. Respondents were asked to record shipping activity identifying the truck type (Class I or II), truck ownership, type of delivery (full or partial loads), and time period.

Frequency distributions and simple descriptive statistics of central tendency and dispersion were computed for different variables in the survey. In addition to computing descriptive statistics for each of the survey variables, various statistical tests were conducted to examine interrelationships among the variables. Selected high-level findings from the survey are illustrative of the survey results.

A total of 22.1 percent of the businesses surveyed reported some shipping activity (i.e., sending or receiving shipments) during the 1-week survey period. Businesses reporting shipping activity were found to be larger (in terms of both square footage and number of employees), to be open longer hours, and to be more likely to have a loading dock. Businesses engaged in wholesale or retail trade, or having more than one city business license, most often reported sending or receiving shipments. Conversely, businesses categorized as professional-occupational and hotel-apartment reported shipping activity least often. Only 10.8 percent of the businesses reported sending at least one shipment per week, whereas 21.4 percent reported receiving at least one shipment. Shipments received were more often delivered by the smaller Class I trucks (55.9 percent of deliveries) than by Class II trucks (44.1 percent of deliveries), and were more often partial truck loads (71.1 percent of deliveries) than full truck loads (28.9 percent of deliveries). The percentage of shipments received by the business' own trucks was low (11.2 percent). Overall, businesses classified as wholesale or retail, as well as businesses with more than one business license, reported above-average shipping activity. Conversely, professional-occupational, hotel-apartment, and services (personal-business and health) categories reported below-average shipping activity. Both shipments sent and received varied significantly as a function of time period, with the highest shipping activity generally between 6 a.m. and 4 p.m. A substantial proportion of businesses surveyed did not own or lease trucks (as evidenced by mean values less than 1.0). However, 80 percent of the trucks owned and leased by businesses surveyed were used to ship goods.

Several factors limit conclusions that can be drawn from the survey results. Because survey respondents provided information concerning shipping activity during a 1-week period only, it is not possible to draw any firm conclusions concerning the percentage of businesses in the survey population that send or receive shipments. All that can safely be concluded is that between 20 and 24.1 percent of the businesses in the survey population sent or received, or both, one or more shipments during the 1-week survey period. In order to extrapolate to the full population, it is necessary to obtain shipping activity data for a longer time period, or for perhaps several different 1-week periods during the course of a year (e.g., to attempt to account for seasonal fluctuations). Data are further limited by the large margin of error for many of the population estimates derived from the survey results. These large margins of error were due to two factors: limited sample sizes and significant variation in the survey sample response data. In order to obtain more precise population estimates, a much larger number of businesses should be surveyed. Because of the small size of the survey sample it was necessary to group business types into larger categories. However, some of the businesses that were combined to form each new group may have been so diverse as to make the comparisons for group differences of little value. Although steps were taken to guard against this possibility, data should be collected from a larger sample of businesses to minimize the need to create such groups for data analysis. Finally, there is no other source of information comparable to that collected by the survey against which the survey results can be compared. The survey respondents were asked to provide information concerning shipping activity having full knowledge that the information provided could serve as the basis for future business regulation. Clearly, the potential for bias in the survey data exists in the absence of some method of verification. Future survey efforts should incorporate, at a minimum, an audit procedure along with a legal requirement to report accurately. Note also, only the movements of goods were examined, and not the provision of services.

CURRENT TCM PROPOSALS

The city of Los Angeles (with technical assistance from the SCAQMD) is preparing to implement peak-period truck operation restrictions, based on their staff analyses. The AB2595 Technical Advisory Group, without participation from the Los Angeles City staff, prepared separate guidelines for local air pollution control districts to consider in the development of truck TCMs.

City of Los Angeles Truck Traffic Management Program Background

In 1988, as part of a larger program to reduce congestion on the city's streets, the Los Angeles Mayor's office proposed restricting heavy-duty truck operations during the peak hours of traffic congestion. This program originally had four components: a placard system to restrict heavy-duty truck traffic

during peak hours; a rapid-response team to clean up truck accidents quickly; a shipper-receiver program to have loading docks receive goods during off-peak hours; and an advisory hearing panel, to review the program and allow for exemptions on a case-by-case basis.

Several of the components have been altered or omitted as the program has progressed. The rapid response component apparently will be part of a state-wide program, established by legislation (AB480). The AB480 program brings together the California Highway Patrol (CHP), California Department of Transportation (Caltrans), and other participants to develop a more efficient way of cleaning up truck accidents and incidents. In addition, the shipper-receiver component has changed in scope and the advisory panel's role has changed.

The original shipper-receiver component required businesses to stay open at least 4 hr between 8:00 p.m. and 5:00 a.m., if five or more shipments were received during peak traffic hours. The city asked the SCAQMD to implement this portion of the program, by developing a rule limiting hours of shippers and receivers. However, rule-making by the District would require up to 18 months. The city, wanting to move ahead quickly with its program, developed a shipper-receiver component for its ordinance.

The current ordinance language defines a shipper-receiver as any facility that ships or receives commercial goods by heavy-duty truck. Shipper-receivers are limited to five deliveries within the peak traffic hours. If an establishment ships or receives more than eight shipments in the peak, then one-third of the shipments (in excess of five) must be rescheduled out of peak hours.

With respect to financing, the city initially proposed to charge a per unit fee for enrolling trucks in the program. The shipper-receiver portion was to be an SCAQMD rule, with fees set for the implementation and enforcement. In 1989, the state legislature passed AB286, which limited the city's ability to set a fee for the issuance of permits to operate trucks on city streets. One option for the city is to fund the program through the AB2766 program. AB2766, enacted by the legislature in 1990, adds $2 to $4 to vehicle registration. These funds are earmarked for transportation air quality programs. Each city receives 40% of the increase, on the basis of the number of vehicles registered in the city. If this option is pursued, then truck program registrants would not pay directly for the establishment of the program.

The current proposed program (November 15, 1990) restricts heavy-duty truck operations in one or both peak periods. The regulation provides facilities with six complying shipment-delivery options to choose from:

Option	*Percent*	*Peak*	*Conditions*
1	60	a.m.	None
2	60	p.m.	None
3	30	Both	None
4	100	Both	24-hr operation Might violate existing law (noise ordinance) All drivers report out of peak Reduce 50% of SOVs for all employees in peak
5	100	a.m.	Restricted to independent operators
6	100	p.m.	Restricted to independent operators

Independent operators have less than three vehicles.

Exemptions

There are nine general exemption classes proposed by the city of Los Angeles, including emergency vehicles (and tow trucks); military vehicles; mail trucks; trucks licensed to transport household goods while directly en route to or from a point of loading or unloading; alcoholic beverage delivery trucks; trucks transporting hazardous materials; trucks delivering wet concrete, hot asphalt, or structural steel where the workshift begins at 6:00 a.m. (unless prohibited by city ordinance or permit restriction); trucks used to restore electrical power, communications services, and pipelines; and trucks operating in conformance with existing contract conditions, permits, city ordinances, or other regulations that specifically restrict daily starting or ending times or duration of operations.

Companies may also apply for a general exemption on the basis of adverse operational or economic impacts of complying with the program. In addition to permanent exemptions, temporary single-day exemptions would be available through an application process. Route exemptions are also proposed for a number of streets within city limits, including the Los Angeles Harbor area and all identified STAA routes within the city.

AB2595 Working Group Strategies

The AB2595 working group reviewed many possible truck TCM strategies to include in its guidance to local air districts. Some proposed strategies were considered to be out of the group's purview, and they may be addressed by other legislation (accident response) or other agencies (tailpipe emission reduction strategies).

Five strategies for controlling truck emissions were analyzed by the technical advisory group:

- Education and training,
- Reduced idling,
- Freight consolidation centers,
- Shipper-receiver restrictions, and
- a.m./p.m. peak-hour restrictions.

Education and Training

The objective of this strategy is two-fold: (a) to increase heavy-truck driver awareness of the impact trucks have on air quality, encouraging practices that reduce emission; and (b) to increase awareness of truck drivers and the general public on sharing the road. By decreasing accident frequency, accident delays that result in higher emission levels can be reduced. A massive education and public awareness program was used during the 1984 Olympics.

The technical advisory group's guidelines recommend inclusion of good driving techniques in the commercial driver's license handbooks, as well as in the regular driver handbooks used by the public when obtaining or renewing licenses.

An area that is perhaps only cursorily addressed by the AB2595 technical advisory group guidelines is ongoing driver training by companies that operate heavy trucks. Untrained drivers are more likely to be involved in accidents (*8*). The United Parcel Service's ongoing and comprehensive program

of driver safety training undoubtedly helped lead to their low accident rate—one-tenth of the industry average (*8*).

The benefits derived from education and training programs are indirect. However, even if a small percentage of truck accidents (perhaps 5 percent) could be eliminated, vehicle hours of delay would be reduced and a corresponding emission reduction benefit would accrue.

Education programs are costly and provide indirect benefits. Thus, it may be difficult for local jurisdictions to justify ongoing expenditures for education programs. Local air pollution control districts are encouraged to make good air-quality-related driving habits part of their overall outreach program.

Reduced Idling

Idling is defined as operating the engine without an engine load. Newer engines require 5 min or less to reach proper operating temperatures. Older engines used to require a considerable period of time to reach proper operating temperature. Thus the AB2595 guidelines recommend the adoption of a statute that restricts idling to 5 min, with some exceptions. It is felt that a uniform state law would provide consistency in enforcement and simplicity for drivers.

Extended idling often occurs as a result of driver habit. Older engines used to require extended time to warm up before operation and to cool down before shut-off. However, much of the extended idling results from facility operating practices that require trucks to inch forward and remain prepared to move at a moment's notice.

Under the proposed regulation, truck drivers as well as the operator of a facility would be liable for excess idling. By also making the facility operator responsible, facility practices that require or encourage idling (slow moving queues, etc.) will be eliminated.

The air quality benefit of this type of strategy could be calculated if truck operating practices were better understood. Excess idling is known to occur within the heavy-duty vehicle fleet; however, the magnitude of excess idling is uncertain. There are approximately 76,000 diesel trucks in the South Coast Air Basin. If the average daily idling were reduced by 10 min per vehicle per day, approximately one-quarter ton of daily hydrocarbon emissions could be saved.

Freight Consolidation Centers

Today's retail shopping center may have hundreds of stores, each restocked by truck. Many stores rely on common carriers rather than company-owned fleets. The objective of this strategy is to reduce trips by for-hire firms by establishing a single freight consolidation area where shipments can be received by the retail center. The retail stores then could pick up their goods and move them into stock rooms with alternatively fueled (e.g., electric) vehicles or with hand trucks.

This strategy works best as a development condition in new construction, although retrofitting could also be effective. The shopping center would be responsible for creating a freight consolidation center and making sure it is available to both merchants and carriers.

The air quality benefit arises through increased delivery efficiency and a reduced number of truck trips to the same address. Common carriers could consolidate orders and ship to multiple stores in a single load. However, data are not available to indicate how many shipments are currently received per store in these facilities. Hence, site-specific delivery issues are a topic for future studies.

There are costs associated with this strategy. The centers would have to not only construct the new facility, but pay personnel to receive and distribute shipments. Common carriers may also incur a slight cost from trip rescheduling. However, there should also be a savings to trucking firms from increased delivery efficiency.

Shipper-Receiver Regulations

The objective of this strategy is to reduce truck VMT during the peak hours of congestion by moving shipping and receiving operations to off-peak hours.

In most cases, the shipper-receiver controls the hours of facility operation and the times when deliveries are allowed to be shipped and received. If the shipper-receiver were open during off-peak hours, deliveries could occur during the off-peak periods, taking trucks out of the peak traffic.

As conceived in the Los Angeles program, those businesses with peak truck trips would have to be open 4 hr between the hours of 8 p.m. and 5 a.m. In many cases, however, this requirement might result in economic hardship if the facility is forced to employ a second operating shift.

There are other ways to move shipping and receiving out of the peak hours. Some retail operations give a key to the supplier, allowing the driver to deliver when the operation is closed. Others provide a safe storage facility with a key to accomplish the same thing.

Many facilities only accept shipments during the morning. If these facilities switched to an afternoon schedule, trucks would not be out in the morning peak. This is applicable to areas like the South Coast, where the morning peak results in the majority of the smog formation. However, this has a drawback in terms of increased traffic congestion during the afternoon peak.

Implementation of this type of strategy can be costly for the regulatory agency as well as industry. With more than 50,000 sources, the SCAQMD would have to provide considerable resources for implementation and enforcement.

It will be difficult to estimate the effect that these strategies will have on traffic volumes and speeds during congested periods. Thus, inherent uncertainties will not allow accurate air quality emissions reduction projections.

Peak-Hour Operating Restrictions

The objective of peak-hour operating restrictions is to reduce emissions from trucks by restricting their operation during peak hours. This type of strategy was discussed as part of the city of Los Angeles' Truck Traffic Management Program. This strategy probably would probably have to be linked to shipper-receiver rules discussed earlier.

There are numerous challenges that may prevent the successful implementation of a.m./p.m. peak-period operating restrictions. The court cases upholding federal transportation policy may limit its application. Most sites within an urban

area are within 5 mi of a STAA facility, leaving few roadways covered. The effect of taking trucks off the roadways might also be negated by growth or latent demand. Enforcement may be complicated. Some industries would require at least a partial exemption, which would further complicate implementation and enforcement.

UNCERTAINTY IN THE EMISSION INVENTORY

Emissions from any type of motor vehicle depend on two sets of general parameters: vehicle activity factors (miles traveled, etc.) and activity-specific emission rates (grams of pollutant per mile traveled, etc.). In addition, the activity-specific emission rates are subject to the application of correction factors (to adjust the emission factors for operating conditions).

In general, emission inventories are developed by defining the vehicle activities and multiplying the activity estimates by the appropriate activity-specific emission rates. Unfortunately, there is a fair amount of uncertainty associated with each set of parameters used to calculate the emission inventory. Hence, uncertain activity factors are multiplied by uncertain activity-specific emission rates. Thus, site-specific economic impacts are also a topic for future studies.

Vehicle Activity

In general, vehicle activity includes such factors as number of trips made, vehicle miles traveled, and time spent at idle. Vehicle activity is often estimated through highway counts, survey techniques, and limited reporting requirements. Uncertainty exists in the estimation of heavy-duty vehicle activity through all of the methods currently used.

The uncertainty in the different methodologies can lead to activity estimates that vary widely. For example, the Caltrans cost allocation study (FY 1986–1987 estimates) prepared by Sydec Inc. estimated the annual truck VMT to be approximately 13.9 billion miles. The Caltrans Truck Miles Traveled report estimated approximately 12 billion truck miles were traveled for the same period (*9*). The EMFAC7D-BURDEN7A model, used by the California Air Resources Board to estimate motor vehicle emissions, indicated that 15.5 billion heavy-duty truck miles were traveled in 1986–1987 (the average of 1986 and 1987 figures). It is clear that a large range of uncertainty is likely to exist for any vehicle activity parameter estimated.

Emission Rates

Emission rates, the masses of emissions per unit of activity, are established for each specific activity. For example, specific vehicle emission rates are determined for such activities as engine starts (cold or hot start emissions), engine cool-down (hot soak emissions—gasoline engines only), vehicle miles traveled (running emissions), diurnal evaporation (gasoline engines only), and running evaporative losses. However, because of limited laboratory capabilities, heavy-duty truck emission factors do not yet exist for hot or cold start and hot soak activities.

Vehicle emission rates are determined through laboratory testing, using the methods and procedures established by the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board. Uncertainty exists from the outset, with a range of precision and accuracy associated with the tests.

The set of individual vehicle emission factors are composited into vehicle class emission factors, using vehicle registration data available through the state. In essence, emission rates are developed for an average vehicle in the vehicle class, again introducing some uncertainty.

For heavy-duty trucks, the emission factors were derived by EPA from a limited testing of 40 heavy-duty engines in 1980, and updated in 1984 to account for new vehicle emission standards (Plattey, personal communication 1989). The engines were tested on engine dynamometers (as opposed to chassis dynamometers used for automobiles), so the applicability of the engine-derived emission factors to vehicles in motion are somewhat uncertain. With the variation in heavy-duty vehicle sizes and weights that are in use today, the uncertainty in the heavy-duty vehicle emission inventory warrants further investigation. The California Air Resources Board, in conjunction with the Southern California Regional Transit District, will begin heavy-duty truck chassis dynamometer testing in mid-1991. The new research should provide additional insight into the accuracy of the emission rates used in current models.

Current Correction Factors

In order to prepare the emission inventory, the fleet emission rates are adjusted, through the use of laboratory-determined correction factors, to account for specific operating conditions, such as the operating environment or trip factors.

The operating environment of the vehicle can impact the emission rates and operating efficiency of the engines. Environmental factors such as temperature and altitude are taken into consideration as emission rate corrections. Additional adjustments are also made for assumed effectiveness of inspection and maintenance programs.

The speed of the vehicle trip is an important factor in determining the emissions from motor vehicles. The emissions of hydrocarbons (HC) and carbon monoxide (CO) from motor vehicles (both gasoline and diesel) have been demonstrated to decrease as vehicle speed increases, while the emissions of oxides of nitrogen (NO_x) have been demonstrated to increase as vehicle speed increases (*10*). Recent research by the California Air Resources Board indicates that although automobile NO_x emissions decrease with speed, the emission rates increase rapidly above about 50 mph. In fact, the increase in emissions rates above 50 mph is so significant that improved enforcement of speed limits is currently under investigation as an emission control strategy.

The methodology used to establish the speed correction factors is cycle correction. The fleet emission factor is modified by the results obtained when vehicles are run through test cycles with different average cycle speeds. This process raises the question as to whether standardized cycles, that differ in number of stops and starts, and cruise periods, can be used to establish valid correction factors for vehicle speeds.

Results from field testing during the South Coast Air Quality Study have indicated that a previous version of the CARB's EMFAC model (EMFAC7C) may seriously have underestimated in-use motor vehicle emissions of hydrocarbons, by as much as a factor of 1.4 to 6.9 (*11*). The current version of the EMFAC model (EMFAC7E) now contains additional emission factors associated with automobile running evaporative losses and may better represent emissions from the vehicle fleet. However, additional corrections are probably still required for gasoline trucks.

Future testing by the California Air Resources Board will begin in early 1991 to determine how second-by-second motor vehicle emissions vary during the cycle tests, and additional field data may indicate how well the EMFAC model performs.

Future Correction Factors

Frequent stop-and-go motion, characteristic of peak-hour operation, is also thought to increase emissions from vehicles. This may be especially true of heavy-duty trucks because of their heavy operating loads and power requirements for acceleration. Although the emission contribution has not yet been quantified, the contribution of acceleration-based emission will likely be examined by the California Air Resources Board in the future.

Currently, the emission inventories do not include contributions from engine idling. To some extent, these emissions are accounted for through the use of average vehicle speeds under the cycle correction factors. However, additional research on vehicle idling is warranted.

It is clear that reducing congestion and increasing vehicle operating speeds (below 50 mph), serves as means to reduce vehicle emissions. However, latent demand (the increase in demand that is often noted to occur when additional capacity becomes available on a road segment) may negate congestion reduction benefits. The latent demand phenomena is an issue that deserves further study and analysis.

Driver habits can affect the magnitude of the emission rates for specific activities. For example, the behavior of drivers at stoplights may be important because vehicle emission rates increase significantly when the engine is revved or the vehicle accelerates rapidly.

Uncertainty Conclusions

It is clear that numerous assumptions and generalizations must be made for a bulk emission inventory to be generated. Such is the nature of uncertainty in the calculation of any emission inventory. Public agencies attempt to ensure that the best available data are used, and that research projects designed to improve the methodologies are undertaken.

Overall, there is a large amount of inherent uncertainty in the methodologies used to estimate emission inventories for heavy-duty vehicles. Both the activity factors and emission rates for heavy-duty vehicles can, and will, be improved by the California Air Resources Board through concentrated research efforts. The California Air Resources Board has already identified research needs and proposed a number of projects designed to improve the heavy-duty truck emission inventory during the next few years. However, in developing heavy-duty truck TCMs, it should be recognized that significant uncertainty appears to exist in the estimation of emission reduction benefits.

CONCLUSIONS

Regulations imposed on stationary sources have already exhausted the major emission reductions that can be obtained from most industrial categories. New stationary source regulations are focusing on smaller and smaller portions of the pie. Thus, the regulation of transportation activity is clearly recognized by federal, state, and local agencies as critical for attaining the national ambient air quality standards.

Truck operations are a significant contributor to the mobile source emission inventory, even though truck traffic constitutes a relatively small portion of the total traffic volume. Truck traffic control measures are available and can have a positive impact on air quality. For example, idling restrictions can have a positive impact with little or no economic impact (in nonattainment states, idling restrictions should be explored as a first step).

Some transportation control measures affecting heavy-duty truck operations are certain to be implemented. However, emission reduction effects from truck traffic control measures are difficult to estimate, given the current state of modeling. The impact that truck traffic control measures will have on air quality and the economics of goods distribution (direct and indirect costs) require further study. Future research should also address the impact of latent demand on the emission reductions achieved and the potential indirect impacts of education programs.

The ability to make informed policy decisions concerning the implementation of traffic control measures requires that detailed traffic, motor carrier, and business surveys be conducted. High survey confidence levels and detailed results are necessary. Because a high number of survey responses is usually required, consideration might be given to conducting mandatory surveys of motor carriers and businesses potentially affected by proposed traffic control measures. Minimal one-time fees could be imposed to cover the administrative costs of surveys. Resistance from motor carriers or business communities to mandatory surveys should be outweighed by the need for accurate information, especially before implementation of traffic control measures with potentially significant economic impacts.

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