Air Quality Offsets for Parking

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As in many downtown areas in large metropolitan areas, air quality has been a serious concern in Portland, Oregon. Since the establishment of federal air quality standards in the early seventies, downtown Portland has been in violation of the 8-hr carbon monoxide standard. But unlike most major metropolitan areas, Portland has been willing to use parking management as a tool for improving air quality. As a central element of its transportation control plan, the city set a ceiling of roughly 40,000 parking spaces in the downtown and has maintained that ceiling for 13 yr. Although there is considerable optimism that the downtown will soon be in compliance with the carbon monoxide standard, there is also pressure to increase the parking ceiling to accommodate new growth in the downtown. This paper describes research conducted by Cambridge Systematics, Inc., and the city of Portland on alternative methods of reducing emissions in the downtown and on the "parking space equivalents" of these alternative measures. The 11 alternative measures that were considered have been referred to as "offsets" because they were viewed as potentially offsetting the air quality impacts of adding more parking downtown. The paper describes the 11 measures considered, the methodology used to evaluate the potential effectiveness of each in Portland, and the conclusions reached about each as a potential offset measure. The project involved considerable quantitative research and modeling to estimate the emissions impacts of different types of parking behavior and to estimate the emissions reduction potential of each measure. As a result, the paper provides new insights into the relationship between parking and air quality and can provide considerable guidance to other cities struggling to balance parking and emissions reduction needs.

Since 1975, the total supply of parking in downtown Portland has been constrained to a maximum of roughly 40,000 spaces as part of an overall transportation strategy to improve downtown air quality. In the 12-yr period since the parking lid was established, employment downtown has increased from roughly 65,000 to more than 80,000. Although much of the additional travel generated by this development has been accommodated through expansion of transit service, the growth has also begun to place pressure on the available parking supply. The desire to redevelop older parts of the downtown and to continue the overall economic growth downtown has prompted the city to explore the implementation of other measures that might meet the same air quality objectives that the parking lid was designed to fulfill. This paper describes research undertaken by the city of Portland (*1*) to identify a range of transportation measures that could help the city to accommodate additional parking while complying with the provisions of the federal Clean Air Act.

Eleven potential measures were examined in the research effort, each having been generated through a process of discussion and consensus building by city, regional, and state agency staff and through public input. The 11 measures were

1. Fringe parking (adjacent to downtown),
2. Alternative work hours (peak spreading),
3. Subsidy of ridesharing and transit,
4. Parking pricing and use management,
5. Park-and-ride remote lots,
6. Restrictions on parking for company fleets,
7. Alternative fuels,
8. Enhanced vehicle inspection and maintenance,
9. Increased transit capacity,
10. Signal timing and other traffic flow improvements, and
11. Improved bicycle access to transit.

These measures were called "offsets" because they were seen as potentially offsetting the emissions generated by additional parking spaces with an equivalent reduction in emissions. Each of the potential offset measures was evaluated in the specific context of downtown Portland, and an estimate of the potential reduction in carbon monoxide (CO) emissions was made for each.

This paper describes the 11 measures considered and presents the results of the research on their potential effectiveness. By describing the problem in Portland, the methodology used for the analysis, and the results of the research, the paper provides insights about the relationship between parking and environmental quality in a downtown area. The paper explores some of the intricacies of parking behavior and pollutant emissions and illustrates that attention to these intricacies is important to the prediction of the emissions impacts of transportation measures.

THE AIR QUALITY PROBLEM IN DOWNTOWN PORTLAND

Since federal air quality standards were established for metropolitan areas in 1970, the downtown area of Portland has exceeded the standard for 8-hr average concentrations of CO. The federal standard requires that the second-highest 8-hr average observed during a year be no more than 10 mg/m^3. Although the values recorded downtown have declined steadily since 1973, as illustrated in Figure 1, the recorded level in 1985 was still 10.1 mg/m^3.

There is optimism on the part of the city that the standard will be achieved by the new deadline imposed by the U.S. Environmental Protection Agency (EPA). There is also recognition, however, that the city's strict adherence to the parking supply ceiling set in 1973 and the concurrent increase in commuter trips on transit have been major factors in the reduction in emissions, particularly in CO concentrations.

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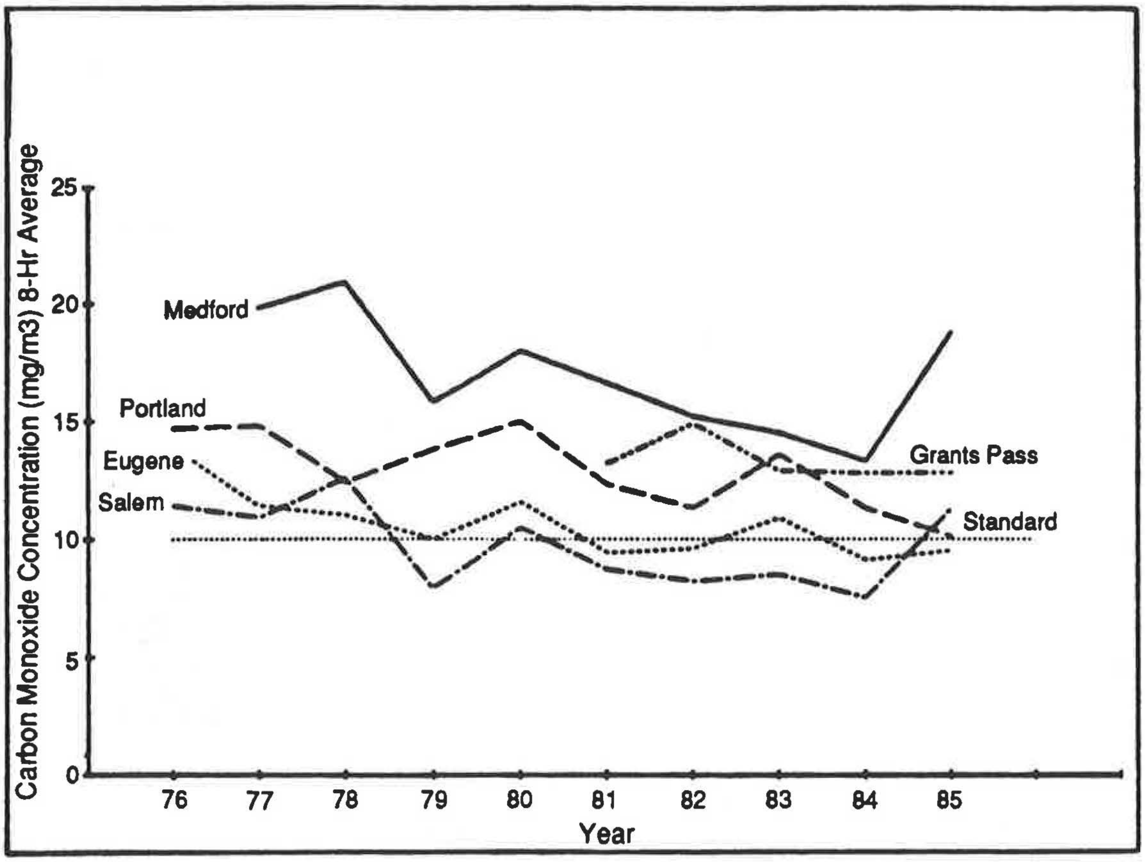

FIGURE 1 Ambient carbon monoxide trends in nonattainment areas, second highest day (2).

The inability to attain the 8-hr CO standard in the past has special implications for the types of offset measures that might be most effective or the types of parking that result in emissions most directly affecting the standard. Figure 2 illustrates the observed hourly concentrations for the permanent recording station located at the corner of Fourth Avenue and Alder Street in downtown Portland. The recording is for March 5, 1984, the day with the second-highest average for that year; it is the measurement by which compliance with the standard was judged.

The most notable characteristic of the measurement is that the 8 highest hours of CO concentration were the hours between about 1:30 p.m. and 9:30 p.m. Although the timing of the highest 8-hr concentration varies from day to day and year to year, the period is almost always in the range from 10:00 a.m. to 10:00 p.m. The highest 1-hr concentrations almost always occur during the hour ending at 5:00 p.m.

A significant factor related to the timing of the peak 8-hr concentration is that it does not include the morning commute period, which in Portland is roughly 6:00 a.m. to 9:00 a.m., with the highest hour being from 7:30 to 8:30. Although it is possible that some of the emissions from this morning commute period affect the 8-hr period, the fraction would be quite small because most would have dissipated within 2 hr.

The dramatically higher hourly concentrations in the afternoon and evening reflect, in part, the significant difference between the rate of CO emissions (expressed in grams per mile traveled) from vehicles entering the downtown after their engines have had sufficient time to warm up and that from vehicles leaving the downtown. The vehicles leaving the downtown are most often being started cold after being off for a period of time, and emission rates immediately after a "cold start" are significantly higher than when the engine is started "warm." The average "cold start" emission rate for passenger vehicles in downtown Portland is estimated to be 114.3 g/mi compared with the "warm start" emission rate of 19.2 g/mi. Both rates are averages over the mix of vehicles, by age, in the downtown area.

Virtually all passenger vehicles are still "warm" if started within 1 hr of being turned off. For parking durations of 1 to 4 hr, only vehicles manufactured before 1975 would still be "warm" when restarted. Vehicles manufactured in 1975 and later have emission control equipment that causes a "cold start" to occur after only 1 hr (*3*, p. 47). Only about 9 percent of the passenger vehicles observed in downtown Portland during a recent survey were manufactured before 1975.

Because of the typical timing of the highest 8-hr concentration of CO and because of the difference between "cold start" and "warm start" emission rates, the parkers who have the most significant impact on the 8-hr CO levels downtown are those who arrive and leave during the peak 8-hr concentration period and who park for more than 1 hr. The level of emissions per trip for these parkers is roughly 123 g, based on an average trip length of 1.5 mi in the downtown area for a round trip to and from the parking location. This is 43 percent higher than the estimated emissions from a commuter (88.5 g) who arrives well before the 8-hr period during which the maximum CO concentration is measured, but who leaves

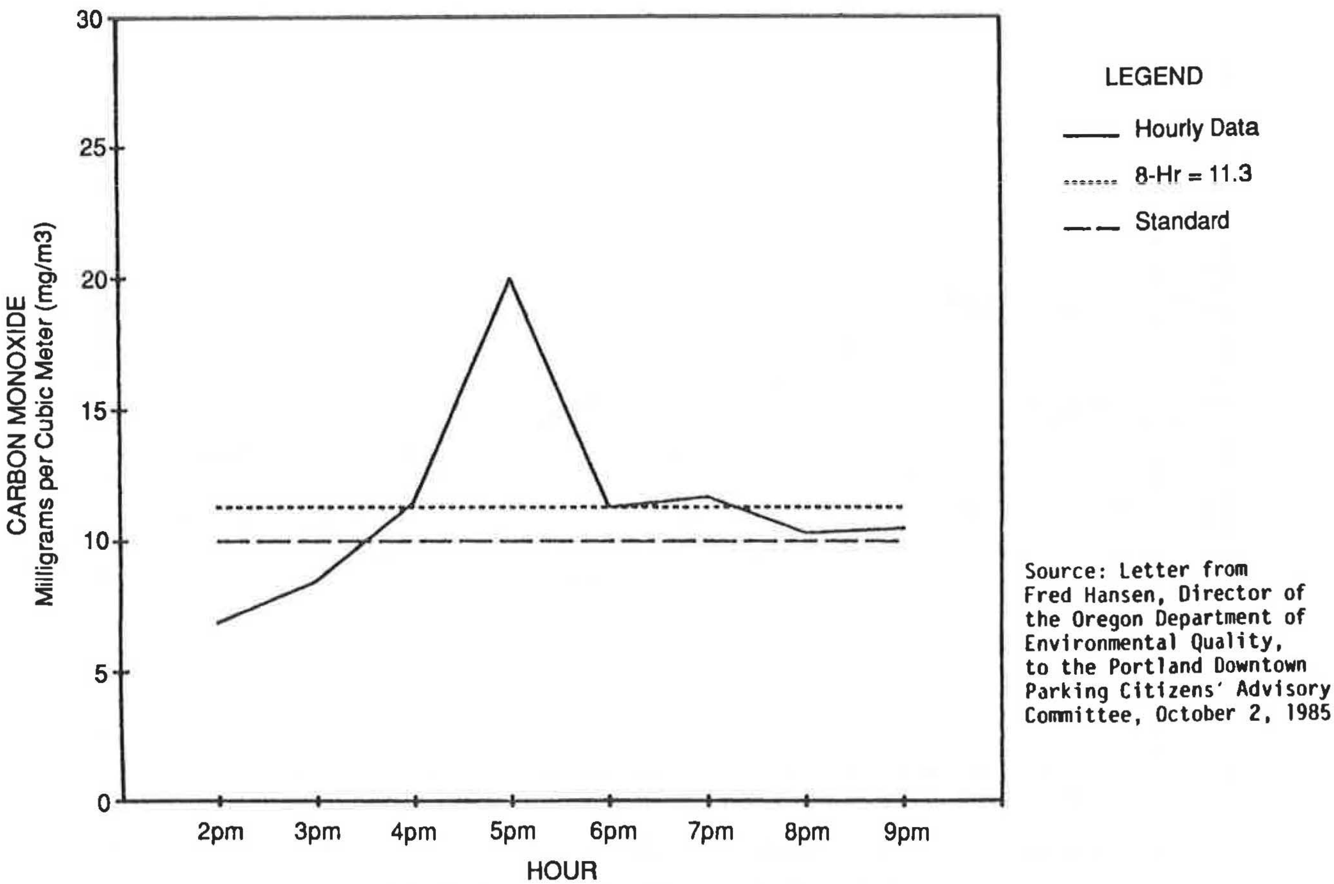

FIGURE 2 Maximum 8-hr carbon monoxide at Fourth and Alder, March 5, 1984.

during the evening commute period after parking for more than 4 hr. The lowest emissions result from the short-term parker who parks for 1 hr or less. The emissions from such a trip are roughly 28.8 g. An estimation of the overall distribution of parkers by duration of stay based on available data is illustrated in Figure 3.

EVALUATION OF OFFSETS

The evaluation of each of the measures included a review of experience with the measure in other cities as well as any experience with the measure in downtown Portland. A computer-oriented model system was also constructed to aid in the quantitative assessment of the potential impacts of each of the measures (*4*). The Figure 3 model system provided predictions of the changes in parking by sector, by type of parking (garage, lot, on-street), by time of arrival, and by duration of stay. The estimates were based on observed sensitivities to changes in parking costs, the cost of other modes, the travel times by alternative modes, and the baseline level of parking demand and travel by mode as could best be constructed from available data. The sensitivities were based on a combination of model parameters from the regional models maintained by the Metropolitan Service District, Portland's regional planning organization, and sensitivities observed in other cities when similar measures were implemented.

The cornerstone of the parking analyses was a computer forecasting system that combines proven models of travel behavior into an integrated modeling approach that can be used to estimate the downtown emission impacts of potential changes in parking and other transportation policies. The overall structure of the resulting air quality offsets model system is illustrated in Figure 4.

The model provided the following analytic capabilities:

- A single, integrated data base oriented to the city's 11 defined parking sectors that combines existing information by type of parking facility, time-of-day occupancy, price, and duration of stay;
- Analysis of the characteristics of current or predicted future parking utilization by location, time of day, and type of facility;
- Examination of the impacts of changes in parking supply or cost, either on the level of parking demand downtown as a whole or by parking location, type, or time of day within the downtown;
- Translation of parking characteristics directly into CO emission impacts; and
- Consideration of the effect of changes in work trip mode choice in the demand for downtown parking by location and type.

The air quality offsets computer model was programmed as a series of interconnected Lotus 1-2-3 spreadsheets and operates on an IBM PC-compatible microcomputer. It was designed to allow city staff to evaluate additional candidate offsets and parking policies as the need arises. This could

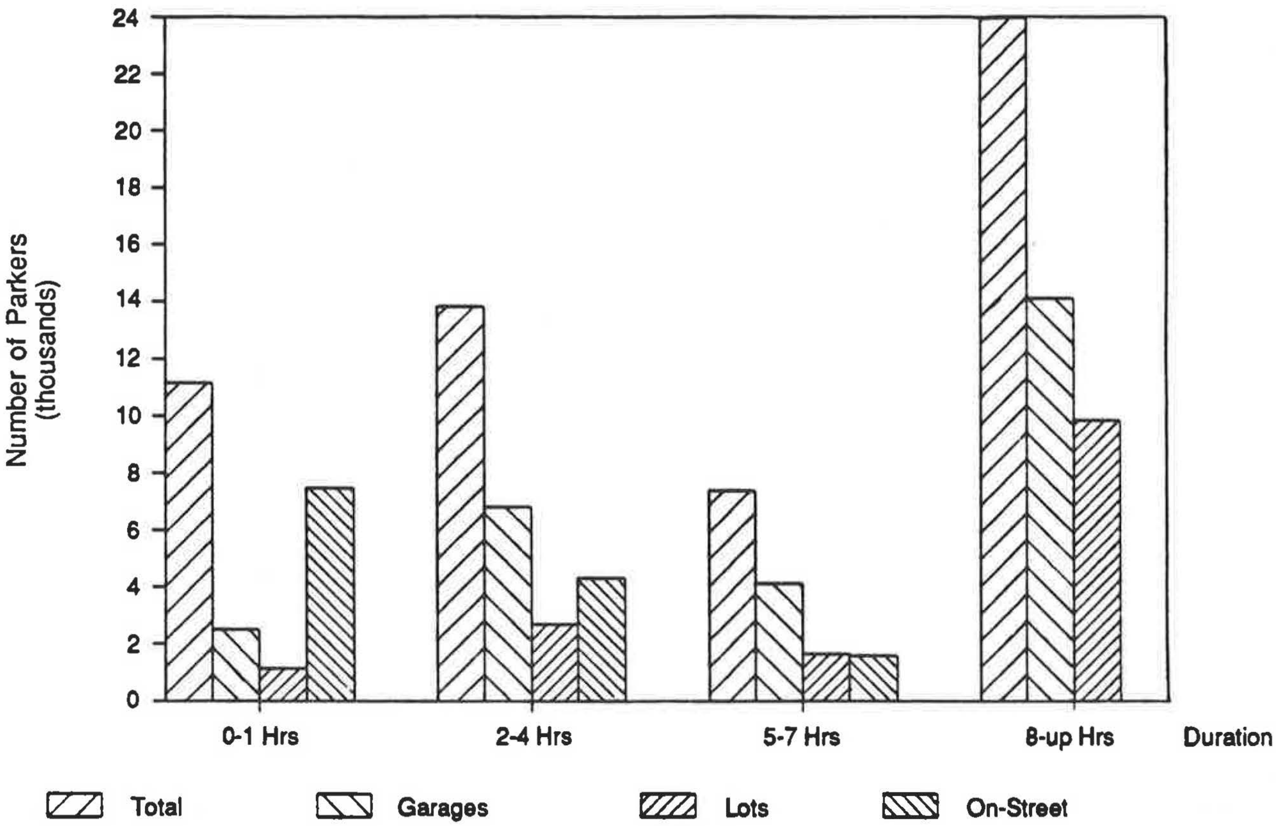

FIGURE 3 Distribution of parking by duration.

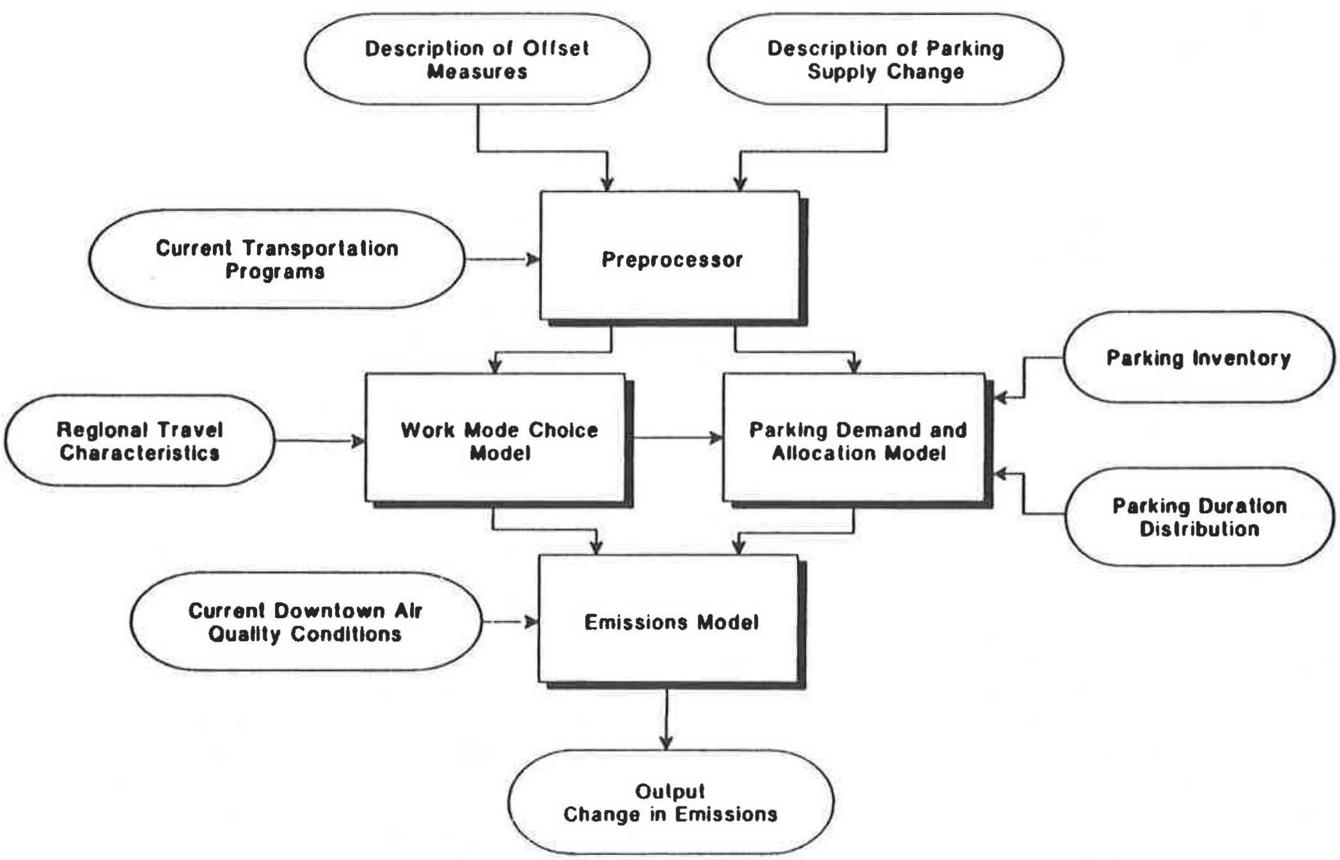

FIGURE 4 Air quality offsets model structure.

include other variations of parking pricing, supply, and hours of operation or variations in the price or level of service for alternative commute modes, such as transit or carpooling.

As illustrated in Figure 4, there are four basic components of the air quality offsets model system:

- A preprocessor,
- A work mode choice and vehicle occupancy model,
- A parking demand and allocation model, and
- A summary and emissions model.

In addition to the four basic components of the model system, there is also a large parking inventory and utilization data base, summarized by sector and type of facility, that forms a fifth component of the model.

The preprocessor prepares user-specified inputs for the parking demand and allocation model. An important part of the analysis conducted for each offset was an assessment of the level of participation that was expected to result from the measure and the extent to which the measure was likely to be implemented in downtown Portland. This could include, for example, estimation of the number of parking spaces that would be affected by a parking surcharge. The preprocessor allows a user to specify changes in parking costs (for example, increasing daily rates by some amount or raising all charges by 20 percent), restrictions on hours of operation (such as limiting availability of spaces in garages and lots to 80 percent of capacity until after 10:00 a.m.), or increases in supply by sector and type of parking facility.

The mode choice model calculates changes in work trip mode shares on the basis of specified changes in in-vehicle travel time, out-of-vehicle travel time, and out-of-pocket cost for each alternative mode. The modes considered in the model are drive alone, shared ride, and transit. The mode choice model is an incremental logit, pivot-point model that begins with current mode shares by market segment and "pivots" about these base shares using model coefficients that represent the sensitivity of mode choice to travel time and cost variables. The model structure and variable specification are based on model estimation work performed by METRO, and the actual coefficients used are taken from Portland's regional model system.

Within the total travel market, the mode choice and its associated vehicle occupancy model differentiate between 10 market segments defined by geographic divisions of the metropolitan area. This differentiation is designed to improve the accuracy with which changes in level of service are estimated. The model is designed to test the impact on each market segment of changes in in-vehicle time, out-of-vehicle time, and cost.

The output of the mode choice model is change in trips by mode, changes in vehicle occupancy for the shared-ride mode, and changes in demand for commute parking spaces downtown. When offsets are being considered for all work trips, the changes in parking demand are distributed to the sectors in proportion to the current estimated level of commuter parking demand. If an offset affects only certain locations, the effects on specific sectors are determined in the parking allocation model.

The parking demand and allocation model uses data from the sector summary of the detailed inventory of parking space supply and utilization and the preprocessor to predict changes in both total demand and the distribution of demand that would result from offset measures. Within the parking demand and allocation model, there are four main modules:

- An input and demand module that applies demand elasticities to estimate overall changes in demand resulting from changes in supply, price, and hours of operation;
- A distribution module that distributes changes in demand among the 11 sectors and among the different types of parking within each parking sector;
- A demand impact module that predicts changes in total demand for parking within the downtown; and
- A summary and emissions module that describes the overall impacts of the offset measures in terms of parking and travel characteristics by sector (e.g., total number of trips and total vehicle miles traveled) and by total change in CO emissions in grams per day attributable to those changes.

The four modules use empirically estimated elasticities with respect to supply and price from other cities where changes similar to the offsets being tested have been made. Some modifications of the elasticities, to reflect differences between Portland and the city where each elasticity was estimated, were made on the basis of professional judgment; no attempt was made to collect information to estimate new elasticities.

The fourth module predicts changes in CO emissions based on changes in

- Vehicle trips to and from the downtown (daily total),
- Vehicle miles traveled (daily total), and
- Daily mix of cold starts and hot starts in the downtown.

EPA's MOBILE3 computer program was used by the Oregon Department of Environmental Quality to calculate emission rates for various speeds, for different vehicle types, and for cold start emissions versus hot start emissions. These emissions rates were then incorporated into the emissions module, where they are used in conjunction with the estimated changes in travel and parking to calculate changes in total daily emissions for the downtown as a whole.

SUMMARY OF POTENTIAL EMISSION IMPACTS OF OFFSETS

The review of the 11 offset measures considered in the study suggested that each measure has some potential role in Portland, either as a parking offset or as a parking management tool. If additional growth is to be accommodated in the downtown in the future, a package of methods will be required, with some that decrease emissions per trip (thereby allowing some increase in the supply of parking) and some that make more efficient or appropriate use of the parking spaces available.

The evaluation of the 11 measures indicated that while the ultimate impact of each measure is not always obvious or predictable, some will clearly be useful as air quality offsets (reducing emissions per trip), whereas others appear more valuable as mechanisms for accommodating more parkers within the limits of capacity available. Successfully managing the supply of downtown parking while continuing to accommodate new development and achieving the federal air quality standards will most likely require a combination of these measures. The analysis conducted in this study should aid the city in selecting the appropriate balance of measures to pursue.

Table 1 presents a summary of the predicted emissions impacts of each of the 11 measures evaluated. The predicted impacts represent the direct impact of the measure and often do not include long-term adjustments that may occur as commuter parkers are shifted out of downtown and spaces are made available, or as travel speeds improve on downtown streets. In some cases, a reaction to these improved conditions (people returning to downtown by car) will result in a lessening of the predicted emissions reduction impact.

The estimated emissions reductions in Table 1 were developed by using the model system described earlier in combination with the review of experience in other cities to estimate a potential impact in downtown Portland. The model system was used to produce an estimate of the rate of change of emissions per unit of offset implementation. The review of national experience and the assessment of how each measure might be implemented in Portland were used to estimate the extent to which each measure would be implemented, or the level of participation that might be expected.

In interpreting the findings in Table 1, it is important to realize that the predicted impacts are based on the assumption that the measures would be implemented under the current conditions and do not represent forecasts of impacts under future conditions. The predictions are also based on the assumption that the system is currently in equilibrium; that is, the demand for parking is not constrained by the supply. The data available to this project do suggest that the parking demand is somewhat constrained by the supply in certain sectors, so the reduction in parking demand predicted for some measures may actually be partially or fully offset by new parkers filling the vacated spaces. Prediction of the full long-run impacts of some of the measures on downtown parking demand and emissions would require a more thorough analysis of current and future land use characteristics and the associated parking needs.

Four measures in Table 1 are significantly different from the others in their potential as offsets for additional downtown

TABLE 1 SUMMARY OF POTENTIAL EMISSIONS IMPACTS OF OFFSETS

Measure	Total Estimated Impact (1): Potential Change	Total Estimated Impact (1): Potential CO Emissions Reduction
1. Fringe Parking	600 Downtown Parkers Diverted	60 kg
2. Alternative Work Schedules	1 MPH Increase in P.M. Speeds - 4,000 Employees	147 kg
3. Subsidy of Ridesharing	$.50/day Subsidy - 35,000 Employees	255 kg
4. Parking Management		
Increase Long-term Rates	$1 increase in All-Day Rate - 30,000 Parkers	129 kg
Increase All Parking Rates	20% Increase for All Parkers - 56,000 Parkers	187 kg
Reserve Off-Street Parking Before 10 A.M.	15% of Core Off-street Spaces Restricted - 2,000 Spaces	302 kg
Reserve Parking for Carpools	1,000 Additional Spaces Used	17 kg
5. Park-and-Ride Remote	335 Spaces Used	13 kg
6. Alternative Fuels	1,000 Light Vehicles Converted	51 kg
7. Reserved Parking	No Apparent Reduction	
8. Enhanced Inspection and Maintenance	Annual Inspection for All Vehicles	462 kg
9. Increased Transit Capacity	6,000 Trips Diverted to Transit	364 kg
10. Traffic Flow Improvement	.5 MPH Increase in P.M. Peak Speeds	73 kg
11. Bicycle Access	50 to 100 Commuters Shifting	5-10 kg

(1) The change in parking and in emissions represents only the reduction in parking produced by the measure. As spaces become available, some additional parkers may be attracted to the downtown and the magnitude of the change is therefore likely to be less. Because of the limitations in the data available to the project, the response to the change in space availability could not be predicted.

parking. Alternative work schedules, alternative fuels, enhanced inspection and maintenance, and traffic flow improvement each affect the rate of emissions per parker rather than the number of parkers themselves. As a result, these measures are most clearly true offsets. Because virtually every space vacated by a parker shifting to another mode or to a parking space outside of downtown is likely to be filled by another parker, the other measures would represent useful offsets only if replacement parking produces lower emissions per space than current parking. Because all of the other measures are oriented toward commuters, the primary impact will be to replace long-term parking with short-term parking.

For the four offsets that produce reductions in emissions rates, the potential emission reduction was assessed in terms of the measure's equivalent in parking spaces—that is, the number of parking spaces for which current estimates of emissions are equal to the emissions reduction that would result from the offset measure. The parking space equivalents have been expressed in terms of four types of space:

- Downtown core, on-street;
- Downtown core, off-street;
- Downtown periphery, on-street; and
- Downtown periphery, off-street.

The parking space equivalents estimated for the four offset measures that would most clearly produce reductions in emissions per trip are presented in Table 2. The greatest potential from a single measure is from the change to an annual inspection and maintenance program. The Portland area currently has bi-annual inspection. This measure would produce a reduction in daily CO emissions of roughly 462 kg. The equivalent in parking spaces ranges from 2,030 spaces to 4,740 spaces depending on the type and location of spaces.

The second most effective measure would be an alternative work schedule program (or a corresponding traffic flow improvement program) that produced a 10 percent (or 1 mph) increase in the average speed in the p.m. peak hour. The total change in emissions would be roughly 147 kg per day. The parking equivalents would range from 650 to 1,500 spaces.

Other methods for improving traffic flow and increasing peak-hour speeds could also produce positive results. A 5 percent increase in p.m. peak-hour speed (.5 mph) would produce a reduction in daily emissions of roughly 73 kg. The range of parking space equivalents would be 320 to 750.

Finally, a fleet fuel conversion program that resulted in the conversion of 1,000 passenger vehicles or light trucks to methanol or compressed natural gas, from which there are only minimal CO emissions, would produce a reduction in CO emissions of roughly 51 kg. The corresponding range of parking equivalents would be from 222 to 520.

Each of the 11 offset measures reviewed in the study offers some potential improvements in air quality or a reduction in total demand for downtown parking. Some measures are clearly more appropriate as offset measures if more parking is to be added to the downtown supply, but others will be essential if the additional development is to be accommodated and air quality standards are to be maintained. Further analysis with more complete data on parking utilization and parking need will allow the city to refine the results presented in this report and develop a comprehensive parking policy for the downtown.

TRANSFERABILITY

Although many of the findings of this research effort are specific to Portland and would not be directly transferable to another city, the methodology could easily be adapted for a similar application in another setting. The potential effectiveness of the 11 measures analyzed for Portland is directly related to the current travel patterns there and the current level and nature of parking use. These characteristics include:

- Current parking occupancy level,
- Duration of stay by location,
- Time of arrival by location,
- Fleet mix by age of vehicle,
- Current work mode split, and
- Current emissions levels.

TABLE 2 PARKING SPACE EQUIVALENTS FOR FOUR OFFSET MEASURES

Measure	Potential Emissions Reductions	Parking Space Equivalents: Core Off-street	Core On-street	Non-Core Off-street	Non-Core On-street
Alternative Work Schedules	147 kg	1200	650	1360	1510
Alternative Fuels	51 kg	420	222	470	520
Enhanced Inspection and Maintenance	462 kg	3770	2030	4290	4740
Traffic Flow Improvement	73 kg	600	320	680	750

The estimated emissions per space in gr/day are: core off-street: 122.5; core on-street: 227.9; non-core off-street: 107.8; and non-core on-street: 97.5. core is Sectors C, E, F, and G.

Information on these characteristics, in addition to information about the current level of use of (or past history of trying) the 11 measures analyzed, was necessary to perform the analysis using the national review and the computer model system that was developed.

Some of the general conclusions about the relative effectiveness of the individual measures as offsets are also transferable. Among the 11 measures considered, 4 clearly achieved their effectiveness by reducing the amount of pollutant emissions per vehicle-mile traveled. These 4 measures are most clearly offsets. The effectiveness of each of the other measures depends to some extent on removing automobile trips from the downtown. Their effectiveness as offsets is therefore dependent on the response to the new availability of parking created by the reduction in automobile trips. If new drivers emerge to replace those diverted to other modes or parking locations outside the downtown, the value of the measure as an offset can be lost. If the shift is also accompanied by an increase in the turnover rate for the space vacated, the effect may even be an increase in the level of emissions.

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