THE PORTLAND TRANSIT MALL IMPACT STUDY

AIR QUALITY IMPACTS REPORT

BUREAU OF PLANNING
CITY OF PORTLAND, OREGON
DECEMBER, 1981

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INTRODUCTION

BACKGROUND

Transit malls are a relatively new form of municipal projects; they have been constructed in the U.S. only within the last 15 years. In the 1970's a new wave of concern over deteriotating business conditions in downtowns combined with increased concern over traffic congestion and environmental problems brought renewed interest in transit improvements as a partial solution. Recognizing that fixed guideway systems are expensive, most cities have begun to focus attention on improving bus service by means of operational measures. Examples are: priority signalization, preferential lanes, improved loading facilities, route rationalization, and improved scheduling. In particular, there has been a trend toward consolidation of routes onto fewer streets in order to make more efficient use of preferential treatment, while also simplifying the transit system and making transfers easier. Also, under the general heading of "Transportation Systems Management," public officials are encouraging carpools, transit usage, shorter trips and pedestrianization to otherwise mitigate the growth of auto congestion.

Transit malls represent a combination of two trends: (1) pedestrian malls and (2) preferential treatment for buses on city streets. They consist of relatively auto free areas which retain a roadway reserved for transit vehicles. Auto access is denied or limited strictly to local traffic and cross-street traffic. Typically, sidewalks are widened and other pedestrian amenities are added. By addressing the needs of pedestrians and facilitating the operation of transit, the mall becomes an important part of the collection-distribution process of a city wide or regional transit system.

A transit mall can be viewed as a compromise shopping mall, designed to satisfy merchants who may feel that some vehicular access is essential to their business. This compromise view is based on the notion that neither pedestrian needs nor transit volumes taken by themselves are sufficient to justify removing entire streets from automobile use, but together they are. Further, pedestrian and transit uses are considered complementary uses. By combining the two, a special focus may be created in the downtown area that brings people together, stimulates business, encourages bus ridership, improves transit service, enhances environmental quality, and stimulates development in a pattern that can be better served by transit.

HISTORICAL DEVELOPMENT OF PORTLAND, OREGON'S TRANSIT MALL

While the concept of segregating transit from auto traffic on Portland's downtown streets was advanced as a solution to downtown traffic problems as early as the 1950's, the idea of a transit mall for Portland, Oregon was initiated in 1970 by a coalition of downtown business leaders and property owners. A Downtown Plan Study Group was formed, involving the City of Portland, Multnomah County and a variety of private consultants. Shortly thereafter, a Technical Advisory Committee, composed of technical personnel from various public agencies, was also formed, as well as a Citizen Advisory Committee.

After 15 months of discussion and study, a report (Planning Guidelines - Portland Downtown Plan) was published which included a transit mall concept for Fifth and Sixth Avenues.

The transit mall concept was identified as an integral element in the Downtown Plan and reiterated in the City's Transportation Control Strategy for Federal Air Quality Standards (1972). Therefore, the transit mall concept should not be viewed as an independent project but as a part of a much broader public and private investment plan.

Through a program funded by the Urban Mass Transportation Administration (UMTA), the Tri-County Metropolitan Transportation District of Oregon (Tri-Met) initiated a feasibility study for a Portland Transit Mall in January of 1973. The results of the study were favorable. This effort was followed by a preliminary design, completed in December of 1975. The funding for the Transit Mall was available under the Urban Mass Transportation Act of 1964 as amended. This act authorized the Secretary of Transportation to provide additional assistance for the development of comprehensive and coordinated mass transportation systems, both public and private, in metropolitan and other urban areas, and for other purposes. The construction was a $15 million project funded 80 per cent by UMTA and 20 per cent by Tri-Met. Construction began in February, 1976; partial operation started in December, 1977; the Mall was completed early in 1978.

The Transit Mall is located in the heart of Portland's Central Business District (see Figure 1), is eleven blocks long (½ mile), and consists of two one-way streets, S.W. Fifth and Sixth Avenues. Physically, the Transit Mall involved reconstructing all improvements within the street right-of-way. This included widening existing 15' sidewalks to 26' along the right lane of each avenue where buses load. Sidewalks on the opposite side of the street were widened from 15' to 18' where there is auto access and to 30' in other blocks. Sidewalks were reconstructed with brick paving and granite curbs. London plane trees, spaced at approximately 25 feet, line the two avenues. This boulevard treatment is enhanced by refurbished historic street light standards and other street furniture. Most significant among the items of street furniture are 31 bronze-clad, glass roofed bus shelters located at bus stops.

An access lane for automobiles was provided in all but six blocks on the two Mall streets. These access lanes do not

FIGURE 1

PORTLAND CENTRAL BUSINESS DISTRICT

allow through traffic, since they run for no more than three continuous blocks. Access from cross streets to these lanes is made by turning left into the Mall street. Cross street traffic is not allowed to turn right into the access lane because this would require turning across the bus lane. The widened sidewalks allow room for people waiting for buses, as well as 250 trees, 31 bus shelters, 54 benches, 34 bicycle bollards, 112 trash containers, 48 banner poles, 84 light bollards, 8 trip planning kiosks, plus display kiosks, concession stands and other features. It has been proposed that the Transit Mall eventually be extended a few blocks to connect with a regional transportation center at the northern end of the downtown. This would provide a link between suburban transit stations, shuttle buses, inter-city buses, Amtrak, and future transit improvements such as light rail.

OBJECTIVES OF THE PORTLAND TRANSIT MALL

Several objectives influenced the design of the Transit Mall. An important objective was to provide a more efficient, convenient transportation alternative for commuters and shoppers. Transit improvements were expected to increase transit use. This, in turn, was expected to promote more efficient land use, reduce energy consumption and reduce pollution. Another objective was to revitalize the downtown area.

The Mall design incorporates a number of features aimed at improving the efficiency and hence the attractiveness of transit. Two lanes on each avenue are designated exclusive bus rights-of-way. They are intended to increase transit capacity and reduce bus travel time by minimizing conflicts between autos and buses. A third lane, adjacent to the two transit lanes in eight of the eleven blocks, provides limited access to non-transit vehicles. The three blocks which do not have this lane act as a barrier to non-transit vehicles which could otherwise use the Mall as a through north-south route. Non-transit vehicles may also cross the Mall on all east-west cross streets. This provides additional access while minimizing auto-bus conflict.

The Mall was also designed to encourage transit by making it more convenient and comfortable. Downtown bus stops were centralized to make transfers easier. Comprehensive route and schedule information are available at bus stops and information kiosks. Sheltered waiting areas and other services are provided. These and other features were included to make it easier for people to understand and use the transit system.

In addition to basic transit improvements, the Mall was designed to provide an environment inviting to residents and visitors, thereby making downtown businesses more competitive with suburban locations. Pedestrian amenities include widened sidewalks, street trees and landscaping, separation of passenger waiting zones from the store fronts and sidewalks, improved street lighting, street furnishings, and more attractive street graphics, signing and traffic control devices.

Finally, it was hoped that the completed Mall would stimulate growth in the downtown area, through stabilization or growth in the number of retail firms, lower vacancy rates, lower turnover rates, increased retail sales and other business activity, greater private and public investments, and more jobs.

THE PORTLAND TRANSIT MALL IMPACT STUDY

The Portland Transit Mall Impact Study was funded by the Urban Mass Transportation Administration to analyze a wide range of impacts related to the Portland Transit Mall. This study is a joint project involving the following agencies: Metropolitan Service District, City of Portland--Bureau of Planning, Tri-

County Metropolitan Transportation District of Oregon, Center for Urban Studies--Portland State University.

The purpose of the study is to provide useful information for public and private organizations at both the national and local level. At the national level, results of the study will help answer questions that are asked of Portland by other local governmental agencies. These agencies have expressed interest in Portland's experience with a transit mall and possible applications to their locale. They are also interested in the transportation-land use interactions that can be achieved through investments in transit. At the local level, information will be used in assessing impacts that relate to the operation, maintenance and possible extension of the Transit Mall.

This study evaluates a wide range of impacts which can be attributed to the construction and operation of Portland's Transit Mall. At the same time it must be recognized that the impacts of the Portland Transit Mall are difficult to isolate from a series of other public and private activities occurring during the same time period.

The specific impacts that were identified, measured and analyzed by this study and the agencies conducting this research are:

- I. Tri-County Metropolitan Transportation District of Oregon
  - A. Transit Operation Impacts
  - B. Safety Impacts
    - 1. Traffic Accidents
    - 2. Crime
  - C. Supervision
  - D. Transit Users Survey
- II. The City of Portland--Bureau of Planning

A. Environmental Impacts
   1. Noise
   2. Air Quality
B. Economic and Land Use Impacts
   1. Economic and Land Use Overview
   2. Downtown Buildings: New Construction, Major Renovation and Demolition
   3. Retail Firm Location and Re-Location Movements
C. Traffic Impacts
D. Pedestrian/Parking Survey

III. Center for Urban Studies--Portland State University
   A. Downtown Employee Impact Survey
      1. Travel Behavior
      2. Mode Changes
      3. Environmental Attitudes and Perception
      4. Design Aspects
   B. Retail Firm Locational Decision Impact Survey
      1. Effects of Transit Mall during construction
      2. Effects of Transit Mall after construction
   C. Economic and Land Use Impacts
      1. Changes in Land Values
      2. Changes in Rental Values
   D. Downtown Revitalization Impacts
   E. Institutional Networks

The following report is one of a series published by the Portland Transit Mall Impact Study. The contents of this report will be integrated into a Final Report.

PURPOSE OF AIR QUALITY IMPACTS REPORT

The purpose of the Air Quality Impacts report is to determine what effects the Transit Mall has had on air quality in the downtown Portland area. One of the original objectives of the Transit Mall was its contribution toward the reduction of air pollution in downtown. Sufficient monitoring data is not currently available to determine the exact impacts of the Mall on downtown air quality, but it is assumed to have played a measureable role since it began operating in 1978. To meet the objective of the report, an emission density an-anysis of 1980 with-Mall conditions versus 1980 without-Mall conditions was conducted to determine whether, in fact, the Mall has contributed toward the reduction of the following four motor vehicle related pollutants: hydrocarbons, carbon monoxide, nitrogen oxides and suspended particulate. The findings of the analysis are usually discussed in terms of emission densities under without-Mall conditions.

An emission density is the mathematically calculated amount of pollutant within a specific area. The major inputs to the calculation are traffic volumes, speeds and pollutant emission factors by type of motor vehicle. These inputs are different for 1980 with-Mall conditions than for 1980 without-Mall conditions. Data for the with-Mall and without-Mall conditions were provided in the <u>Traffic Effects Analysis</u> report also prepared for the Portland Transit Mall Impact Study (13). The DEQ provided emission factor data.

This report is composed of five sections. Section I briefly describes the background relationships between the Transit Mall and downtown and air quality planning efforts in the early 1970's. Section II describes trends in air quality in the Portland region, focusing on the downtown area, from 1970 to 1980. The purpose of this section is to establish an overall context of air quality in the Portland region and the downtown area for a better understanding of the findings presented in Section IV. Section II provides the reader with a basic understanding of the air pollution problem in Portland, as well as the sources and behaviors of the individual seven major pollutants over time. Section III describes in detail the methodology used for the emission density analysis, and Section IV presents the findings of the analysis. Major findings are summarized in Section V. Discussion of the findings is usually in terms of without-Mall conditions.

SECTION I

BACKGROUND

As early as 1970, efforts to improve air quality in Portland were integrated with combined public and private planning efforts to revitalize a declining downtown.

The Portland Transportation Control Strategy (TCS) is part of the Oregon Clean Air Implementation Program, prepared in response to the requirements of the Federal Clean Air Act of 1970. The TCS is a program jointly developed by the City of Portland, Tri-County Metropolitan Transit District (Tri-Met), and the Oregon Department of Environmental Quality (DEQ). The objective of the Strategy is to achieve and maintain compliance with national ambient air quality standards for motor vehicle related air contaminants in downtown Portland. The Strategy is aimed at motor vehicles because they are responsible for the majority (85-90%) of downtown air shed emissions.

The TCS was drafted with the assistance of several Task Forces before adoption by the Portland City Council in 1972. This draft was amended by DEQ before submitting the Strategy to the U.S. Environmental Projection Agency (EPA) for final approval (12). The Strategy is subject to periodic revisions.

In the meantime, concern for the gradual visual and economic decay of downtown Portland became formalized in 1970 when individuals representing downtown business and property interests created a Downtown Committee. The Committee determined that adoption and implementation of a Downtown Plan was essential in order to prevent the gradual death of the downtown area. As a result of these efforts, the City of Portland sponsored a Downtown Plan study that was financed jointly by private and public organizations.

The Downtown Plan Team was organized late in 1970 under the direction of the Multnomah County Planning Department. The team consisted of traffic engineering and urban planning consultants, who drew assistance from a Technical Advisory Committee composed of various public agency personnel. Further assistance was provided by the planning section of the Port of Portland, the Portland State University Center for Urban Studies, and the Columbia-Willamette Air Pollution Authority.

After 15 months of work, the Downtown Plan Team published its report entitled Planning Guidelines - Portland Downtown Plan. In the Plan, the Portland Transit Mall formed the spine of downtown, running north-south through the middle of the high density office development area from W. Burnside to S.W. Market Streets and between S.W. Fourth Avenue and S.W. Broadway.

The Transit Mall, as proposed in the Downtown Plan, was also an integral part of the Transportation Control Strategy which specifically assigned to mass transit the responsibility of reducing downtown air pollutants. Construction of the Transit Mall and related transit improvements were originally targeted to reduce pollutants by seven percent by increasing ridership 50 percent by June 1, 1975 (11).

SECTION II
AIR QUALITY TRENDS 1970-1980

Early in the 1950's, the Portland City Health Officer began receiving complaints about eye irritation believed to be caused by air pollution. The complaints were not numerous, but were enough to spark an interest in the phenomenon. A few years later, a U.S. Department of Health, Education and Welfare study confirmed these reports of air pollution incidents. Not only did the study find evidence of pollution-caused eye irritation, but also "certain soiling of buildings, wearing apparel, vehicles, and home and office furnishings." (2).

As Portland grew so did the air pollution. By the early 1970s, the haze once thought to be unique to the Los Angeles basin had begun to make regular appearances in the hot, sunny months of late summer. Portland, by then a major metropolitan center, was not immune to the consequences of urban growth and development.

The reasons for Portland's pollution problem are many and complex. All, however, are tied to two main factors: the city's location and climate, and the nature of certain activities that take place within that location -- mainly transportation.

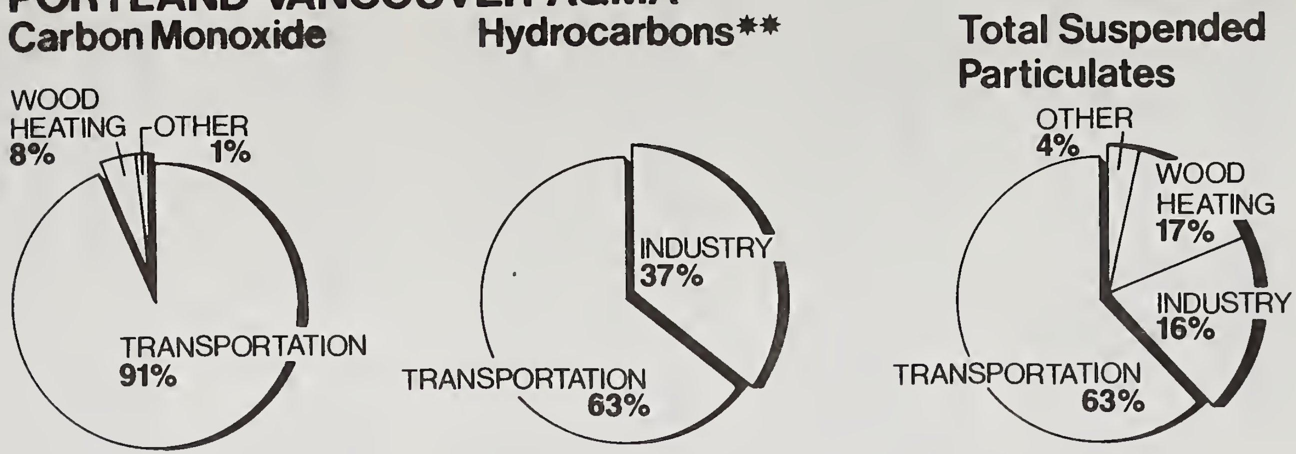
The high percentage of transportation related sources of emissions in the Portland-Vancouver Air Quality Maintenance Area (AQMA, designated by DEQ) is illustrated in Figure 2.

GEOGRAPHIC LOCATION AND CLIMATE

The geography of Portland has long been a source of pride for the city and its residents. Portland's location at the confluence of the Columbia and Willamette Rivers has been an

FIGURE 2

SOURCES OF EMISSIONS IN PORTLAND-VANCOUVER AQMA*



*These percentages are based on 1980 emmisions inventory data. Actual air quality impacts may be different due to differences in source locations and dispersion patterns.

**Hydrocarbons are a factor in ozone formation.

Source: Oregon Air Quality Report, 1980, DEQ important key to the economic vitality of the region. And the hills that surround the city make it one of the more attractive urban areas in the country. The Coast Range to the west protects the area from the severe effects of Pacific winter storms, and the Cascades act as a barrier to intrusions of cold air masses from the east. Portland's climate is thus characterized by predominantly mild temperatures with few seasonal extremes.

This same geography makes the Portland area one of the most conducive to air pollution problems in the entire nation. The hills and mountains that surround the Willamette Valley tend to confine the movement of air and trap pollutants in the basin. The same mountains that provide Portland with its mild climate also prevent strong winds from blowing the polluted air out of the valley and away from the city (2).

AMBIENT AIR QUALITY STANDARDS

There are seven major types of air pollution: carbon monoxide, total suspended particulate, photochemical oxidants (ozone), hydrocarbons, oxides of nitrogen, oxides of sulfur and lead. The Environmental Projection Agency has developed standards for each of these pollutants from which most states have developed their own standards. Federal air quality standards are divided into two classes, primary and secondary. Primary standards are designed to protect public health with a built-in margin of safety. Secondary standards are generally the same or more rigorous than primary ones and are designed to protect the public welfare from effects such as visibility reduction, soiling, material damage and nuisances. Federal and Oregon state standards for each of these pollutants are displayed in Table 1.

Oregon has adopted state standards at least as stringent as

TABLE 1

AMBIENT AIR QUALITY STANDARDS
FEDERAL AND STATE OF OREGON
1980

POLLUTANT	AVERAGING TIME	FEDERAL STANDARDS PRIMARY (HEALTH)	FEDERAL STANDARDS SECONDARY (WELFARE)	OREGON STANDARDS
Carbon Monoxide	8 hours (1)	10 mg/m^3	10 mg/m^3	10 mg/m^3
	1 hour (1)	40 mg/m^3	40 mg/m^3	40 mg/m^3
Total Suspended Particulate	Annual Geometric Mean	75 ug/m^3	60 ug/m^3	60 ug/m^3
	24 hours (1)	260 ug/m^3	150 ug/m^3	150 ug/m^3
	Monthly (2)	-	-	100 ug/m^3
Ozone (4)	1 hour	235 ug/m^3 (3)	235 ug/m^3 (3)	160 ug/m^3 (3)
Hydrocarbons (Nonmethane)	3 hours (1) (6-9 a.m.)	160 ug/m^3	160 ug/m^3	160 ug/m^3
Nitrogen Dioxide	Annual Arithmetic Average	100 ug/m^3	100 ug/m^3	100 ug/m^3
Sulfur Dioxide	Annual Arithmetic Average	80 ug/m^3	-	60 ug/m^3
	24 hours (1)	365 ug/m^3	-	260 ug/m^3
	3 hours (1)	-	1300 ug/m^3	1300 ug/m^3
Lead	Monthly	-	-	3 ug/m^3
	Calendar Quarter	1.5 ug/m^3	1.5 ug/m^3	-

(1) Not to be exceeded on more than one day per year.
(2) 24 hour average not to be exceeded more than 15 percent of the time.
(3) A statistical standard, but basically not to be exceeded more than an average one day per year based on the most recent three years of data.
(4) The federal standards were revised in February, 1979, and the state standard changed from photochemical oxidant to ozone in June, 1979.

ug/m^3 = micrograms of pollutant per cubic meter of air.
mg/m^3 = milligrams of pollutant per cubic meter of air.

Source: Oregon Air Quality Report 1980, DEQ

the federal secondary standards for all pollutants except lead. The Environmental Protection Agency adopted a standard in September, 1978 for lead that is somewhat stricter than Oregon's standard which was adopted in 1975. To comply with the Clean Air Act, Oregon must adopt a standard at least as strict as the federal standard. The Oregon Environmental Quality Commission will consider a new state standard for lead in the near future. In the case of ozone, EPA revised the federal standard upward in February, 1979 and established 1987 as the attainment date. Oregon retained the more stringent standard, but moved the compliance date ahead to 1992.

The EPA is assessing the possibility of establishing a standard for fine particulate separate from the total suspended particulate standard, based on evidence that smaller particles penetrate deeper into the lung and cause more serious health effects than do larger particles. DEQ has established a fine particulate monitoring network and is compiling data to determine current levels of fine particulate and to evaluate trends (3, 10).

PORTLAND AIR POLLUTANTS

Air quality in the Portland area has been steadily improving since the early 1970's when the State began implementing clean air programs. Improvements in concentrations* of each of the seven major pollutants has varied by year and by location in the general region due to weather, general human activity, the specific characteristics of each pollutant, and just recently, the eruption of Mount St. Helens.

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*A "concentration" is an amount of pollutant per volume of air. Air quality standards and monitoring of pollutants are usually in terms of concentrations.

Currently, Portland is in one of four areas in the state designated as not being in attainment with federal air quality standards for one or more pollutants. The Portland - Vancouver Air Quality Maintenance Area (AQMA) contains areas in which concentrations of three of the major pollutants — carbon monoxide, total suspended particulate and ozone — violate federal standards. Control strategies have been or are being developed as part of the State Clean Air Act Implementation Plan to bring all areas with air pollution violations into compliance with federal standards. The status of the Portland - Vancouver AQMA plans and their projected attainment dates are shown in Table 2. The plans aim to bring the region into attainment for total suspended particulate by 1987, for carbon monoxide by 1985 and for ozone by 1987 (by 1995 for attainment of the more stringent state standard).

TABLE 2

PORTLAND-VANCOUVER AQMA AIR QUALITY ATTAINMENT
PLANS AND PROJECTED DATES

	POLLUTANT		
	TOTAL SUSPENDED PARTICULATE	CARBON MONOXIDE	OZONE
Portland-Vancouver AQMA			
Plan Adoption Date	Dec., 1980	By July 1, 1982	Expected June, 1982
Projected Attainment Date	1987	1985	1987 (1995 for state standard)

Source: Oregon Air Quality Report 1980, DEQ

The behavior of each of the seven major pollutants from 1970 to 1980 is discussed in the following pages. Each discussion focuses on the downtown Portland area since it is the major area of concern of the Portland Transit Mall Impact Study. A summary of air quality data collected by DEQ for each pollutant at one or more of the downtown DEQ monitoring stations is included. The locations of these stations are shown in Figure 3.

FIGURE 3

LOCATION OF DOWNTOWN PORTLAND DEQ AIR QUALITY MONITORING STATIONS

░░░	TRANSIT MALL	
✸A	718 W. BURNSIDE	CAMS
✸B	S.W. 4th AND ALDER	PRIOR TO 9-75 LOCATED AT 600 S.W. 4th AVE.
✸C	55 S.W. ASH	CENTRAL FIRE STATION

600'

Carbon Monoxide

Carbon monoxide is a colorless, odorless, highly toxic gas. It is the most widely distributed and commonly occurring air pollution in the nation. There is more carbon monoxide emitted into the atmosphere than all other major pollutants combined. Most carbon monoxide comes from the incomplete or inefficient combustion of fuels containing carbon, and the primary source is the motor vehicle engine.

In the Portland area, carbon monoxide is almost totally caused by motor vehicle combustion. Portland's major problem areas are located in the downtown and adjacent areas on the east side of the Willamette River. In addition, several roadways have been identified as problem areas, among them Sandy Boulevard, Interstate 5, McLoughlin Boulevard, and 82nd Avenue. Most of the carbon monoxide problems occur during the winter months, when inversions are frequent and the air is relatively stagnant.

Within the Portland-Vancouver AQMA, the overall carbon monoxide problem steadily improved throughout the 1970's and is projected to continue to improve in the next several years. Problem areas, or "hot spots," do still exist on several roads, however, mostly in the downtown Portland area and may still violate standards by the 1985 attainment deadline (2).

Downtown Portland exceeded the federal and state standard for carbon monoxide throughout the 1970's. The carbon monoxide summary of downtown from 1970 to 1980 is presented in Table 3. The number of days in violation of the eight hour standard of 10 mg/m^3 fluctuated from year to year, but the long-term trend over the eleven year period was toward a reduction in carbon monoxide violations in the downtown area. The reductions in both the AQMA and downtown are attributed to new federal vehicle emission controls, to the Portland area DEQ motor

TABLE 3

CARBON MONOXIDE SUMMARY (mg/m^3)*
PORTLAND DOWNTOWN AREA
1970 - 1980

MONITORING STATION	YEAR	1 HOUR AVERAGES MAXIMUM	1 HOUR AVERAGES 2ND HIGHEST	8 HOUR AVERAGES NO. OF DAYS 10 mg/m^3	8 HOUR AVERAGES MAXIMUM	8 HOUR AVERAGES 2ND HIGHEST
718 W. Burnside	1970	50.6	48.3	89	25.5	20.8
(CAMS)	1971	48.3	41.4	116	22.1	21.8
	1972	42.6	39.1	120	28.9	27.0
	1973	39.1	36.8	109	25.6	22.4
	1974	27.6	27.6	75	18.7	17.8
	1975	39.1	36.8	51	21.6	21.1
	1976	34.5	33.3	25	17.2	15.2
	1977	25.3	25.3	44	17.5	17.4
	1978	31.0	26.4	36	16.3	15.2
	1979	31.0	31.0	21	24.1	13.2
	1980	27.9	23.7	19	13.9	13.4
4th & Alder	1975(1)	32.2	25.3	14	14.9	12.7
Began 9/75	1976	24.1	21.8	32	15.9	14.7
	1977	23.0	23.0	14	14.9	14.8
	1978	23.0	20.7	9	13.2	12.4
	1979	36.8	27.6	5	14.5	13.8
	1980	26.0	24.9	11	18.9	15.0

*mg/m^3 = milligrams per cubic meter

(1) Partial year data

STANDARD: Averaging Time	Federal Primary	Federal Secondary	Oregon
8 hours**	10 mg/m^3	10 mg/m^3	10 mg/m^3
1 hour**	40 mg/m^3	40 mg/m^3	40 mg/m^3

**Not to be exceeded on more than one day per year.

Source: Oregon Air Quality Report 1980, DEQ

vehicle inspection program, and particularly in the downtown, to the Transportation Control Strategy.

The more frequent occurrence of carbon monoxide pollution problems in the winter months is illustrated in Table 4, which presents the number of days per month from 1970 to 1980 experiencing eight-hour carbon monoxide concentrations in excess of 10 mg/m^3.

<u>Total Suspended Particulate</u>

Particulates are any solid or liquid materials dispersed in the air that are smaller than approximately 500 microns (any larger and the matter would not remain airborne). Particulates of this size can stay in the air anywhere from a few seconds to a few months. Included in this category of pollution are dust, smoke, fumes, mists, sprays, aerosols and pollen.

Particulates come from just about everywhere, including paved and unpaved roads, field and slash burning, solid waste disposal, industrial processes, fuel combustion, and transportation of all kinds.

The total suspended particulate problem in Portland has been the subject of controversy for some time. Early studies by the Oregon State Sanitary Authority estimated that industrial sources were the primary source of all particulates—indeed, all pollution—in the Willamette basin (2). However, later research began to suggest that this might not be the case. In 1976 the Associated Oregon Industries, the Port of Portland and the Oregon Legislature funded a study, the Portland Aerosol Characterization Study (PACS), designed to identify the sources of total suspended particulate, using the most advanced methods available. In April of 1979 the results of the study were published. Contrary to earlier conclusions

TABLE 4

NUMBER OF DAYS PER MONTH WITH 8-HOUR CARBON MONOXIDE CONCENTRATIONS GREATER THAN 10 mg/m^3
PORTLAND DOWNTOWN AREA
1970-1980

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	YEAR TOTAL
MONITORING STATION													
718 W. Burnside (CAMS)													
1970	15	9	9	2	1	5	1	2	6	7	12	19	88
1971	16	11	9	6	1	6	2	5	11	15	16	18	116
1972	15	15	12	10	3	5	6	3	11	10	19	11	120
1973	14	10	11	4	4	4	2	3	8	12	21	16	109
1974	7	6	6	6	2	3	1	3	1	9	16	15	75
1975	10	6	1	1	1	3	0	6	1	11	9	2	51
1976	6	1	0	0	0	0	0	1	1	5	2	9	25
1977	5	3	2	0	1	1	0	2	8	7	6	9	44
1978	12	0	5	1	0	0	0	0	2	1	10	5	36
1979	5	2	0	0	0	0	0	0	0	2	3	9	21
1980	4	1	0	0	0	1	0	0	0	2	6	5	19
SW 4th & Alder*													
1972	-	-	-	-	-	0	0	4	2	6	18	21	51
1973	16	16	10	8	9	18	10	19	12	19	18	15	170
1974	4	4	3	6	3	1	3	6	9	13	17	10	79
1975	1	7	1	1	0	0	2	-	3	4	3	5	27
1976	1	1	2	0	0	1	0	0	3	7	8	10	33
1977	8	2	1	1	0	1	0	1	0	0	0	0	14
1978	1	0	0	0	0	0	0	0	0	1	4	3	9
1979	2	1	1	0	0	0	0	0	1	0	0	0	5
1980	1	2	0	0	0	0	0	0	1	2	1	4	11

*Prior to September 1975, site was located at 600 SW 4th.

Source: Oregon Air Quality Report 1980, DEQ

the PACS revealed that the major source of locally generated particulates (those not a result of background pollution*) was soil and road dust, with vegetative burning (fire places, wood burning stoves, field and slash burning) the second largest contributor. Industrial sources of total suspended particulates contribute less than three percent of the total, on an annual basis according to the study(2).

Exactly what the results of the study will mean to Portland will depend to a great degree on upcoming federal actions. EPA is examining and might revise the federal standards for particulates. The agency is not only considering the stringency of the standards but also the very manner in which the pollutant is to be measured. Currently the standard measures total suspended particulates, regardless of size or weight. The problem is that recent research has suggested that larger particulates are not a significant health problem. It is the finer particulate that presents the greater problem. The smaller particulates are not captured as efficiently by the human body's normal filtering systems and are more easily inhaled and deposited in the lungs. Fine particulates also contribute to visibility degradation. For these reasons EPA is considering changing the particulate standard to one based on fine, not total particulates.

The PACS anticipated this problem and analyzed the sources of fine as well as total suspended particulates in Portland. According to the study, fine particulates account for approximately 31 percent of the total particulates in Portland.

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*"Background pollution" is that level of pollution which exists relatively naturally in locations isolated from industrial and transportation sources; also referred to as "ambient pollution" (8).

Aside from background sources, the greatest contributors to Portland's fine particulate pollution are vegetative burning, auto exhaust, diesel exhaust and distillate oil sources.

The problem is clear. If the standard continues to measure total particulates then Portland's control strategies will necessarily focus on controlling soil and road dust, since these are the main sources of total suspended particulate. However, if the standard is changed to a more size specific rule, then control measures will have to change accordingly. Instead of controlling soil and road dust the main concerns will shift to controlling field burning, chimney smoke and motor vehicle exhaust (2). The DEQ has established a fine particulate monitoring network and is compiling data to determine current levels and to evaluate trends.

Monitoring of total suspended particulate in the downtown area between 1970 and 1980 is summarized in Table 5. The federal primary standard is exceeded when 24 hour samples are greater than 260 ug/m^3. This standard was rarely exceeded between 1970 and 1979 as shown in Table 5. The higher incidences in 1980 of exceeding the standard are due to the eruptions of Mount St. Helens.

The number of days that total suspended particulate counts exceeded the Oregon and federal secondary standard of 150 ug/m^3 steadily decreased between 1970 and 1977. The last three years of the summary, 1978-1980, the number of days exceeding the standard increased again slightly. The 1980 figures result in part from the eruption from Mount St. Helens.

Another standard imposed on total suspended particulate is the Oregon annual arithmetic mean of 60 ug/m^3. At both of the monitoring stations in Table 5, total suspended

TABLE 5

TOTAL SUSPENDED PARTICULATE SUMMARY (ug/m^3)*
PORTLAND DOWNTOWN AREA
1970-1980

MONITORING STATION	YEAR	NO. OF 24-HOUR SAMPLES	NO. OF DAYS GREATER THAN: 150 ug/m^3	260 ug/m^3	ANNUAL GEOMETRIC MEAN	24 HOUR AVERAGES MAXIMUM	2ND HIGHEST
718 W. Burnside	1970	102	7	0	64.5	187	183
(CAMS)	1971	118	9	0	70.6	213	204
	1972	92	5	0	77.9	200	182
	1973	53	4	0	76.0	242	235
	1974	49	4	0	71.2	210	172
	1975	58	0	0	51.1	123	101
	1976	59	2	0	55.5	220	160
	1977	37	0	0	62.7	140	110
	1978	55	2	0	64.8	274	214
	1979	59	4	1	62.5	466	199
	1980	61	9	4	81.6	459	376
55 SW Ash	1970	90	13	0	68.2	214	206
(Central Fire Station)	1971	91	15	2	86.3	270	262
	1972	91	12	0	84.7	229	215
	1973	76	9	1	73.9	376	210
	1974	60	4	0	67.6	185	172
	1975	56	0	0	57.8	127	127
	1976	58	4	0	65.5	220	200
No data 11/78 - 12/78	1977	60	2	1	70.7	290	160
	1978	34	3	0	66.4	173	159
	1979	55	6	0	75.8	200	195
	1980	58	16	6	99.2	640	562

*ug/m^3 = micrograms per cubic meter

STANDARD:	Averaging Time	Federal Primary	Federal Secondary	Oregon
	Annual Geometric Mean	75 ug/m^3	60 ug/m^3	60 ug/m^3
	24 hours**	260 ug/m^3	150 ug/m^3	150 ug/m^3
	Monthly***	-	-	100 ug/m^3

** Not to be exceeded on more than one day per year.
***24 hour average not to be exceeded more than 15% of the time.

Source: Oregon Air Quality Report 1980, DEQ

particulate counts exceeded this standard from 1970 to 1974, fell below it in 1975, and exceeded it again annually from 1977 to 1979. The particulate air quality in Portland has degraded since 1976 as a result of emissions associated with general population growth and a large increase in wood heating (3).

Compliance with the 24 hour secondary standard of 150 ug/m^3 not to be exceeded more than once per year is determined by the second highest value recorded at the monitoring station during the calendar year. According to the figures in Table 5, Portland was out of compliance with this standard at both stations for almost every year between 1970 and 1979. Both stations were in compliance in 1975 and the Burnside station was again in compliance in 1977.

Photochemical Oxidants (Ozone)

Photochemical oxidants are a group of oxygen-bearing compounds that are created by photochemical reaction. Ozone, the oxidant of major concern, is a colorless, pungent gas. Photochemical oxidants are not emitted directly into the atmosphere. They are created when the ultraviolet light energy of the sun is absorbed by nitrogen dioxide in the presence of hydrocarbons. Since strong sunlight is a necessary prerequisite to the formation of ozone, this pollution problem is largely confined to the hot summer months of July, August and September (2).

Motor vehicles are largely responsible for the ozone problem in Portland. Ozone is created by the combination of hydrocarbons, nitrogen dioxide and sunlight. Both hydrocarbons and oxides of nitrogen are byproducts of fossil fuel combustion. Approximately 67 percent of the hydrocarbons and 80 percent of the oxides of nitrogen are created by motor vehicles in Portland and the surrounding area.

Despite the close connection with motor vehicles, the highest concentrations of ozone are not located near the congested roadways or downtown Portland or near the freeways. The photochemical process that creates ozone takes several hours. This gives Portland's prevailing summer winds from the north a chance to blow the pollution from its origin to the south. Hence, the highest concentrations of ozone in the Portland area are near the settlements of Canby and Molalla, several miles south of Portland.

Since ozone problems created in the Portland region impact most severely those areas south of the City, downtown monitoring was carried out only from 1974 to mid-1979. The ozone summary for this period recorded at the downtown monitoring station is shown in Table 6.

TABLE 6

OZONE SUMMARY (ug/m^3)*
PORTLAND DOWNTOWN AREA
1974-1979

MONITORING STATION	YEAR	1 HOUR AVERAGES MAXIMUM	2ND HIGHEST	NO. OF DAYS GREATER THAN: 160 ug/m^3	235 ug/m^3
718 W. Burnside	1974	127	-	0	0
(CAMS)	1975	206	147	1	0
	1976	204	196	3	0
Discontinued 6/79	1977	184	165	2	0
	1978	227	208	4	0
	1979	133	123	0	0

*ug/m^3 = micrograms per cubic meter.

STANDARD:	Averaging Time	Federal Primary	Federal Secondary	Oregon
	1 hour	235 ug/m^3**	235 ug/m^3**	160 ug/m^3**

**A statistical standard, but basically not to be exceeded more than an average one day per year based on the most recent three years of data.

Source: Oregon Air Quality Report 1980, DEQ

The number of days per year in excess of the one-hour state standard of 160 ug/m^3 increased during the five-year period from one day in 1974 to four days in 1978. There were no days in excess of the state standard recorded in 1979. Monitoring during that year, however, ceased in June, 1979 prior to the summer months during which ozone levels are the worst. Ozone levels never exceeded the more lenient federal standard of 235 ug/m^3 during the six-year period.

Ozone concentrations decreased at the Canby monitoring station from 1975 to 1980. The DEQ suggests that more data is needed to be sure the trend is meaningful and not simply the result of recent meteorological behavior. Some reduction in ozone levels was predicted, however, in the Canby area during the latter 1970's due to federal and state motor vehicle emission control programs (3).

Hydrocarbons

Hydrocarbons are a large family of compounds containing hydrogen and carbon in various combinations. Some are gaseous, some liquid, some solid. There are, in fact, over a thousand different hydrocarbons compounds. The hydrocarbons that are involved in the creation of air pollution are termed "volatile organic combounds" (VOC) and are defined as those organic compounds that evaporate rapidly at room temperature.

Hydrocarbons, like carbon monoxide, are created by the incomplete combustion of gasoline in motor vehicle engines. They are also to a great extent created from vapors escaping the gasoline tank, the carburetor or the crank case (2).

Hydrocarbons by themselves pose no air pollution problem nor health hazards; their major impact on air quality is their role in the production of photochemical oxidants (ozone). One of the most effective ways to control ozone is through the reduction of hydrocarbons. The primary purpose of monitoring hydrocarbons is to collect more thorough data on ozone. The DEQ monitors total hydrocarbons which are not comparable to nonmethane hydrocarbons to which the state and federal standards in Table 1 apply.

Oxides of Nitrogen

Nitrogen itself is a colorless, odorless, tasteless gas that constitutes a little less than 80 percent of the atmosphere. At high temperatures it can combine with oxygen in the air to form several different gaseous compounds known collectively as oxides of nitrogen. Nitric oxide and nitrogen dioxide are the two most important. The latter, a brownish gas, is highly poisonous.

Both nitric oxide and nitrogen dioxide are formed when combustion temperatures exceed about 2,000^{o}F. The motor vehicle engine is the largest single source of these compounds, though nitrogen dioxide is also generated by natural sources (2). State and federal standards apply only to nitrogen dioxide, primarily because nitric oxide very quickly turns into nitrogen dioxide. Like hydrocarbons, a major importance of nitrogen oxide is the role it plays in the formation of ozone, which does violate federal standards in Portland. Unlike hydrocarbons, nitrogen oxide by itself degrades air quality and poses a health hazard.

The monitoring summary of concentrations of nitrogen dioxide in the downtown area is shown in Table 7. The Oregon and federal air quality standard for this pollutant is an annual arithmetic average of 100 ug/m^3. The average never exceeded the standard between 1970 and 1980, and actually fluctuated by no clear pattern of increase or decrease during the eleven year period. The annual arithmetic average for 1980 was almost the same as in 1970. The downtown Portland area is clearly in compliance with federal and state standards.

TABLE 7

NITROGEN OXIDE SUMMARY (ug/m^3)*
PORTLAND DOWNTOWN AREA
1970-1980

MONITORING STATION	YEAR	ANNUAL ARITHMETIC AVERAGE	MAXIMUM 1 HOUR AVERAGE
718 W. Burnside	1970	53.0	451
(CAMS)	1971	46.6	244
	1972	46.7	357
	1973	54.5	301
	1974	46.4	357
	1975	49.8	206
	1976	60.7	357
	1977	66.6	395
	1978	40.2	282
	1979	64.7	508
	1980	52.0	301

*ug/m^3 = micrograms per cubic meter

STANDARD:	Averaging Time	Federal Primary	Federal Secondary	Oregon
(Nitrogen Dioxide)	Annual Arithmetic Average	100 ug/m^3	100 ug/m^3	100 ug/m^3

Source: Oregon Air Quality Report 1980, DEQ

Lead

Lead is a soft gray metal that is relatively abundant in the earth's crust. It is also present in food, water, soil, dustfall, paint, air and other materials with which the general public commonly comes in contact.

Lead in the atmosphere appears primarily in the form of organic particulates emitted from automobiles using leaded gas. There are some stationary sources of lead emissions, including lead smelting operations and iron and steel manufacturing plants, but these account for little more than ten percent of the problem. The major source is leaded gasoline (2).

Portland is currently in compliance with federal and state standards for lead. The lead monitoring summary for 1973 to

1980 from two downtown stations is shown in Table 8. Lead is not directly monitored. Lead particles are isolated from total suspended particulate samples.

TABLE 8

LEAD SUMMARY (ug/m^3)*
PORTLAND DOWNTOWN AREA
1973-1980

MONITORING STATIONS (Sites are the same as particulate sites)	YEAR	NO. OF VIOLATIONS (Quarter in which violation occurred)	MAXIMUM CONCENTRATION IN A CALENDAR QUARTER
718 W. Burnside	1973	2(1,4)	2.19
(CAMS)	1974	1(4)	1.74
Partial data in 1977	1975	0	1.08
	1976	1(4)	1.63
	1977	0	0.59
	1978	0	1.18
	1979	0	0.82
	1980	0	0.67
55 SW Ash	1973	0	1.18
(Central Fire Station)	1974	1(4)	1.62
Partial data in 1973 and 1978	1975	0	0.91
	1976	1(4)	1.57
	1977	0	1.29
	1978	0	0.84
	1979	0	0.89
	1980	0	0.82

*ug/m^3 = micrograms per cubic meter

STANDARD: Averaging Time	Federal Primary	Federal Secondary	Oregon
Monthly	-	-	3 ug/m^3
Calendar Quarter	1.5 ug/m^3	1.5 ug/m^3	-

Source: Oregon Air Quality Report 1980, DEQ

Compliance with the federal primary and secondary standard of 1.5 ug/m^3 is based on a calendar quarter average concentration of the pollutant. Lead concentrations exceeded this standard in 1973, 1974 and 1976, but remained in compliance in the downtown area between 1976 and 1980.

Oxides of Sulfur

Sulfur is a non-metallic element found in coal, oil and some ores. When these materials are burned, usually as fuel, the sulfur contained in them is converted to sulfur dioxide and sulfur trioxide. These are nonflammable, pungent gases, both of which combine easily with water vapors to become sulfuric acid.

Nationwide, two-thirds of all sulfur oxide emissions come from coal or oil-fired electricity generating plants. Other sources of this type of pollution include the burning of distillate and residual oil as a home heating fuel and in industrial processes.

Of the sulfur oxides, air quality standards apply only to sulfur dioxide. Of the seven major pollutants, only sulfur dioxide is not primarily caused by autos or other transportation-related sources. Most of the Portland area sulfur dioxide emissions are a product of industrial operations and the combustion fuels such as heating oil. Portland does not currently violate federal standards for these pollutants (2).

The sulfur dioxide summary for 1970 to 1980 is presented in Table 9. The federal primary standard is the annual arithmetic average of 80 ug/m^3. The Oregon state standard is the more stringent arithmetic average of 60 ug/m^3. The downtown Portland area was clearly in compliance with both standards every year during the eleven year monitoring period, and concentrations of the pollutant steadily declined between 1973 and 1980.

TABLE 9

SULFUR DIOXIDE SUMMARY (ug/m^3)*
PORTLAND DOWNTOWN AREA
1970-1980

MONITORING STATION	YEAR	NUMBER OF SAMPLES	24 HOUR MAXIMUM	ANNUAL ARITHMETIC AVERAGE
718 W. Burnside	1970	8350	193	33.6
(CAMS)	1971	8162	226	37.1
	1972	8217	185	39.8
	1973	8364	210	33.0
	1974	8030	144	32.6
	1975	5968	124	14.4**
	1976	7216	200	21.2
	1977	8013	217	20.4
	1978	7991	85	13.0
	1979	8309	215	16.4
	1980	8078	99	16.5

*ug/m^3 = micrograms per cubic meter

**Does not include June, July, December

STANDARD:	Averaging Time	Federal Primary	Federal Secondary	Oregon
	Annual Arithmetic Average	80 ug/m^3	-	60 ug/m^3
	24 hours***	365 ug/m^3	-	260 ug/m^3
	3 hours***	-	1300 ug/m^3	1300 ug/m^3

***Not to be exceeded on more than one day per year

Source: Oregon Air Quality Report 1980, DEQ.

SECTION III
METHODOLOGY FOR EMISSION DENSITY ANALYSIS

The foregoing section describes general trends in the concentrations of the seven major air pollutants in the downtown Portland area between 1970 and 1980. It is assumed that the Transit Mall has contributed to the trends of most of these pollutants since it began operating in 1978. However, sufficient monitoring data are not currently available to determine the specific contributions of the Mall. Therefore, an emission density analysis of 1980 with-Mall traffic conditions versus 1980 without-Mall traffic conditions was conducted for four of these pollutants to determine what effect the Mall has had on each of them within a defined downtown study area. The four pollutants involved in the analysis are hydrocarbons, carbon monoxide, nitrogen oxides and suspended particulate. The remaining three major pollutants are excluded from the analysis because emission factors were not available for them.

An emission density is the mathematically calculated amount of a pollutant within a specific area. While the pollutants can actually be emitted by numerous sources, the pollutants involved in this analysis are emitted primarily by motor vehicles in the downtown area, as described in Section II. The major inputs to the calculations are traffic volumes, speeds and pollutant emission factors by type of motor vehicle. These inputs are different for 1980 with-Mall conditions than for 1980 without-Mall conditions. Data for the with-Mall and without-Mall conditions were provided in the Traffic Effects Analysis report also prepared for the Portland Transit Mall Impact Study (13). The DEQ provided emission factor data.

STUDY AREA

The study area used for the Air Quality Impacts analysis extends east-west from SW Fourth Avenue to SW Broadway and north-south from W. Burnside to SW Madison Street, as shown in Figure 4. This area includes the streets which underwent the greatest changes in traffic circulation as a result of the Transit Mall (1, 13), but does not include all impacted streets. Traffic was diverted from SW Fifth and SW Sixth Avenues to streets throughout the downtown. The study area does not include all impacted streets, but is centrally located within the broader impacted area. The results of the emission density analysis cannot be applied literally throughout the downtown, but they are indications of the effects of the Mall on pollutant emissions in the whole downtown area.

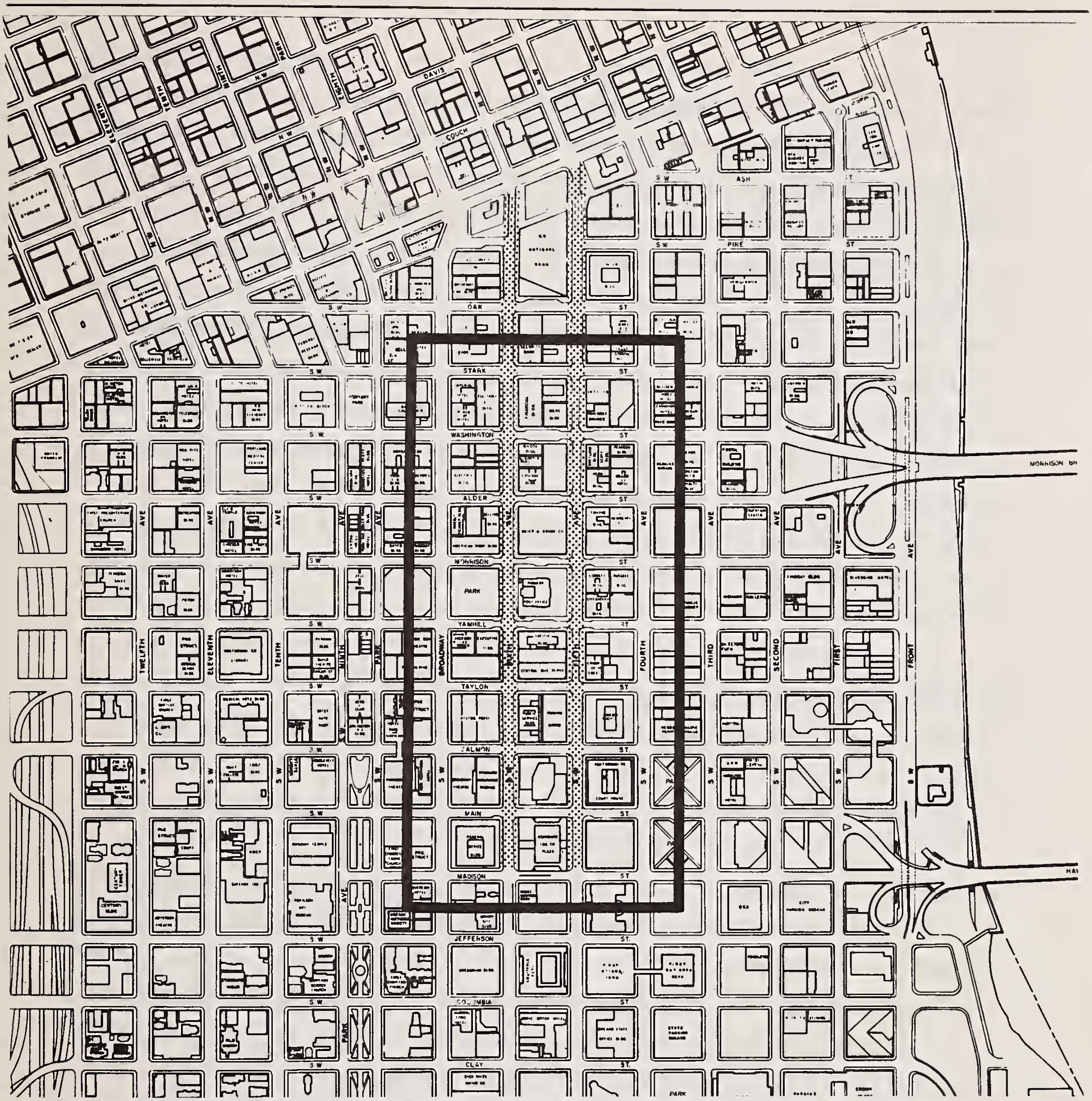
EMISSION DENSITY

An emission density is the amount of pollution within a given area. An emission density is usually expressed in terms of pollutant weight produced over an established period of time within the given area. It should not be confused with a concentration which is the amount of pollutant per volume of air. Air quality standards and DEQ monitoring of air pollutants are usually in concentrations. An emission density involves no monitoring of actual levels of pollutants.

EMISSION DENSITY CALCULATIONS

Emission density calculations were used to estimate impacts of the Transit Mall on air quality based on the assumption that pollution concentration is proportional to emissions.

FIGURE 4



STUDY AREA FOR EMISSION DENSITY ANALYSIS

TRANSIT MALL

STUDY AREA

600'

Generally, the higher the emissions, the higher the pollution levels. The assumption must be applied carefully. One cannot necessarily conclude that concentrations at a certain receptor on a link are reduced because the emissions on that one link are reduced. Other emissions in the vicinity of the link must also be considered since they can easily be transported to the receptor where they influence the concentration levels of the pollutant being monitored. However, increases or decreases in emissions within an area including several links can be assumed to indicate parallel increases or decreases in pollution concentration levels within the same area (8). The emissions on no fewer than the eight links comprising each of the four north-south streets in the study area were added for the discussion of findings in Section IV.

Formula For Calculations

Emissions for each pollutant were calculated for a single street link (intersection to intersection) by using the following formula:

$$E = V \times Dist \times EF$$

where: E = Emissions of pollutants in grams (converted to kilograms for this analysis; 1000 grams = 1 kilogram).

V = The 24 hour average volume of vehicles on the link.

Dist = The length of the link in miles.

EF = The emission factor for the pollutant in grams/vehicle mile.

The emission density of an area is simply the sum of the emissions on all links in the area (8).

Vehicle Volumes

The 24 hour average bus and non-bus vehicle* volumes for each link in the study area were obtained for both 1980 with-Mall and without-Mall conditions from the Traffic Effects Analysis report (13). The 1980 with-Mall volumes were modelled on the basis of actual traffic counts. The 1980 without-Mall volumes were modelled on the basis of before-Mall traffic circulation patterns, actual traffic counts and projected volumes without the Mall (13). The with-Mall and without-Mall 24 hour average bus, non-bus and total vehicle volumes for each street in the study area are presented in Table 10.

As shown in the Table, under with-Mall conditions, SW Fifth and Sixth Avenues handle all north-south bus traffic and only minimal non-bus traffic compared to all other streets in the study area. SW Fourth Avenue and SW Broadway, on the other hand, handle no bus traffic but carry significantly more non-bus traffic than any of the other streets.

Under without-Mall conditions, traffic composition changes dramatically as the model allocates significant volumes of non-bus traffic onto SW Fifth and Sixth Avenues and distributes bus traffic onto numerous other streets in the study area. Under these conditions, all four north-south streets carry mixed bus and non-bus traffic, but SW Fourth and Fifth Avenues are the primary north-south bus routes. Each of these two streets handles about half the volume of bus traffic that would be handled by SW Fifth and Sixth Avenues with the Mall, but their volumes still exceed any experienced by other streets in the study area.

Therefore, without the Mall, bus volumes increase on SW Fourth Avenue and SW Broadway and decrease on SW Fifth and

*Non-bus vehicles in the downtown area include automobiles, light duty trucks and heavy duty gasoline trucks.

TABLE 10

24 HOUR AVERAGE BUS
AND NON-BUS VEHICLE VOLUMES
WITH-MALL AND WITHOUT-MALL
1980

NORTH-SOUTH STREETS	WITH-MALL			WITHOUT-MALL		
	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL
SW Fourth Ave.	0	13,960	13,960	709	11,559	12,268
SW Fifth Ave.	1,416	797	2,213	885	9,481	10,366
SW Sixth Ave.	1,365	152	1,517	363	10,812	11,175
SW Broadway	0	14,262	14,262	288	10,972	11,260
EAST-WEST STREETS						
SW Stark St.	0	5,933	5,933	228	4,014	4,242
SW Washington St.	0	6,312	6,312	201	8,722	8,923
SW Alder St.	0	8,018	8,018	166	10,360	10,526
SW Morrison St.	152	5,556	5,708	176	3,765	3,941
SW Yamhill St.	239	6,774	7,013	145	7,068	7,213
SW Taylor St.	0	8,259	8,259	332	6,065	14,324
SW Salmon St.	0	5,093	5,093	128	5,236	5,364
SW Main St.	0	9,807	9,807	408	7,532	7,940
SW Madison St.	478	4,031	4,509	277	4,006	4,283

Sixth Avenues. Simultaneously, non-bus volumes decrease on SW Fourth and Broadway and increase dramatically on SW Fifth and Sixth Avenues. Total 24 hour average traffic (bus and non-bus) volumes decrease by 1692 vehicles on SW Fourth Avenue and by 3002 vehicles on SW Broadway, and increase by 8153 vehicles on SW Fifth Avenue and by 9658 vehicles on SW Sixth Avenue. Strictly in terms of total traffic volumes, SW Sixth Avenue experiences the greatest impact under without-Mall conditions and SW Fifth the second greatest impact. Because SW Fifth Avenue is a primary north-south bus route under both with and without-Mall conditions, the traffic and related pollution emission results under without-Mall conditions are generally a little less pronounced on SW Fifth than on SW Sixth Avenue.

Distance

The length of each street link in the study area was provided in the Downtown Parking and Circulation Study, prepared for the City of Portland in 1980 (6). Most of the north-south links are 260 feet (.049 mile) long; the others are 265 feet (.05 mile) in length. All of the east-west links are 280 feet (.053 mile) long.

Emission Factors

The 1980 emission factors for each pollutant under both with-Mall and without-Mall conditions were provided by DEQ and are shown in Table 11. They were calculated for all pollutants except particulate on the basis of vehicle type, year of manufacture and speed on the link. Emission factors were calculated separately for buses and non-bus vehicles using EPA's MOBILE 2 emission factor program. This program requires age distribution and mileage accumulations (miles driven/year) for all vehicles 20 years old or newer. Tri-Met supplied the registration and mileage accumulation information for their bus fleet. The information for the non-bus vehicles (automobiles, light duty trucks, and heavy duty gasoline trucks) was obtained from several sources. The registration information for automobiles was obtained from the Motor Vehicles Division of Oregon's Department of Transportation. National default values published by EPA were used for the age distributions for the other vehicle types and for all of the non-bus mileage input.

Another input required by MOBILE 2 is the amount of vehicle miles travelled (V x Dist) in the hot and cold start modes. These were estimated from information generated about downtown traffic in the Downtown Parking and Circulation Study (6, 8).

Emission factors were calculated for buses at 5 mph under with-Mall conditions and interpolated for buses at 3.5 mph under without-Mall conditions. Factors were calculated for

TABLE 11

EMISSION FACTORS* FOR EMISSION DENSITY ANALYSIS 1980

POLLUTANT	WITH-MALL BUS @ 5 mph	WITH-MALL NON-BUS @ 15 mph	WITHOUT-MALL BUS @ 3.5 mph	WITHOUT-MALL NON-BUS @ 15 mph
Hydrocarbons	6.6	3.8	7.4	3.8
Carbon Monoxide	29.5	71.0	34.0	71.0
Nitrogen Oxides	36.4	3.2	40.4	3.2

	WITH AND WITHOUT-MALL BUS	WITH AND WITHOUT-MALL NON-BUS
Suspended Particulate (Tailpipe)	1.3	0.2

*grams/vehicle mile

non-bus vehicles at 15 mph under both with-Mall and without-Mall conditions, and weighted as follows for a single non-bus emission factor for each pollutant:

Non-Bus Vehicle Type	%
Automobiles	86.3
Light Duty Trucks	9.7
Heavy Duty Gas Trucks	4.0

EPA's MOBILE 2 emission factor program does not include suspended particulate. Emission factors for particulate (tailpipe only for this analysis) were calculated using the older EPA MOBILE 1 program. While tailpipe particulate emissions are speed related, MOBILE 1 does not include the speed variable. Therefore, the tailpipe particulate emission factor is different for bus and non-bus vehicles but the same for buses at both 5 mph and 3.5 mph (8).

Sum of Emissions

The emissions on links comprising each street in the study area were summed for with-Mall and without-Mall conditions, for each of the four pollutants and for the entire study area. The results are presented in Table 12 for with-Mall conditions and in Table 13 for without-Mall conditions. The results are actually the emission densities of the north-south streets and the entire study area. The three block length of the east-west streets was considered insufficient area to constitute an emission density for analysis purposes.

Using with-Mall conditions as the base, without-Mall emissions were subtracted from with-Mall emissions to determine the numerical differences in emissions for each pollutant had the Mall not been constructed. The results of this exercise are presented in Table 14. Finally, the numerical differences were translated into percentage differences without the Mall.

TABLE 12

SUM OF POLLUTANT EMISSIONS*
WITH-MALL
1980

NORTH-SOUTH STREETS	POLLUTANTS											
	HYDROCARBONS			CARBON MONOXIDE			NITROGEN OXIDES			TAILPIPE PARTICULATE		
	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL
4th	0	20.7	20.7	0	387.1	387.1	0	17.4	17.4	0	1.1	1.1
5th	3.7	1.1	4.8	16.7	21.1	37.8	20.6	1.0	21.6	.7	.1	.8
6th	3.6	.2	3.8	16.0	4.5	20.5	19.7	.2	19.9	.7	0	.7
Broadway	0	21.1	21.1	0	394.4	394.4	0	17.8	17.8	0	1.1	1.1
EAST-WEST STREETS												
Stark	0	3.6	3.6	0	67.0	67.0	0	3.0	3.0	0	.2	.2
Washington	0	3.8	3.8	0	71.3	71.3	0	3.2	3.2	0	.2	.2
Alder	0	4.8	4.8	0	90.5	90.5	0	4.1	4.1	0	.3	.3
Morrison	.2	3.4	3.6	.7	62.7	63.4	.9	2.8	3.7	0	.2	.2
Yamhill	.3	4.1	4.4	1.1	76.5	77.6	1.4	3.4	4.8	.1	.2	.3
Taylor	0	5.0	5.0	0	93.2	93.2	0	4.2	4.2	0	.3	.3
Salmon	0	3.1	3.1	0	57.5	57.5	0	2.6	2.6	0	.2	.2
Main	0	5.9	5.9	0	110.7	110.7	0	4.9	4.9	0	.3	.3
Madison	.5	2.4	2.9	2.2	45.5	47.7	2.8	2.1	4.9	.1	.1	.2
Study Area	8.3	79.2	87.5	36.7	1482.0	1518.7	45.4	66.7	112.1	1.6	4.3	5.9

*Expressed in kilograms/vehicle mile.

TABLE 13

SUM OF POLLUTANT EMISSIONS*
WITHOUT-MALL
1980

NORTH-SOUTH STREETS	POLLUTANTS											
	HYDROCARBONS			CARBON MONOXIDE			NITROGEN OXIDES			TAILPIPE PARTICULATE		
	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL
4th	2.1	17.1	19.2	9.5	319.9	329.4	11.3	14.4	25.7	.4	.9	1.3
5th	2.6	14.1	16.7	11.8	262.8	274.6	14.0	11.8	25.8	.5	.7	1.2
6th	1.1	16.3	17.4	4.9	304.2	309.1	5.8	13.7	19.5	.2	.9	1.1
Broadway	.8	16.3	17.1	3.9	305.2	309.1	4.6	13.7	18.3	.1	.9	1.0
EAST-WEST STREETS												
Stark	.3	2.4	2.7	1.2	45.3	46.5	1.5	2.0	3.5	.1	.1	.2
Washington	.2	5.3	5.5	1.1	98.5	99.6	1.3	4.4	5.7	0	.3	.3
Alder	.2	6.3	6.5	.9	116.9	117.8	1.1	5.3	6.4	0	.3	.3
Morrison	.2	2.3	2.5	1.0	42.5	43.5	1.1	1.9	3.0	0	.1	.1
Yamhill	.2	4.3	4.5	.8	79.8	80.6	.9	3.6	4.5	0	.2	.2
Taylor	.4	3.7	4.1	1.8	68.5	70.3	2.1	3.1	5.2	.1	.2	.3
Salmon	.2	3.2	3.4	.7	59.1	59.8	.8	2.7	3.5	0	.2	.2
Main	.5	4.6	5.1	2.2	85.0	87.2	2.6	3.8	6.4	.1	.2	.3
Madison	.3	2.4	2.7	1.5	45.2	46.7	1.8	2.0	3.8	.1	.1	.2
Study Area	9.1	98.3	107.4	41.3	1832.9	1874.2	48.9	82.4	131.3	1.6	5.1	6.7

*Expressed in kilograms/vehicle mile

TABLE 14

NUMERICAL DIFFERENCE IN POLLUTANT EMISSIONS*
BETWEEN WITH-MALL AND WITHOUT-MALL CONDITIONS
1980

	POLLUTANTS												
	HYDROCARBONS			CARBON MONOXIDE			NITROGEN OXIDES			TAILPIPE PARTICULATE			
NORTH-SOUTH STREETS	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS	NON-BUS	TOTAL	BUS
4th	2.1	- 3.6	- 1.5	9.5	- 67.2	-57.7	11.3	- 3	8.3	.4	- .2	.2	.5
5th	-1.1	13	11.9	-4.9	241.7	236.8	-6.6	10.8	4.2	-.2	.6	.4	-.4
6th	-2.5	16.1	13.6	-11.1	299.7	288.6	-13.9	13.5	- .4	-.5	.9	.4	-.7
Broadway	.8	- 4.8	- 4	3.9	-89.2	-85.3	4.6	-4.1	.5	.1	-.2	-.1	.2
EAST-WEST STREETS													
Stark	.3	- 1.2	-.9	1.2	-21.7	-20.5	1.5	-1	.5	.1	-.1	0	.1
Washington	.2	1.5	1.7	1.1	27.2	28.3	1.3	1.2	2.5	0	.1	.1	.1
Alder	.2	1.5	1.7	.9	26.4	27.3	1.1	1.2	2.3	0	0	0	0
Morrison	0	-1.1	-1.1	.3	-20.2	-19.9	.2	- .9	-.7	0	-.1	-.1	.1
Yamhill	-.1	.2	.1	-.3	3.3	3.0	-.5	.2	-.3	-.1	0	-.1	-.1
Taylor	.4	-1.3	- .9	1.8	-24.7	-22.9	2.1	-1.1	1.0	.1	-.1	0	.1
Salmon	.2	.1	.3	.7	1.6	2.3	.8	.1	.9	0	0	0	0
Main	.5	-1.3	- .8	2.2	-25.7	-23.5	2.6	-1.1	1.5	.1	-.1	0	.1
Madison	-.2	0	- .2	-.7	- .3	- 1.0	-1.0	- .1	-1.1	0	0	0	0
Study Area	.8	19.1	19.9	4.6	350.9	355.5	3.5	15.7	19.2	0	.8	.8	0

*Expressed in kilograms/vehicle mile

Percentages are presented on Table 15. The discussion of findings in Section IV is based on this table. The positive or negative signs in front of the numerical and percentage differences indicate whether the pollutant emissions increase or decrease, respectively, under without-Mall conditions. Generally, findings are discussed in terms of without-Mall conditions.

TABLE 15

PERCENTAGE DIFFERENCE IN POLLUTANT EMISSIONS*
BETWEEN WITH-MALL AND WITHOUT-MALL CONDITIONS
1980

NORTH-SOUTH STREETS	HYDROCARBONS BUS	HYDROCARBONS NON-BUS	HYDROCARBONS TOTAL	CARBON MONOXIDE BUS	CARBON MONOXIDE NON-BUS	CARBON MONOXIDE TOTAL	NITROGEN OXIDES BUS	NITROGEN OXIDES NON-BUS	NITROGEN OXIDES TOTAL	TAILPIPE PARTICULATE BUS	TAILPIPE PARTICULATE NON-BUS	TAILPIPE PARTICULATE TOTAL
4th	+	-17	- 7	+	-17	- 15	+	- 17	48	+	- 18	18
5th	-30	1181	248	-29	1145	626	-32	108	19	-29	600	50
6th	-69	805	358	-69	6666	1408	-71	6750	- 2	-71	+	57
Broadway	+	-23	-19	+	-23	-22	+	-23	3	+	-18	- 9
EAST-WEST STREETS												
Stark	+	-33	-25	+	-32	-31	+	-33	17	+	-50	0
Washington	+	39	45	+	38	40	+	38	78	0	50	50
Alder	+	31	35	+	29	30	+	29	56	0	0	0
Morrison	0	-32	-31	43	-32	-23	22	-32	-19	0	-50	-50
Yamhill	-33	5	2	-27	4	4	-36	6	- 6	-100	0	-33
Taylor	+	-26	-18	+	-27	-25	+	-26	24	+	-33	0
Salmon	+	3	10	+	3	4	+	4	35	0	0	0
Main	+	-22	-14	+	-23	-21	+	-22	31	+	-33	0
Madison	-40	0	- 7	- 32	-.7	- 2	-36	- 5	-22	0	0	0
Study Area	10%	24%	23%	13%	24%	23%	8%	24%	17%	0%	19%	14%

*Expressed in kilograms/vehicle mile

SECTION IV
FINDINGS

Section IV presents the results of the emission density analysis, generally in terms of without-Mall conditions. The emission densities of the four pollutants without the Mall apply to the study area but cannot be applied literally throughout the downtown. The study area includes the streets which underwent the greatest changes in traffic circulation as a result of the Mall, but does not include all impacted streets. Traffic was diverted from SW Fifth and SW Sixth Avenues to streets throughout the downtown. While the study area does not include all impacted streets, it is centrally located within the broader impacted area. Therefore, the results of the emission density analysis are indicators of the effects of the Mall on pollutant emissions in the whole downtown area.

The findings of the emission density analysis indicate that the Transit Mall has resulted in overall reductions in the vehicular emissions of four pollutants in the central downtown area. Had the Mall not been constructed, total emissions of each of the four pollutants analyzed for this report would have been higher within the study area and probably in the whole downtown area in 1980.

Buses and non-bus vehicles emit different quantities of each pollutant. Therefore, the positive effect of the Mall is not uniform on all streets in the study area because of the variations in bus and non-bus vehicular mix. Some streets have actually been negatively impacted by the Mall for certain pollutants and positively impacted for other pollutants.

The greatest impacts have been on the Mall streets, SW Fifth and SW Sixth Avenues. The emissions of all pollutants except nitrogen oxides would increase by at least 50 percent, and in most cases by over 100 percent, on these two streets without the Mall. Nitrogen oxide emissions would increase by only 12 percent on SW Fifth Avenue and actually decrease 2 percent on SW Sixth Avenue without the Mall. The high nitrogen oxide levels with the Mall can be explained by the fact that the emission rate is far greater for buses than for automobiles, as shown in Table 11. Therefore, SW Fifth and Sixth Avenues would be expected to have relatively high emissions of nitrogen oxides with the Mall.

In the study area, total hydrocarbon and carbon monoxide emissions both increase 23 percent without the Mall, nitrogen oxides increase 17 percent, and tailpipe particulates increase 14 percent. While these percentages cannot be literally applied throughout the downtown area, they are clear indications that the mall has contributed toward overall reductions in these pollutant emissions. Individual discussions of the effects of the Transit Mall on each of the four pollutants follow.

HYDROCARBONS

Had the Transit Mall not been constructed, total hydrocarbon emissions in the study area would be 23 percent higher than under present 1980 with-Mall conditions. Generally, the Mall has had a positive effect on hydrocarbon emission levels on those streets in the study area which experienced lower total traffic volumes as a result of its construction. Conversely, the effect has been negative on those streets which experienced higher total traffic volumes with the Mall.

The Mall has resulted in the greatest reductions in hydrocarbon emissions on SW Fifth and SW Sixth Avenues. Without the Mall, emissions increase almost 250 percent on SW Fifth and almost 360 percent on SW Sixth. Emissions would decrease seven percent on SW Fourth Avenue and 19 percent on SW Broadway without the Mall. Hence, the Mall has resulted in increased emissions on SW Fourth and Broadway.

CARBON MONOXIDE

The Transit Mall has resulted in an overall reduction in carbon monoxide emissions in the study area. Total carbon monoxide emissions are 23 percent higher under without-Mall conditions. On a street by street basis, the effects of the Transit Mall on carbon monoxide emissions follow the same pattern as hydrocarbon emissions. That is, positive and negative effects on individual streets are directly linked to decreases and increases, respectively, in total vehicle volumes on each street without the Mall.

The Mall has resulted in the greatest reductions in carbon monoxide emissions on SW Fifth and SW Sixth Avenues. Without the Mall, emissions increase by over 600 percent on SW Fifth and by over 1400 percent on SW Sixth Avenue. Percentage-wise, these increases in emissions are greater than for any of the other pollutants in the study area under without-Mall conditions. Therefore, of the four pollutants analyzed for this report, the Mall has had the most beneficial impact on carbon monoxide emissions on these two streets.

The Mall has negatively impacted SW Fourth Avenue and SW Broadway. Without the Mall, emissions are 15 percent lower on SW Fourth Avenue and 22 percent lower on SW Broadway than with the Mall. This pattern of positive and negative impacts is explained in large part by the fact that, in general, automobiles emit more carbon monoxide than buses, as shown in Table 11. Without the Mall, the numbers of automobiles using SW Fourth Avenue and SW Broadway decrease significantly while they increase dramatically on the Mall streets, SW Fifth and SW Sixth Avenues.

NITROGEN OXIDES

The Transit Mall has resulted in an overall reduction in nitrogen oxide emissions in the downtown study area. Without the Mall, total emissions are 17 percent greater than with the Mall. The pattern of positive and negative effects on individual streets differs from hydrocarbons and carbon monoxide. Increases and decreases in total nitrogen oxide emissions on individual streets without the Mall are very closely related to changes in bus volumes. The nitrogen oxide emission rate of buses is far greater than automobiles, so that emissions due to a slight change in bus volumes would equal a much greater change in non-bus volumes.

With the Mall, nitrogen oxide emissions have improved somewhat on SW Fifth but have increased on SW Sixth Avenue. Without the Mall, emissions are actually two percent lower on SW Sixth and only 19 percent higher on SW Fifth Avenue. SW Fourth Avenue, however, experiences an almost 50 percent increase in emissions due to the large number of buses which would use that street without the Mall. Emissions on SW Broadway would increase three percent. Again, these differences are due to the greater emission rate of buses than automobiles.

SUSPENDED PARTICULATE (TAILPIPE)

The Transit Mall has resulted in overall reductions in tailpipe particulate emissions in the study area. Without the Mall, total tailpipe particulate emissions would be 14 percent higher. On a street by street basis, emissions would increase at least 50 percent on SW Fifth and SW Sixth Avenues and 18 percent on SW Fourth Avenue. Emissions would decrease only on SW Broadway under without-Mall conditions. The emission rate of buses is significantly higher than automobiles. Under without-Mall conditions, SW Broadway would handle fewer buses than the other north-south routes. Hence, the reduction of tailpipe particulate emissions on this street.

SECTION V

SUMMARY OF FINDINGS

Following are the most important findings of the Air Quality Impacts analysis. These findings apply to the study area only, but are indications of the probable impacts of the Mall throughout the downtown area.

- The Transit Mall has resulted in overall reductions in air pollutant emissions in the downtown study area of hydrocarbons, carbon monoxide, nitrogen oxides and suspended particulate (tailpipe). Hydrocarbon and carbon monoxide emissions both increase by 23 percent under without-Mall conditions, nitrogen oxides by 17 percent and tailpipe particulate by 14 percent.

- The overall positive effect of the Mall on air pollutant emissions is not uniform on all streets throughout the study area. Buses and non-bus vehicles emit different quantities of each pollutant. Therefore, due to variations in bus and non-bus vehicle mix, some streets have actually been negatively impacted by certain pollutants and positively impacted by other pollutants as a result of the Mall.

- Under with-Mall conditions, SW Fifth and SW Sixth Avenues have experienced the greatest reduction in emissions of all pollutants except nitrogen oxides. Without the Mall, emissions on both of these two streets would increase by <u>at least</u> 248 percent for all pollutants except nitrogen oxides.

- The Transit Mall has resulted in a reduction of nitrogen oxide emissions on SW Fifth Avenue, but has increased emissions on SW Sixth. Without the Mall, nitrogen oxide emissions would increase 19 percent on SW Fifth and decrease two percent on SW Sixth Avenue. These effects are due to the far greater nitrogen oxide emission rate of buses relative to automobiles.

- The Transit Mall has increased all pollutant emissions except nitrogen oxides on SW Broadway in the study area. Without the Mall, the emissions of the other three pollutants on this street decrease between nine and 25 percent. SW Broadway is impacted in this way because of the four north-south streets, it is not a major bus route under either with or without-Mall conditions.

- The Transit Mall has negatively impacted SW Fourth Avenue for hydrocarbon and carbon monoxide emissions, and positively impacted this street for nitrogen oxide and tailpipe particulate.

LIST OF REFERENCES

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