THE PORTLAND TRANSIT MALL IMPACT STUDY

NOISE IMPACTS REPORT

BUREAU OF PLANNING
CITY OF PORTLAND, OREGON
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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

▬▬▬ TRANSIT MALL

0 1200'

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. Retial 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 THE NOISE IMPACTS REPORT

The primary purpose of this report is to determine what impacts, if any, the Transit Mall has had on noise levels both on the Mall and on adjacent streets off the Mall. The noise impacts were determined by comparing noise measurements taken before the Mall was constructed to measurements taken after its completion. These comparisons were made in anticipation of being able to detect consistent patterns of change in noise levels after the Mall was built.

Noise in downtown Portland is primarily the result of vehicular traffic sources. Therefore, any changes in noise levels resulting from these comparisons are assumed to be directly related to vehicular traffic noise, and to changes in the composition (particularly bus and non-bus) of vehicular traffic. The report presents the comparisons and the resulting changes in noise levels, but does not analyze traffic counts or patterns as a means of explaining these changes.

A secondary purpose of this report is to discuss the significance of the noise levels in downtown Portland with the Transit Mall. These noise levels accurately predict the noise impacts which a transit mall similar to the Portland Transit Mall will have in any city, particularly in a downtown area.

The report is composed of seven sections. Section I introduces the problem of noise, particularly urban noise, and the measurement and description of noise. Section II briefly discusses three separate sets of noise standards which are relevant to the Portland Transit Mall. Section III outlines the three sources of before-Mall and after-Mall noise measurements, and Section IV presents each of nine noise comparisons made for this study. Section V presents the findings of the noise comparisons, and Section VI concludes the text of the report. Section VII is the Appendix which describes in detail noise measurement data sources which are outlined in Section III.

SECTION I
ABOUT NOISE

Section I introduces the problem of noise, particularly urban noise, and the measurement and description of noise.

Noise is usually defined as unwanted or annoying sound. Urban noise is the background or residual level* of sound in which urban dwellers carry on their daily activities. It is the accumulation of all natural and human-made sounds in the urban environment, from wind in the trees to automobile traffic to operating construction equipment.

NOISE POLLUTION

Noise, especially urban noise, has become recognized as a major environmental pollution problem (14). Like other forms of pollution, noise is directly related to increasing technological developments. Noise as pollution is more prevalent in urban areas where there are greater concentrations of people and therefore more numerous applications of these technological developments.

Characteristics of Urban Noise

Several characteristics of urban noise have contributed to its recognition as a serious pollution problem (15). First, noise is pervasive. The chance of gaining refuge from noise in the urban environment is disappearing rapidly. Jet aircraft, vehicular traffic and building construction noises

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*"Background" or "residual noise level" refers to the total of all noise at a point which results from the combination of sounds from many individually indistinguishable sources. Often referred to as "ambient noise level" (1).

characterize the urban outdoors and influence indoor noise environments as well. Homes are subject to noises of more and more conveniences such as heating and air-conditioning systems, dishwashers and stereo sound systems. Noise has long been associated with factory work, but is now an increasing problem in contemporary office environments. Open space office design with partitions rather than walls and with large glass windows results in increasing noise reflection rather than absorption. Office equipment such as copy machines, word processing machinery, telephones and paging systems contribute to increasing noise levels* in the typical office environment.

Secondly, noise sources are multiplying rapidly. The industrial and technological development of urban society is producing an increasing number of devices with higher accumulated noise outputs. Aircraft, automobiles, trucks, motorcycles, construction equipment, household appliances, lawnmowers and air conditioners all contribute to the noise environment. Furthermore, noise pollution increases in proportion to population density, and the number of people who use noise products is increasing.

Thirdly, background noise levels are rising. Isolated studies of transportation activity in German cities have concluded that street noise has increased since the mid-1930's. Some contend that noise levels increased by 30 decibels, or one decibel per year, between 1940 and 1970 (15).

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*"Noise level" refers to the weighted sound pressure level as measured by a standard sound level meter and expressed in terms of decibels, symbolized dB (1).

Finally, noise can affect human health in both obvious and insidious ways. Obvious effects are those recognized by people as irritating or as nuisances. These noise effects generally result in interference with thought and speech communication, in sleep disturbance and in general stress.

The insidious effects of noise are not as readily recognized by their victims. Hearing loss is an excellent example. One may permanently lose up to 40 percent of hearing before noticing a loss which a hearing examination will reveal. Noise has also been identified as a contributing factor in certain stress-related diseases, including peptic ulcer and hypertension. Sleep deprivation, which may be aggravated by noise, has been suggested as one explanation for certain behavior disturbances. Noise may also stimulate the onset of auditory hallucinations among particular types of schizophrenic patients (15). The extent of these physiological affects of noise are not known.

Vehicular Traffic Noise

Vehicular traffic is the principal source of urban noise (14). Notice in Table 1 the number of times that vehicles are given or implied (e.g. "busy downtown area") as typical urban noise sources. By comparing the various columns in Table 1, one can get a sense of the relative "noisiness" of certain levels of decibels. For example, steadily flowing freeway traffic will emit noise levels between 80 and 90 decibels, similar to the sounds of a home garbage disposal. This noise range is considered too loud for satisfactory telephone use. A passenger car going 65 mph will emit a peak noise level* between 70 and 80 decibels from a distance of 25 feet. This same noise

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*"Peak noise level" refers to the maximum instantaneous sound pressure for a transient or impulsive sound of short duration (1).

TABLE 1

COMPARATIVE NOISE LEVELS AND NOISE EFFECTS

NOISE RANGE dBA*	PERCEPTION AND EFFECTS	TYPICAL URBAN NOISE SOURCES	INDUSTRY AND HOME NOISE SOURCES	LOUDNESS - SUBJECTIVE JUDGEMENT OF NOISE*
130-140	Near permanent damage level from short exposures.	Military jet takeoff from carrier (50 ft).	Hydraulic press (3 ft).	135 dBA - 64 times as loud as 75 dBA
120-130	Painful to ears.	Turbo-fan jet as takeoff power (100 ft).	Oxygen torch. Boiler shop.	125 dBA - 32 times as loud as 75 dBA
110-120	Uncomfortably loud.	Rock and roll band. Unmuffled cycle (2-3 ft).	Scraper-loader. Riveting machine.	115 dBA - 16 times as loud as 75 dBA
100-110	Discomfort threshold.	Jet fly over (1,000 ft). Unmuffled cycle (25 ft).	Textile loom. Noisy newspaper press.	105 dBA - 8 times as loud as 75 dBA
90-100	Very loud.	Train whistle (500 ft). Diesel truck (25 ft).	Air compressor (20 ft). Power lawnmower.	95 dBA - 4 times as loud as 75 dBA
80-90	Intolerable for phone use.	Steady flow-freeway traffic. 10-HP outboard motor.	Garbage disposal. Food Blender.	85 dBA - 2 times as loud as 75 dBA
70-80	Prevention of extra auditory physiological effects.	Passenger car, 65 mph (25 ft). Busy downtown area.	Automatic dishwasher. Vacuum cleaner.	75 dBA
50-60	Quiet.	Large transformer (200 ft).	Window air conditioner in room.	55 dBA - 1/4 as loud as 75 dBA
40-50	Prevention of sleep interference.	Occasional private auto at (100 ft). Bird calls.	Quiet home during evening hours.	45 dBA - 1/8 as loud as 75 dBA
30-40	Very quiet.	Soft whisper (5 ft).	Room in quiet house at midnight.	35 dBA - 1/16 as loud as 75 dBA

*On the logarithmic decibel scale on the left each increase of 10 dB represents a several-fold increase in sound pressure, but only an approximate doubling in a subjective assessment of loudness as the average human ear hears the noise or as it affects the nervous system. This subjective loudness range is shown in the column on the right (14).

range is typical of a busy downtown area, an automatic dishwasher or a vacuum cleaner.

The noise produced by a large transformer from a distance of 200 feet registers between 50 and 60 decibels, a noise range which is generally perceived as quiet, although not quiet enough to assure the prevention of sleep interference. According to Table 1, noise levels somewhere between 60 and 70 decibels will be perceived by most people as changing from quiet to noisy.

The Portland Transit Mall Area. This study of the Portland Transit Mall Noise Impacts is particularly concerned with vehicular traffic noise levels typical of a busy downtown area. The Transit Mall is located on SW Fifth and SW Sixth Avenues which were major north-south traffic streets through the center of downtown long before the Mall was constructed. Prior to the Transit Mall, these two streets were used by all traffic. Since its completion, the Mall is used almost exclusively by the majority of buses passing through downtown. Therefore, the primary noise source for both the before-Mall and after-Mall noise environments has been vehicular traffic.

After-Mall changes in noise levels would be expected to be related to differences in the composition and volume of vehicular traffic before and after the Mall. These changes would not be expected to be dramatic (in excess of 10 dBA, for example) for several reasons. First, the Mall area has typified a busy downtown area since long before the Transit Mall was constructed. Second, average daily traffic volumes entering downtown Portland increased by 2% per year between 1976 and 1980, not a dramatic increase in regards to noise impacts (23). Third, peak hour (commuter) traffic volumes in downtown have remained relatively stable since 1975 when the City imposed a maximum number of parking spaces allowable in downtown. This "parking lid" was equal to the total number of spaces in downtown in 1973. Had the Mall been constructed in a quieter part of town or, for example, on the site of streets formerly closed except to pedestrians and bicycles, or had vehicle volumes changed significantly, the impacts on the noise levels would be expected to be dramatic. The relationships between composition and volume of vehicle traffic and noise levels was not included as part of this study.

HUMAN RESPONSE TO NOISE

Human reaction to and perception of noise varies with each individual. Numerous personal and external factors including expectations, beliefs, attitudes, experiences with noise and times of day and year interact to determine individual reactions and perceptions.

Personal Factors

Some of the identified personal factors affecting individual response to noise include (8):

- Feelings about the necessity or preventability of the noise. If people feel that attempts are being made to mitigate annoying noise out of concern for their welfare, they are more tolerant of the noise and are willing to accommodate higher noise levels. If people feel their needs are being ignored, they are more likely to feel hostility toward the noise. Feelings of alienation or of being ignored are at the root of many human annoyance reactions.

- Judgment of the importance of the activity producing the noise.

- Activity at the time of the noise and the disturbance experienced as a result. Sleep, rest and relaxation are more easily disrupted by noise than communication and entertainment activities.

- Attitudes about environment. Some noises are unexpected in certain environments and therefore considered undesirable. An example might be the loud sounds of a rock band practicing in a home in a quiet residential neighborhood.

- Sensitivity to noise. People vary in their abilities to hear sound, their physiological predispositions to noise and their emotional experiences with annoyance related to given noises.

- Concern for the physiological effects of noise.

- Fear associated with noise. If individuals fear physical harm from the source of the noise, their responses will likely be negative.

<u>External Factors</u>

In addition to the foregoing personal factors, research has shown that the following external factors also contribute to individual responses to noise (8):

- Type of neighborhood. Instances of annoyance and complaint associated with a particular noise exposure will be higher in residential areas than in commercial and industrial areas. People expect residential areas to be quieter than central city areas, and will therefore be very sensitive to disruptions of the expected quiet.

- Time of day. Noise intrusions are considered more annoying in the early evening and at night than during the day.

- o Season. Noise is considered more disturbing in the summer than in the winter. There is likely to be more noise exposure in the summer because windows are open and more recreational activities take place outdoors.

- o Predictability of the noise. Individuals demonstrate a lower tolerence to unpredictable noise than to predictable noise.

- o Control over the noise source. Individuals who have no control over the noise source will demonstrate a lower tolerence to the noise than those who are able to exercise some control.

- o Duration of noise exposure. Research has produced little evidence to support the argument that annoyance due to noise decreases with continued exposure. Under some circumstances, annoyance may increase with duration of noise exposure.

Common Response

The variability in individual response to noise requires the application of statistical analysis for purposes of describing noise and assessing its impacts on groups of people. Through statistical analysis, common demoninators of human response to noise can be determined, and with their use, noise can be described in terms of its impacts not simply on one individual but on whole communities.

MEASUREMENT AND DESCRIPTION OF NOISE

Simply stated, the measurement of noise depends on the intensity and frequency of the sound and the characteristics of the human ear (1).

Intensity of Sound

The intensity of a particular sound is its sound pressure level, which diminishes with distance from the source of the sound. Sound radiates more or less equally in all directions from its source, forming a sphere of acoustical power. The sphere increases proportionally with the increase in distance from the source, but the intensity, or the power per unit of area, decreases because the constant power quantity is being distributed over an expanding area (1). The intensity of noise is expressed in terms of decibels (dB).

The range of sound pressures which can be heard by humans includes over one million units, from sound barely audible to sound which is painful to the ear. This wide range is compressed to a workable span by using the decibel unit of measurement. The decibel expresses a logarithmic ratio of the measured sound pressure to a base or reference sound pressure (0.0002 microbars). Decibels range from zero, which represents the minimum audible level, to 140, representing sound which is so loud that it is painful to the human ear (1) (15).

The decibel notation is arithmetic, but increases and decreases in decibels are geometric in scale. For every arithmetical increase (or decrease) of 10 decibels, the relative change in sound energy* increases (or decreases) geometrically ten times (15). Generally, a change in the noise level of 3 dB is barely audible to most humans. A

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*"Sound energy" is the total amount of energy radiated into the atmospheric air per unit time by a source(s) of sound (1).

change of 4 to 5 dB is considered significant in that it will be noticed by almost all people, and a 10 dB change will be perceived as a doubling (or halving) of loudness (22).

Numbers of decibels are never added arithmetically because they are logarithms of ratios. For example, if two similar noise sources each produce 100 dB, the combined noise level will be 103 dB, not 200 dB. Decibels are converted to relative power, added or subtracted, and then converted back to corresponding decibels (1) (15). All calculations for the Noise Impacts study of the Transit Mall were performed by this procedure.

Frequency of Sound

The frequency of sound represents the number of times a complete sound wave cycle, consisting first of an elevation and then a depression below atmospheric pressure, occurs in one second. Hertz (Hz) is designated as the unit for measuring frequencies of sound. The general frequency range of human hearing is usually defined as being between 20 and 20,000 Hz and is referred to as the audible frequency area (15).

Perception of Loudness

Noise intensity and frequency interact to determine the degree of loudness that is perceived by the human ear. Perception of loudness by all people generally follows these four rules (1):

1. At low intensity levels, high frequency tones sound louder than low frequency tones of the same intensity.

2. At high intensity levels, all tones of the same in-

tensity sound almost equally loud, regardless of their frequency.

3. At low intensity levels, a given change in intensity level produces a larger change in loudness at low frequencies than at high frequencies.

4. At high intensity levels, a given change in intensity level produces practically the same change in loudness regardless of frequency.

Standard sound level meters used to measure noise generally do not, without adjustments, discriminate against low and high frequencies like the human ear. The meters are adjusted by specific "weighting" networks to make these discriminations. The A-weighted network, or the A-scale, is the most widely used for the measurement of urban noise because its frequency response corresponds to the way the human ear perceives sound. All noise measurements in this report are expressed in terms of A-weighted sound levels in decibels, or dBA (15).

Measurement and Description of Noise

One of the purposes of measuring noise is to be able to describe the noise environment for given periods of time within a 24-hour day. Another purpose is to determine whether the noise environment changes over longer periods of time than a day, for example, from month to month or from year to year.

The urban noise environment is comprised of sounds from a variety of sources. Urban noises vary with time of day and proximity to noise sources. Typical urban noises vary from the quiet wind rustling through trees to the loud sounds of aircraft or cars and trucks passing nearby. Due to this variability of urban noise sources, a single sound level measurement is usually inadequate for describing the character of the noise during a specified time of day, for a longer portion of a day or for a 24-hour period. Statistical analysis is used to describe the time varying distribution of noise and to compute single number descriptors. Some commonly used descriptors include (22):

L_x - The sound level which is exceeded "x" percent of the time during a measurement period. For example:

L_1 - The sound level which is exceeded one percent of the time; often used to represent the maximum or "peak" sound level.

L_{10} - The sound level which is exceeded 10 percent of the time; often used to represent the "intrusive" sound level.

L_{50} - The sound level which is exceeded 50 percent of the time; often referred to as the "median" sound level.

L_{90} - The sound level which is exceeded 90 percent of the time; often referred to as the "background," "residual" or "ambient" sound level.

L_{eq} - The equivalent sound level, defined as the steady sound level, which if held constant over a specified measurement period, would contain the same sound energy as the time-varying sound present during the same period. The L_{eq} is mathematically different from the average sound level but may be considered an approximation of it (19). The L_{eq} is the only noise level descriptor which can be added and averaged (11) (12). Because of these particular characteristics of the L_{eq}, it was the only noise descriptor used to compare noise levels for the Transit Mall Noise Impacts study.

$L_{eq}(n)$ represents the equivalent sound level for a n-period of time. The $L_{eq}(12)$ is used in this report, generally to represent the steady sound level for twelve daytime hours from early morning to early evening.

L_{dn} - The day - night equivalent sound level for a 24-hour period. Research has revealed that people are approximately 10 dBA more sensitive to noise during nighttime hours than during the day. In calculating the L_{dn}, 10 dBA are generally added to each of the L_{eq} values obtained during the nighttime period to compensate for this heightened sensitivity (12) (19).

While these are the most commonly used descriptors, sound levels which are exceeded any percent of the time can be similarly described.

SECTION II
NOISE STANDARDS

A number of attempts have been made to develop standards for noise control, protection and abatement, particularly by public agencies. Some enforceable standards have been adopted to control individual noise sources such as vehicles and the allowable time exposure to certain noise levels of workers in industrial or factory settings. Many individual noise sources can be monitored and controlled at the source. Similarly, noise levels can be controlled when the sources are known and the noise environment is defined by physical boundaries, as the inside of a factory. However, when the noise sources are numerous and cannot be defined by physical parameters, background noise is extremely difficult to control. Only the U.S. Department of Housing and Urban Development (HUD) has developed enforceable standards for background noise levels in certain areas (5). These and two other sets of noise standards which are relevant to the Portland Transit Mall are discussed in this section.

STANDARDS DEVELOPED FOR FINAL ENVIRONMENTAL IMPACT ASSESSMENT OF THE PORTLAND TRANSIT MALL (1974)

The consultants who prepared the Final Environmental Impact Statement of the Portland Transit Mall developed standards in order to predict noise impacts of the Mall on pedestrian speech interference, office worker task interference, and hotel sleep interference (6) (7) (22). These standards are presented in Table 2.

Pedestrian Speech Interference

A threshold at L_{10} of 70 dBA was established as the standard for determining pedestrian speech interference on the Mall. The standard assumed conversation in a normal voice between two people two feet apart and facing one another on the sidewalks of the Mall. If noise levels exceeded 70 dBA more than 10 percent of the time, pedestrians would have difficulty conversing.

It was found that pedestrians were having difficulty conversing under existing before-Mall conditions. Noise measurements taken for preparation of the Final EIS are presented in Table AX-2 in the Appendix. Note that the L_{10} noise levels exceed the standard both on and off the Mall more often than not. Predictions expected the L_{10} noise levels to continue to exceed the standard after the Mall was constructed and for pedestrians to have continuing and possibly increasing difficulty conversing on the Mall.

Office Worker Task Interference

The standard for determining office worker task interference was a threshold at L_{50} of 46 dBA. The standard required that the noise levels not exceed 46 dBA more than 50 percent of the time to avoid noise disturbance to office workers. A series of noise measurements taken from typical office buildings along the Mall indicated that the exterior construction of these buildings reduced incoming sound by approximately 17 dBA with windows open and 22 dBA with windows closed. These measurements also revealed that in certain "noisiest" cases noise levels inside these buildings with windows open were reaching 49 dBA, indicating that the existing before-Mall levels were occasionally exceeding the standard.

Modelling procedures were applied to "noisiest" case findings to predict that the Transit Mall would raise noise levels inside offices with windows open from L_{50} of 49 dBA to approximately 56 dBA, and to approximately 51 dBA with windows closed. These projections were based on the traffic peak hour*. Midday noise levels were predicted to range from 52 to 54 dBA. All predicted cases exceeded the standard by at least five dBA.

TABLE 2

STANDARDS DEVELOPED FOR FINAL ENVIRONMENTAL IMPACT ASSESSMENT OF THE PORTLAND TRANSIT MALL (1974)

STANDARD	NOISE LEVEL
Pedestrian Speech Interference	L_{10} of 70 dBA on sidewalks both on and off the Mall.
Office Worker Task Interference	L_{50} of 46 dBA inside typical office buildings on the Mall.
Sleep Interference	Peak of 45 dBA inside hotel sleeping rooms on the Mall.

Hotel Sleep Interference

A peak noise level of 45 dBA occurring inside hotel sleeping rooms and caused by a transit vehicle passby was established as the standard for sleep interference in hotels on the Mall. Since a single transit vehicle passby during sleeping hours can cause awakening, the peak noise level of the passby is a more useful interference standard than any frequency of events.

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*"Peak hour" or "peak period" refer to those times of day when vehicular traffic is the most congested, generally in the morning when people are going to work and in the late afternoon when they are leaving work. The "peak" in this report generally refers to the afternoon period. "Peak hour" should not be confused with "peak noise level," defined on page 13 .

Peak noise levels inside typical hotel sleeping rooms due to vehicle passbys were determined by subtracting 22 dBA (typical office building reduction, windows closed) from the peak noise of each type of transit vehicle - diesel, trolley and light rail. Peak noise levels inside hotel sleeping rooms exceeded the standard in each case, with diesel being the worst case. Inside noise peaks due to diesel bus passbys were determined to be 16 dBA in excess of the standard or 61 dBA. Hotel sleep interference was predicted to continue because of the anticipated continued use of diesel buses, and to become more frequent due to more numerous bus passbys with the Mall in operation.

STANDARDS PROPOSED BY THE OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

In 1977, DEQ developed proposed noise standards for the protection of pedestrians and workers on the Mall (21). These standards were never adopted by the State Environmental Quality Commission. Nevertheless, they represent desirable maximum noise levels for a busy downtown area where vehicular traffic is the predominant noise source. Noise levels in excess of these proposed standards are considered irritating and/or dangerous to human health. The standards proposed by DEQ are presented in Table 3. The standards are expressed in terms of the $L_{eq}(12)$, the equivalent noise level for the period between 7 a.m. and 7 p.m.

TABLE 3

DEQ PROPOSED NOISE STANDARDS
ON-MALL NOISE EXPOSURE

STANDARD	NOISE LEVEL $L_{eq}(12)$
Hearing Loss: To protect against hearing loss due to long term exposure.	72 dBA
Communication: To insure speech communication and intelligibility.	67 dBA

HUD NOISE STANDARDS FOR HOUSING

The U.S. Department of Housing and Urban Development has developed standards applicable to the use of HUD monies for new residential construction and rehabilitation of existing structures for residential use (5). Federally guaranteed funding of housing can be refused due to excessive external noise levels, typically caused by motor vehicle traffic and other transportation sources in urban areas. "The magnitude of the external noise environment at a site is determined by the value of the day-night average sound level produced as the result of the accumulation of noise from all sources contributing to the external noise environment at the site. Day-night average sound level... is the 24-hour average sound level, in decibels, obtained after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m." (5). These standards, presented in Table 4, are expressed in terms of the L_{dn}.

TABLE 4

HUD NOISE STANDARDS
FOR SITE ACCEPTABILITY

ACCEPTABILITY	NOISE LEVEL L_{dn}
Acceptable	Not exceeding 65 dBA
Normally Unacceptable**	Greater than 65 dBA but not exceeding 75 dBA
Unacceptable**	Greater than 75 dBA

**Standards can be subject to special approvals and requirements.

SECTION III

BEFORE-MALL AND AFTER-MALL NOISE MEASUREMENT DATA SOURCES

In order to determine noise impacts both on the Mall and on adjacent streets off the Mall, noise measurements taken before the Mall was constructed were compared to measurements taken after its completion. Three noise measurement data sources were used, and no new noise measurements were taken for the comparisons. The three sources, which are referred to throughout this report as Sources A, B and C, are summarized in Table 5. Complete descriptions of Sources A-C noise measurements are found in the Appendix, including tables describing site locations and tables presenting the various statistical noise level data.

TABLE 5

BEFORE-MALL AND AFTER-MALL NOISE MEASUREMENT DATA SOURCES

BEFORE-MALL	SITES USED	ON/OFF-MALL
Source A		
Final Environmental Impact Statement: Fifth and Sixth	A1, A3, A4	On-Mall
Avenues Transit Mall, Portland, Oregon, U.S. DOT, UMTA, December, 1975.	A9 - A12	Off-Mall
Source B		
Transit Mall Noise Impact Study, Oregon Dept. of Environmental Quality, October, 1975 - April, 1981.	B1	On-Mall
AFTER-MALL		
Source B		
Same as above.	B2 - B3	On-Mall
Source C		
The City of Portland Urban Noise Survey, U.S. EPA,	C1, C21	On-Mall
March, 1979.	C8, C9 C10, C14	Off-Mall

BEFORE-MALL SOURCES

Sources A and B provide all of the before-Mall data. Source A measurements were taken in 1973-74 for the required environmental impact assessment, to describe the noise environment of the Mall alignment area before construction and to predict certain noise impacts of the Mall when completed and operating. These measurements were taken at four on-Mall sites and eight off-Mall sites for particular times of day. Measurements taken at three on-Mall sites and four off-Mall sites were used for the noise comparisons. Source A provides most of the before-Mall noise data, thereby establishing the parameters in most cases for comparisons with after-Mall measurements.

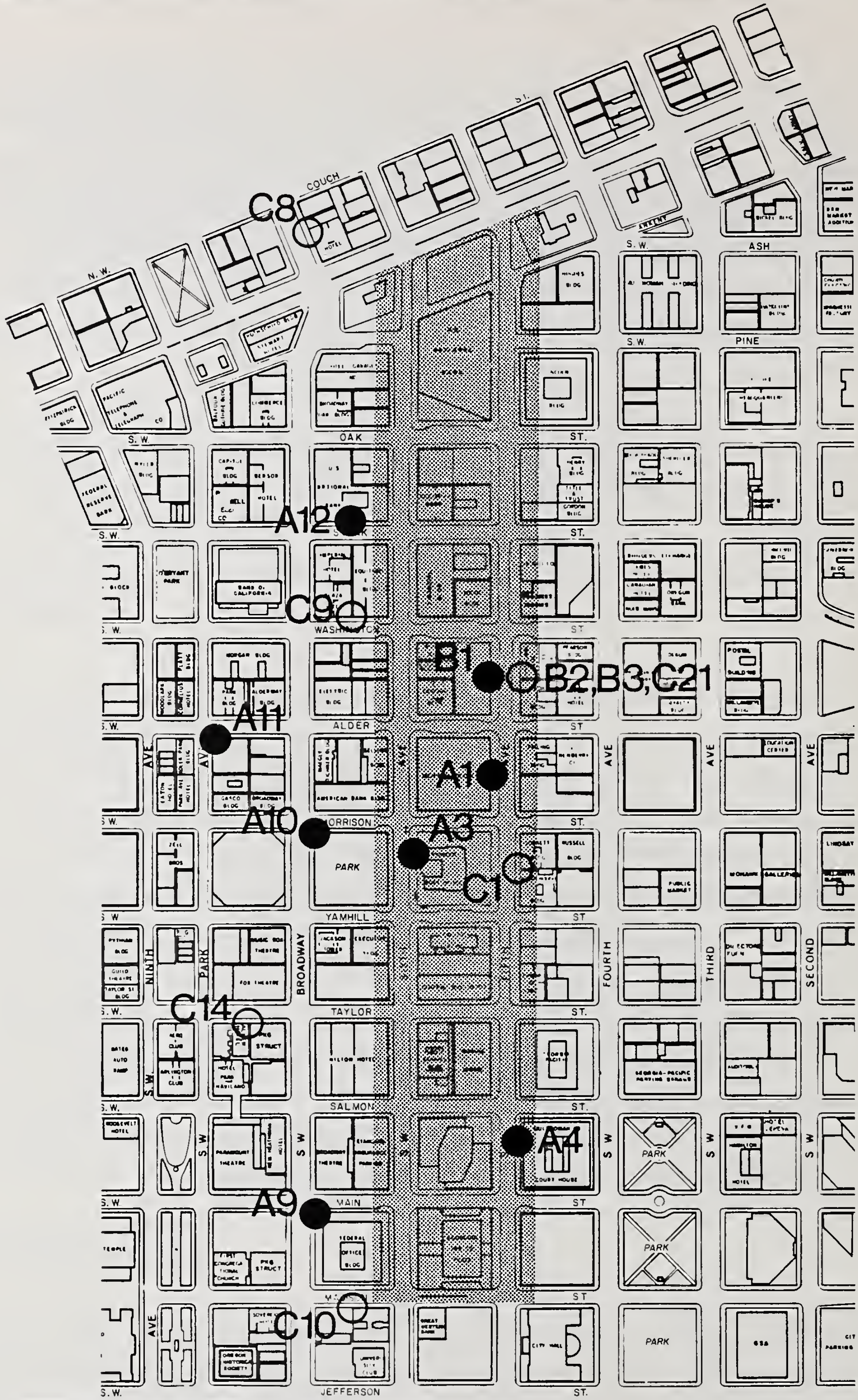
Source B noise levels were selected from a series of noise measurements taken by the Oregon Department of Environmental Quality between late 1975 and early 1981. The DEQ measurements were taken for the purposes of assessing the noise impacts of the Mall and to test noise level predictions which had been made prior to its construction. Source B provides both before-Mall and after-Mall noise measurements. All of the DEQ measurements were taken on the Mall. Three sets of the measurements, taken at Sites B1, B2 and B3, were selected for this Noise Impacts study on the basis of their comparability with other noise measurements. Only Site B1 provides before-Mall data. Measurements were taken at this site in 1976 prior to the beginning of Transit Mall construction.

AFTER-MALL SOURCES

Sources B and C provide all of the after-Mall data. Sites B2 and B3 from Source B provide measurements taken on the Mall in 1978 and 1981, respectively. Source C measurements were taken in 1979 by the City of Portland as part of a major noise survey in the downtown area. The research was conducted under contract with the U.S. Department of Housing and Urban Development. Noise measurements taken at six of the seventeen sites downtown were selected for this Noise Impacts study on the basis of their comparability with other noise measurements. Sites C1 and C21 were located on the Mall, and Sites C8, C9, C10 and C14 were located between ½ and 1½ blocks west of the Mall.

Figure 2 shows the location of all before-Mall and after-Mall noise measurement sites used in this Noise Impacts study.

FIGURE 2



BEFORE·MALL AND AFTER·MALL NOISE MEASUREMENT COMPARISON SITES

● BEFORE·MALL SITE

○ AFTER-MALL SITE

PORTLAND TRANSIT MALL

0 400'

SECTION IV
BEFORE-MALL AND AFTER-MALL NOISE MEASUREMENT COMPARISONS

The purpose of the Transit Mall Noise Impacts study is to determine what impacts, if any, the Transit Mall has had on noise levels both on the Mall and on adjacent streets off the Mall. The noise impacts were determined by comparing noise measurements taken before the Mall was constructed to measurements taken after its completion. These comparisons were made in anticipation of being able to detect consistent patterns of change in noise levels after the Mall was built.

COMPARISON PROCEDURES

The L_{eq} was the only noise descriptor used for noise measurement comparisons in this analysis because of its particular characteristics. First, the L_{eq} is mathematically different from the average noise level, but it may be considered an approximation of it. Secondly, unlike the other noise descriptors, L_{eq} values can be added and averaged, a calculation procedure which was necessary for the noise measurement comparisons. Before-Mall L_{eq} noise values were compared to after-Mall L_{eq} noise values on an Individual Site basis and an Aggregated Site basis.

Individual Site Comparisons

L_{eq} values recorded at one site before the Mall was constructed were compared to L_{eq} values recorded at a comparable site after the Mall was constructed. Comparability of individual sites was determined primarily by location relative to the Mall and to one another. On-Mall individual sites which were compared were all on SW Fifth Avenue and were either at the same locations, or as in most cases, at mid-block points across the street from one another or separated by one or several blocks. There were no comparable individual before-Mall and after-Mall sites on SW Sixth Avenue. Four on-Mall Individual Site Comparisons were made for the Noise Impacts study.

Off-Mall individual sites which were compared were located on parallel streets which run perpendicularly to the Mall streets. All off-Mall individual sites were mid-block points located ½ block west of the Mall and from one to several blocks apart. There were no comparable individual before-Mall and after-Mall sites located east of the Mall. Two off-Mall Individual Site Comparisons were made for the Noise Impacts study.

Of the six Individual Site Comparisons, five each involved only two sites, one providing before-Mall measurements and one providing after-Mall measurements. The remaining comparison involved three sites, one providing before-Mall measurements and two providing after-Mall measurements all taken by DEQ from approximately the same location on the Mall. This set of three measurements essentially tracked the noise environment of the Mall at one location over time. This particular comparison is discussed first under the NOISE MEASUREMENT COMPARISONS subheading in this section.

Aggregated Site Comparisons

Average before-Mall L_{eq} values were compared to average after-Mall L_{eq} values in the same manner as the Individual Site Comparisons. The L_{eq} values, however, are averages derived from adding multiple L_{eq} values from several sites. L_{eq} values were aggregated - this is added and averaged - to provide more generalized descriptions of noise conditions than the Individual Site Comparisons could allow. Averaging the L_{eq} values reduced the site specific noise characteristics of the individual site measurements. Measurements were aggregated only if the sites shared common characteristics including being all before-Mall, all after-Mall, all on-Mall, or all off-Mall. Three Aggregated Site Comparisons were made for the Noise Impacts study, two on-Mall and one off-Mall.

CONSIDERATIONS

Noise measurement is not generally used for comparative purposes as it has been used for this study. Noise measurements are much more commonly used to describe the existing noise environment and for making predictions through modelling procedures of noise impacts of certain decisions.

Comparing noise measurements even under the most controlled conditions is technically a very difficult exercise. Perhaps the most desirable and complete study of the noise impacts of the Transit Mall would necessitate replicating the noise measurement procedures followed before the Mall for the after-Mall measurements. Ideally, conditions such as days, dates, times of day, weather conditions and placement of metering equipment would be the same for the after-Mall measurements. In addition, records would have been kept of major construction, demolition and renovation on and near the Mall; of traffic counts separated for bus and all other vehicles; and of any other new developments which could impact noise absorption or propagation or the noise environment in general. Even under such controlled conditions, it is still difficult to technically compare noise levels because it is impossible to know all of the factors influencing and resulting in those levels.

For purposes of any comparison of noise measurements, it must be assumed that they were taken under normal acoustical conditions at each site. While the assumption means that no unusual nor major noise-producing construction, demolition or activity was occurring near the sites during measurement periods, it is in fact impossible to know this unless someone was constantly present during the measurement periods, noting all unusual noise sources. Similarly, the assumption implies that the noise environment of each site could be considered characteristic of typical on-Mall or off-Mall conditions, which is simply not the case. The averaged L_{eq} values employed in the Aggregated Site Comparisons tend, however, to reduce site specific characteristics and to more closely approximate typical on-Mall or off-Mall noise conditions than the Individual Site Comparisons. This is not to say that the Aggregated Site Comparisons are likely to be more accurate than the Individual ones. Averaged measurements, however, can be compared with less caution than individual site measurements.

As mentioned earlier, sites used for Individual Site Comparisons were selected on the basis of location relative to the Mall and to one another. Sites were eliminated if they were not located adjacent to buildings built out to property lines, in order to maintain the street canyon effect on all the utilized noise measurements. The street canyon effect is a noise buildup due to multiple reflections between buildings (22).

Noise levels were scrutinized for apparent aberrations compared to other noise measurements. For example, one before-Mall site (Site A2, not included in Appendix) was not used because of its combined characteristics of very high L_{eq} values for the daytime and peak periods and of being located adjacent to the rear lawn of Pioneer Courthouse on SW Fifth Avenue. Before-Mall Site A4 was used with caution in Individual Site Comparison #3 (see page 40) because of its significantly high L_{eq} values for the evening and nighttime measurement periods.

Comparison of site measurements were made for times of day as close to the same as possible. Source A data, being the primary source of before-Mall noise measurements, established the parameters for the time periods which could be compared. Source A noise levels represented the following four one-hour time periods: day (11:00 am - noon), peak (4:30 - 5:30 pm), evening or eve (9:00 - 10:00 pm), and night (11:30 pm - 12:30 am). In many cases, after-Mall measurements were more extensive and the time periods were not exactly the same, thereby necessitating some calculation prior to the comparison. For example, there may have been four after-Mall L_{eq} values representing the four consecutive 15-minute intervals during an evening period. In order to compare these four measurements to the single before-Mall Source A L_{eq}, they had to be added and averaged to obtain a single L_{eq} value representative of the one-hour period.

The numerical changes in dBA's which resulted from the site comparisons cannot be taken literally except in the case of Individual Site Comparison #1. Noise measurements in this case were taken at the same location, thereby reflecting actual changes in noise levels which occurred at one location over time. All of the other comparisons involved measurements which, because they were recorded at different locations, could only be used to generally represent before-Mall or after-Mall conditions. The primary importance of all the comparison results is the increase or decrease in L_{eq} values, indicating greater or less noise after the Mall was constructed.

NOISE MEASUREMENT COMPARISONS

All findings are based on the results of the following six Individual Site Comparisons and three Aggregated Site Comparisons. Locations of all sites are shown in Figure 2.

Individual Site Comparison #1: On-Mall

The Noise Control Division of the Oregon Department of Environmental Quality in Portland took a series of noise measurements on SW Fifth Avenue mid-block between SW Washington and SW Alder Streets. These measurements, taken between January 1976 and April 1981, are part of a larger study by the DEQ of the Transit Mall. The purposes of the study were to determine the actual impacts of the Mall on the noise environment and to test predicted noise impacts of the Mall made prior to its construction.

Of the series of measurements, three sets were used for this comparison; they were recorded at Sites B1, B2 and B3. Only Site B1 measurements represent before-Mall conditions. Site B1 was located on the west side of SW Fifth Avenue, across the street from after-Mall Sites B2 and B3 which shared the same location. Site B1 measurements were taken in January 1976 just prior to the beginning of Mall construction. Site B2 measurements were recorded in April 1978, and Site B3 measurements were taken in April 1981.

These three sets of measurements formed a trend of progressively increasing noise levels over time at one location on the Mall. The L_{eq} values are displayed in Table 6. The $L_{eq}(12)$ represents the equivalent noise level for a 12-hour period, generally from early morning to early evening. The figures in Table 6 indicate that the $L_{eq}(12)$ noise level increased .5 dBA after the Mall was built and an additional .9 dBA by 1981. The overall increase in the $L_{eq}(12)$ on the Mall was 1.4 dBA.

Daytime and peak period L_{eq} values demonstrated trends very similar to the $L_{eq}(12)$. The increases from 1976 before the Mall was built to 1978 when it had just begun operating were less than ½ dBA for both measurement time periods. Increases from 1978 to 1981 were both just over 1 dBA. The overall increase from 1976 to 1981 in the daytime L_{eq} was 1.9 dBA and was 1.3 dBA during the peak period.

TABLE 6

NOISE LEVEL COMPARSION OF
BEFORE-MALL SITE B1 TO AFTER-MALL SITES B2 AND B3
ON-MALL

PERIOD	TIME	L_{eq} BEFORE-MALL SITE B1	L_{eq} AFTER-MALL Site B2	CHANGE B1-B2	L_{eq} AFTER-MALL Site B3	CHANGE B2-B3	CHANGE B1-B3
Day	11:00 am - noon	71.6	72	.4	73.5	1.5	1.9
Peak	4:30-5:30 pm	73.8	est. 74*	.2	75.1	1.1	1.3
	$L_{eq}(12)$	72.2	72.7	.5	73.6	.9	1.4

*Estimated (See Table AX-5 in Appendix)

<u>Individual Site Comparison #2: On-Mall</u>

Before-Mall noise measurements taken at Site A1 in 1973 were compared to after-Mall measurements taken at Site C1 in 1979. Site A1 was located on the west side of SW Fifth Avenue, mid-block between SW Alder and SW Morrison Streets. Site C1 was located on the east side of SW Fifth Avenue, mid-block between SW Morrison and SW Yamhill Streets. The two sites were on opposite sides of the street and one block apart. The L_{eq} noise levels for four one-hour time periods during the day were compared. These periods are day (11:00 am - noon), peak (4:30 - 5:30 pm), evening (9:00 - 10:00 pm) and night (11:30 pm - 12:30 am). Results of the comparison are shown in Table 7.

Individual Site Comparison #2 indicates that the L_{eq} increased on the Mall after its construction for all four time periods. The smallest increase of 1.8 dBA occurred during the daytime period. Increases during the peak and evening time periods were both in excess of 3 dBA which is significant in that most people could detect the changes. The greatest increase of 6.3 dBA occurred during the nighttime period.

TABLE 7

L_{eq} NOISE LEVEL COMPARISON OF
BEFORE-MALL SITE A1 TO AFTER-MALL SITE C1
ON-MALL

PERIOD	TIME	L_{eq} BEFORE-MALL SITE A1	L_{eq} AFTER-MALL SITE C1	CHANGE
Day	11:00 am - noon	69	70.8	1.8
Peak	4:30 - 5:30 pm	71	74.9	3.9
Eve	9:00 - 10:00 pm	66	69.4	3.4
Night	11:30 pm - 12:30 am	61	67.3	6.3

Individual Site Comparison #3: On-Mall

Before-Mall noise measurements taken at Site A4 in 1973 were compared to after-Mall measurements taken at Site C1 in 1979. Site A4 was located on the east side of SW Fifth Avenue, in front of Multnomah County Courthouse, twenty feet south of the corner of SW Fifth and SW Salmon. Site C1 was also located on the east side of SW Fifth, mid-block between SW Morrison and SW Yamhill Streets. The two sites were three blocks apart. The L_{eq} noise levels were compared for the same four time periods as in Individual Site Comparison #2. Results of this comparison are found in Table 8.

Individual Site Comparison #3 indicates that the L_{eq} increased after the Mall was constructed for all measurement time periods except the evening one in which it decreased 4.6 dBA. The before-Mall evening and nighttime period L_{eq} values (of 74 dBA and 67 dBA, respectively) recorded at Site A4 are higher than evening and nighttime L_{eq} values at the other Source A on-Mall sites, indicating that some particular noise-producing activity was probably occurring at that location. In 1973 when Site A4 measurements were taken, the

Continental Trailways bus station was located across the street from the site location. The noise produced by arriving and departing buses was absorbed during the noisier daytime and peak periods, but became obvious to the sound level meter in the evening and nighttime periods when the general noise character of SW Fifth Avenue before the Mall was built was quieter than these particular measurements would indicate.

The evening period L_{eq} values for the two other Source A on-Mall sites were 66 dBA and 67 dBA, and the nighttime L_{eq} values were 61 dBA and 60 dBA. Had the Site A4 evening and nighttime L_{eq} values been closer to these values, this comparison would have resulted in an increase in evening period L_{eq} values and a greater increase during the nighttime period.

The results in Table 8 indicate that L_{eq} increases during the daytime and nighttime periods were both less than 1 dBA, and the increase indicated during the peak period was 1.9 dBA.

TABLE 8

L_{eq} NOISE LEVEL COMPARISON OF BEFORE-MALL SITE A4 to AFTER-MALL SITE C1 ON-MALL

PERIOD	TIME	L_{eq} BEFORE-MALL SITE A4	L_{eq} AFTER-MALL SITE C1	CHANGE
Day	11:00 am - noon	70	70.8	.8
Peak	4:30 - 5:30 pm	73	74.9	1.9
Eve	9:00 - 10:00 pm	74	69.4	-4.6
Night	11:30 pm - 12:30 am	67	67.3	.3

Individual Site Comparison #4: On-Mall

Before-Mall noise measurements taken at Site A1 in 1973 were compared to after-Mall measurements taken at Site B3 in 1981. Site A1 was located on the west side of SW Fifth Avenue, mid-block between SW Alder and SW Morrison Streets. Site B3 was located on the east side of SW Fifth, mid-block between SW Washington and SW Alder Streets. The two sites were on opposite sides of the street and one block apart. The L_{eq} noise levels were compared for the same four time periods as in Individual Site Comparisons #2 and #3. Results of this comparison are found in Table 9.

TABLE 9

L_{eq} NOISE LEVEL COMPARISON OF BEFORE-MALL SITE A1 TO AFTER-MALL SITE B3 ON-MALL

PERIOD	TIME	L_{eq} BEFORE-MALL SITE A1	L_{eq} AFTER-MALL SITE B3	CHANGE
Day	11:00 am - noon	69	72.7	3.7
Peak	4:30 - 5:30 pm	71	75	4.0
Eve	9:00 - 10:00 pm	66	70.6	4.6
Night	11:30 pm - 12:30 am	61	70.1	9.1

Individual Site Comparison #4 indicates that the L_{eq} increased after the Mall was constructed for all four time periods. All of the changes in L_{eq} noise levels are in excess of 3 dBA which is significant in that they could all be detected by the human ear. The nighttime increase of 9.1 dBA would be perceived by people as a near doubling of loudness.

Individual Site Comparison #5: Off-Mall

Before-Mall measurements recorded at Site A12 in 1974 were compared to after-Mall measurements taken at Site C9 in 1979. Site A12 was located on the north side of SW Stark Street, mid-block between SW Sixth Avenue and SW Broadway. Site C9 was located on the north side of SW Washington Street, also mid-block between SW Sixth Avenue and SW Broadway. The two sites were both ½ block west of the Mall and one block apart. The L_{eq} noise levels were compared for the day, peak and evening time periods. Nighttime measurements were not available for before-Mall Site A12. Results of this comparison are found in Table 10.

TABLE 10

L_{eq} NOISE LEVEL COMPARISON OF
BEFORE-MALL SITE A12 TO AFTER-MALL SITE C9
OFF-MALL

PERIOD	TIME	L_{eq} BEFORE-MALL SITE A12	L_{eq} AFTER-MALL SITE C9	CHANGE
Day	11:00 am - noon	68	68	0
Peak	4:30 - 5:30 pm	74	68.5	-5.5
Eve	9:00 - 10:00 pm	63	66.5	3.5

Individual Site Comparison #5 indicates that the L_{eq} did not change during the daytime period, decreased by 5.5 dBA during the peak period, and increased by 3.5 dBA during the evening period after the Mall was constructed. The changes during the peak and evening periods are significant in that both could be detected by most people.

Individual Site Comparison #6: Off-Mall

Before-Mall measurements recorded at Site A12 in 1974 were compared to after-Mall measurements taken at Site C10 in 1979. Site A12 was located on the north side of SW Stark Street, mid-block between SW Sixth Avenue and SW Broadway. Site C10 was located on the south side of SW Madison Street, also mid-block between SW Sixth and SW Broadway. The two sites were both ½ block west of the Mall and eight blocks apart. The L_{eq} noise levels were compared for the day, peak and evening time periods. Nighttime measurements were not available for before-Mall Site A12. Results of the comparison are shown in Table 11.

TABLE 11

L_{eq} NOISE LEVEL COMPARISON OF
BEFORE-MALL SITE A12 TO AFTER-MALL SITE C10
OFF-MALL

PERIOD	TIME	L_{eq} BEFORE-MALL SITE A12	L_{eq} AFTER-MALL SITE C10	CHANGE
Day	11:00 am - noon	68	70	2
Peak	4:30 - 5:30 pm	74	69	- 5
Eve	9:00 - 10:00 pm	63	64.5	1.5

Individual Site Comparison #6 indicates that daytime and evening period L_{eq} levels increased after the Mall was constructed, and that the peak period L_{eq} decreased by 5 dBA. The latter change, unlike the other two, is significant in that it could be detected by all people.

Aggregated Site Comparison #1: On-Mall

The values in Table 12 were aggregated for the purpose of comparing average before-Mall and after-Mall peak period (4:30 - 5:30 pm) L_{eq} values only. All sites were located on the Mall. An average before-Mall peak period L_{eq} noise level of 71.1 dBA was computed form peak period measurements taken at Sites A1, A3 and A4. The comparable after-Mall average L_{eq} value of 74.5 dBA was computed from peak period measurements taken at Sites C1, C21, and B3. The locations of all sites are shown on Figure 2. Results of the comparison are found in Table 12.

Aggregate Site Comparison #1 indicates that the average on-Mall L_{eq} value during the peak period increased after the Mall was constructed by 3.4 dBA.

TABLE 12

AVERAGE BEFORE-MALL AND AFTER-MALL
PEAK PERIOD (4:30 - 5:30 pm) L_{eq} NOISE LEVELS
ON-MALL

BEFORE-MALL		AFTER-MALL		CHANGE
SITE	L_{eq}	SITE	L_{eq}	L_{eq}
A1	71	C1	74.9	
A3	68	C21	74.1	
A4	73	B3	74.5	
Average:	71.1	Average:	74.5	3.4

Aggregated Site Comparison #2: On-Mall

Before-Mall measurements from four on-Mall sites were compared to after-Mall measurements taken at two sites also located on the Mall. Average before-Mall L_{eq} noise levels were calculated from individual measurements taken at Sites A1, A3 and A4 in 1973. Comparable after-Mall average L_{eq} noise levels were calculated from individual measurements taken at Sites C1 and C21 in 1979. The average L_{eq} values were compared for four one-hour time periods during the day. These periods are day (11:00 am - noon), peak (4:30 - 5:30 pm), evening (9:00 - 10:00 pm) and night (11:30 pm - 12:30 am). Table 13 shows the comparisons and the after-Mall changes.

TABLE 13

AVERAGE BEFORE-MALL AND AFTER-MALL
L_{eq} NOISE LEVELS
ON-MALL

PERIOD	TIME	AVERAGE L_{eq} BEFORE-MALL SITES A1, A3, A4	AVERAGE L_{eq} AFTER-MALL Sites C1, C21	CHANGE
Day	11:00 am - noon	69.7	70.5	.8
Peak	4:30 - 5:30 pm	71.1	74.5	3.4
Eve	9:00 - 10:00 pm	70.5	68.2	-2.3
Night	11:30 pm - 12:30 am	63.8	67.8	4.0

Aggregated Site Comparison #2 indicates that the average on-Mall L_{eq} noise level decreased by 2.3 dBA during the evening time period after the Mall was constructed. The peak period averaged L_{eq} increased by 3.4 dBA and the nighttime period average L_{eq} increased by 4 dBA. The daytime average L_{eq} demonstrated a slight increase of .8 dBA.

Aggregated Site Comparison #3: Off-Mall

Average L_{eq} values calculated from four before-Mall sites located west of the Mall were compared to average L_{eq} values calculated from four after-Mall sites also located west of the Mall. All sites were located between ½ and 1½ blocks off the Mall. There were no opportunities to compare off-Mall noise measurements east of the Mall on either an Individual Site or an Aggregated Site basis.

L_{eq} values were calculated for the day, peak and evening time periods. Nighttime period data was not available for comparison. Before-Mall average L_{eq} noise levels were computed from individual measurements taken at Sites A9-A12 in 1974. After-Mall average L_{eq} noise levels were computed from individual measurements taken at Sites C8-C10 and C14 in 1974. Table 14 shows the comparisons and the after-Mall changes.

TABLE 14

AVERAGE BEFORE-MALL AND AFTER-MALL L_{eq} NOISE LEVELS OFF-MALL

PERIOD	TIME	AVERAGE L_{eq} BEFORE-MALL SITES A9-A12	AVERAGE L_{eq} AFTER-MALL SITES C8-10, C14	CHANGE
Day	11:00 am - noon	69.1	71.9	2.8
Peak	4:30 - 5:30 pm	72.9	69.7	-3.2
Eve	9:00 - 10:00 pm	67.5	66.5	-1.0

Aggregated Site Comparison #3 indicates that the daytime average L_{eq} noise level increased 2.8 dBA after the Mall was constructed. The evening and peak period average L_{eq} values decreased by 1 dBA and 3.2 dBA, respectively.

SECTION V

FINDINGS

SUMMARY OF NOISE MEASUREMENT COMPARISONS

The individual results of the nine comparisons described in the foregoing section demonstrate great consistency in noise level changes after the Transit Mall was built. The numerical changes in dBA's cannot be taken literally, except in the case of Individual Site Comparison #1 in which all measurements were taken at the same location. The numbers of occurrences, however, of increases and decreases in noise levels from all the other comparisons can be tallied together to provide dependable indications of what impacts the Transit Mall has had on the noise environment. Table 15 summarizes these occurrences after the Mall was built for both on-Mall and off-Mall locations.

TABLE 15

SUMMARY OF OCCURRENCES OF L_{eq} NOISE LEVEL INCREASES AND DECREASES AFTER-MALL ON-MALL AND OFF-MALL

	ON-MALL						OFF-MALL					
PERIOD	INDIVIDUAL SITE COMPARISONS		AGGREGATED SITE COMPARISONS		TOTAL		INDIVIDUAL SITE COMPARISONS		AGGREGATED SITE COMPARISONS		TOTAL	
	+	-	+	-	+	-	+	-	+	-	+	-
Day	4		1		5	0	1		1		2	0
Peak	4		2		6	0		2		1	0	3
Eve	2	1		1	2	2	2			1	2	1
Night	3		1		4	0	NA		NA		NA	

Results of the tallies in Table 15 indicate that noise levels have increased on the Mall during the daytime, peak and nighttime measurement periods. The on-Mall comparisons resulted in equal numbers of noise level increases and decreases during the evening measurement period, making it difficult to determine what noise level changes may have occurred, if any, during that time of day since the Mall was constructed.

The tallies of off-Mall comparisons indicate that noise levels have increased during the daytime and decreased during the peak period. The evening period tally indicates by a 2-to-1 margin that noise levels have increased off the Mall. There were no data available for the nighttime period off the Mall.

Overall, the results of the noise comparisons clearly indicate that since its construction, the Mall has become a noisier place for all measurement time periods with the possible exception of the evening one. Furthermore, streets adjacent to and west of the Mall have also become noisier during the daytime and evening. The only clear indication of reductions in noisiness occurred off the Mall during the peak period. Changes in evening period noisiness both on and off the Mall tend towards increases, but the numbers of occurrences of both increases and decreases are very close.

On the Mall, the day long changes expressed by the $L_{eq}(12)$ indicate that noise levels increased after the Mall was constructed and continued to increase during the next three years. Individual Site Comparison #1 resulted in an increase in the $L_{eq}(12)$ of .5 dBA between 1976 and 1978 on the Mall. After three years of operation, on-Mall measurements indicated an additional .9 dBA increase in the $L_{eq}(12)$, resulting in an overall day long increase of 1.4 dBA between 1976 and 1981.

Changes in noise levels of less than 3 dBA are generally not perceived by most humans. Therefore, the overall increase of 1.4 dBA in the $L_{eq}(12)$ might not appear significant. The fact that noise levels on the Mall have increased at all and are demonstrating a trend toward increasing more is significant because SW Fifth and SW Sixth Avenues were noisy prior to the construction of the Mall and continue to be noisy today.

As indicated in Table 1 and stated earlier in this report, most people perceive the environment to be noisy somewhere between 60 and 70 dBA. A typical busy downtown area is characterized by a noise range between 70 and 80 dBA. The $L_{eq}(12)$ on SW Fifth Avenue before the Mall was constructed was 72.2 dBA, a noise level considered to be noisy. Even the relatively small increases in the noise levels since that time mean that the Mall area is becoming a noisier place.

Furthermore, $L_{eq}(12)$ levels on the Mall fall within the 70 - 80 dBA range which, if exceeded, can result in extra-auditory physiological effects. Some of these effects which are briefly discussed in Section I include peptic ulcer, hypertension, and certain behavior disorders indirectly related to noise via sleep deprivation.

RELATIONSHIP BETWEEN TRAFFIC AND NOISE

Changes in noise levels resulting from these comparisons are assumed to be related to vehicular traffic. However, an analysis of the relationships between traffic volumes, traffic composition, and noise measurements was not included in this Noise Impacts Report because complete information was not available. If traffic counts separated for bus and all other vehicles had been taken consistently at all sites during the noise measurement periods, noise level changes could be directly related to bus traffic noise, other vehicular traffic noise, and non-traffic related noise, if any.

SIGNIFICANCE TO NOISE STANDARDS

Please refer to Section II for a description of the noise standards discussed under this subheading.

Standards Developed for Final Environmental Impact Assessment of the Portland Transit Mall (1974)

Findings for the EIS in 1974 indicate that the standards for pedestrian speech interference and office worker task interference were both being exceeded before the Mall was constructed. Those standards are being exceeded slightly more with the Mall based on the findings in this Noise Impacts study that the L_{eq}(12) noise level has increased 1.4 dBA on the Mall since before its construction. Hotel sleep interference on the Mall has become more frequent than before the Mall was built due to the increased number of buses passing by hotels located on the Mall.

Standards Proposed by the Oregon Department of Environmental Quality

The Site B3 1981 L_{eq}(12) of 73.6 dBA is in excess of DEQ's proposed standard of 72 dBA to protect against hearing loss for people on the Mall who are exposed for long periods of time to Mall noises. These people would include food and flower vendors and Mall maintenance people who spend all day on the Mall. The before-Mall L_{eq}(12) of 72.2 dBA, calculated by DEQ in January 1976 from measurements taken at Site B1, indicates that noise levels were exceeding the DEQ proposed standard to protect against hearing loss before the Mall was built as well.

The DEQ communication standard of L_{eq}(12) of 67 dBA was also being exceeded prior to Mall construction, but is exceeded more frequently with the Mall in operation. This conclusion is reinforced by the fact that even many of the before-Mall L_{50} noise levels and most of the after-Mall L_{50} noise levels are in excess of 67 dBA (see Appendix). Speech interference on the Portland Transit Mall is an important consideration because the Mall was originally intended to be an attractive people place as well as a convenient transit patron place.

The Mall does in fact appear to be an attraction to people, evidenced by the high patronage which on-Mall outdoor cafes experience, even though the noise generated by buses is unquestionably irritating, especially to conversationists.

HUD Noise Standards for Housing

L_{dn} values are available for all Source C sites used for the noise comparisons (4). All of these values, which are found in Table 16, exceed the "Acceptable" noise standard of 65 dBA. While none of the L_{dn} values fall into the "Unacceptable" category of greater than 75 dBA, all of them are close to the maximum allowable L_{dn} of 75 dBA of the "Normally Unacceptable" category.

TABLE 16

SOURCE C L_{dn} NOISE LEVELS
ON-MALL AND OFF-MALL

	ON-MALL		OFF-MALL			
Site	C1	C2	C8	C9	C10	C14
L_{dn} (dBA)	74.3	74.5	71.3	72.5	73.9	74.1

Sites C1 and C21 on the Mall have higher L_{dn} values than the off-Mall Source C sites. The implication of these findings is that federally guaranteed funding of housing would be difficult to obtain for new construction or redevelopment locations on or very near the Transit Mall. Funding would be contingent upon special approval for the use of noise reduction construction materials and techniques.

SECTION VI
CONCLUSIONS

Following are the more important conclusions drawn from the Noise Impacts study.

- o Noise levels have increased on the Mall since before its construction. The Transit Mall is located in an area which was noisy before its construction, became noisier after construction, and is continuing to become a noisier place since construction.

- o Noise level increases have occurred on the Mall during the daytime (11:00 am - noon), peak (4:30 - 5:30 pm) and nighttime (11:30 pm - 12:30 am) measurement periods. Findings do not indicate whether evening period (9:00 - 10:00 pm) noise levels have increased or decreased on the Mall.

- o The average day long noise level on the Mall, represented by the L_{eq}(12) (7:00 am to 7:00 pm) at one on-Mall site increased .5 dBA between 1976, just prior to the beginning of Mall construction, and 1978 several months after completion of the Mall. The L_{eq}(12) increased an additional .9 dBA between 1978 and 1981, for an overall increase of 1.4 dBA since 1976.

- o Off the Mall, noise levels have increased during the daytime period and decreased during the peak period. Findings indicate that evening period noise levels have also increased.

- o Standards for the protection of speech communication on the Mall are regularly exceeded.

- o Federally guaranteed funding of housing would be difficult to obtain for new construction or redevelopment locations on or very near the Transit Mall because of high noise levels.

- Noise level changes are assumed to be directly related to vehicular traffic volumes and compositions. If traffic counts separated for bus and non-bus had been taken consistently at all sites during the noise measurement periods, noise level changes could be directly related to bus traffic noise, other vehicular traffic noise and non-traffic related noise, if any.

NOISE MITIGATION

The most expedient, albeit expensive, methods of reducing noise levels on and near the Mall involve various changes in the transit vehicles themselves, including:

- The purchase of quieter buses for the transit fleet;

- The initiation of a major retrofit program to install noise reduction and control equipment on the existing fleet; and

- The purchase and use of alternative transit vehicles such as electric trolley buses or light rail vehicles.

Noise exposure can be reduced through noise-reducing architectural treatment of buildings and pedestrian rest areas.

SECTION VII

APPENDIX: BEFORE-MALL AND AFTER-MALL NOISE MEASUREMENT DATA SOURCES

BEFORE-MALL AND AFTER-MALL
NOISE MEASUREMENT DATA SOURCES

This section provides a complete description of three sources of noise measurement data.

BEFORE-MALL SOURCES

Source A: Final Environmental Impact Statement: Fifth and Sixth Avenues Transit Mall, Portland, Oregon, U.S.DOT, UMTA, December 1975.

The Final EIS findings provide most of the before-Mall noise measurement data for this Noise Impacts study. Noise measurements were taken for the Final EIS before the Mall was constructed for the dual purpose of describing the existing (1973-74) noise environment in the vicinity of the proposed Transit Mall, and of assessing the impacts of the proposed Mall on the noise environment under the following conditions:

- That the Transit Mall was built as proposed;
- That the Transit Mall was not built and that present (1973-74) traffic trends continued; and
- That alternative transit systems such as electric trolley bus and light rail were used.

Noise measurements were taken in 1973-74 at four on-Mall and eight off-Mall sites in downtown Portland. The noise samples were obtained on weekdays during periods of dry pavement, and were taken at ten-minute intervals four times a day as follows:

Day	11:00 a.m. - Noon
Peak	4:30 p.m. - 5:30 p.m.
Evening	9:00 p.m. - 10:00 p.m.

Night 11:30 p.m. - 12:30 a.m.

"Night" measurements were not taken at any off-Mall sites.

All measurement sites were carefully selected to be representative of desired noise exposure conditions, such as at mid-block between high buildings set close to the street, at more open mid-block points, and at street intersections. All measurements were taken at the street level approximately five feet above the sidewalk and three feet from the curb. Five sites were located at mid-block points, five were corner sites, and the remaining two sites were fifteen and twenty feet from a corner. Three on-Mall sites - A1, A3 and A4 - and four off-Mall sites - A9-A12 - were selected for comparison to after-Mall noise measurements for this Noise Impacts study. The locations of these seven sites are illustrated in Figure 2 on page 32 of this report, and their location descriptions are found in Table AX-1 in this section. The statistical noise levels for each of the seven sites are presented in Table AX-2.

All noise measurements were recorded using specially modified magnetic tape recorders, a field microphone and a preamplifier. Each recording was calibrated with an acoustical standard sound pressure level using a Bruel and Kjaer (B & K) Calibrator.

Source B: Transit Mall Noise Impact Study, Oregon Department of Environmental Quality, October 1975 - April 1981.

The Noise Control Division of the Oregon Department of Environmental Quality (DEQ) in Portland took a series of noise measurements on SW Fifth and SW Sixth Avenues before, during and after construction of the Transit Mall. The Division's purposes were to assess the actual impact of the

TABLE AX-1

SOURCE A
SITE* LOCATION DESCRIPTIONS
BEFORE-MALL
ON-MALL AND OFF-MALL

ON-MALL SITES	LOCATION DESCRIPTION
A1	West side SW Fifth Avenue, mid-block between SW Alder & SW Morrison Streets.
A3	East side SW Sixth Avenue, 15 feet from corner of SW Sixth Avenue & SW Morrison Street.
A4	East side SW Fifth Avenue, 20 feet from corner of SW Fifth Avenue & SW Salmon Street.
OFF-MALL SITES	
A9	Southeast corner of SW Main Street & SW Broadway.
A10	Southeast corner of SW Morrison Street & SW Broadway.
A11	Southeast corner of SW Alder Street & SW Park Avenue.
A12	North side SW Stark Street, mid-block between SW Sixth Avenue and SW Broadway.

*All Source A sites were at the street level and 3 feet from the curb.

TABLE AX-2

SOURCE A
STATISTICAL NOISE LEVELS (dBA)
BEFORE-MALL
ON-MALL AND OFF-MALL

ON-MALL SITES	PERIOD	TIME	L_1	L_{10}	L_{50}	L_{90}	L_{eq}
A1	Day	11:00 am - noon	80	72	64	60	69
	Peak	4:30 - 5:30 pm	83	74	66	61	71
	Evening	9:00 - 10:00 pm	78	69	61	55	66
	Night	11:30 pm - 12:30 am	73	64	57	51	61
A3	Day	11:00 am - noon	79	72	68	65	70
	Peak	4:30 - 5:30 pm	77	71	67	62	68
	Evening	9:00 - 10:00 pm	76	71	64	58	77
	Night	11:30 pm - 12:30 am	70	63	55	51	60
A4	Day	11:00 am - noon	80	74	68	62	70
	Peak	4:30 - 5:30 pm	83	78	69	61	73
	Evening	9:00 - 10:00 pm	84	79	68	62	74
	Night	11:30 pm - 12:30 am	79	70	59	53	67
OFF-MALL SITES							
A9	Day	11:00 am - noon	82	73	64	58	70
	Peak	4:30 - 5:30 pm	82	74	68	62	71
	Evening	9:00 - 10:00 pm	80	72	64	57	69
A10	Day	11:00 am - noon	79	72	66	61	69
	Peak	4:30 - 5:30 pm	85	76	69	63	74
	Evening	9:00 - 10:00 pm	82	75	66	59	71
A11	Day	11:00 am - noon	82	71	64	60	69
	Peak	4:30 - 5:30 pm	84	74	67	62	72
	Evening	9:00 - 10:00 pm	64	57	50	46	54
A12	Day	11:00 am - noon	77	72	66	61	68
	Peak	4:30 - 5:30 pm	82	78	72	66	74
	Evening	9:00 - 10:00 pm	73	65	60	56	63

Mall on the noise environment, as well as to test noise levels which had been predicted for the Mall by both DEQ and in the Final EIS.

The Division took noise measurements on six different days, two times on SW Sixth Avenue and four times on SW Fifth Avenue from several site locations between October 1975 and April 1981. Three of the noise measurement sets recorded at Sites B1, B2 and B3, on SW Fifth Avenue were selected for this Noise Impacts study. All measurements were recorded on weekdays. Only Site B1 provides before-Mall noise data; Sites B2 and B3 provide after-Mall data. All three site locations are illustrated in Figure 2 on page 32 in this report, and their site location descriptions are found in Table AX-3 in this section. Statistical noise levels for before-Mall Site B1 are found in Table AX-4.

Before-Mall Site B1 noise measurements on SW Fifth Avenue were taken for a 12-hour period beginning at 6:48 a.m. and ending at 5:45 p.m. on Wednesday, January 21, 1976. Measurements were taken from the third floor fire escape of Lipman's Department Store (now Frederick and Nelson), about 12 feet from the building. The site is located on the west side of SW Fifth Avenue, mid-block between SW Washington and SW Alder Streets.

The primary sampling equipment used for the noise measurements included a GR 1933 Type I sound level meter coupled to a Wang 600 programmable calculator and a Sony TC 800B tape recorder. The Wang calculator was used to sample the statistical noise levels and the Sony recorder was used to make a permanent record. The back-up equipment was a B & K 166B/S45 Environmental Noise Classifier. The Wang and the Classifier ran continuously while the Sony ran periodically.

TABLE AX-3

SOURCE B
SITE LOCATION DESCRIPTIONS
BEFORE-MALL AND AFTER-MALL
ON-MALL

BEFORE-MALL SITE	LOCATION DESCRIPTIONS
B1	West site SW Fifth Avenue, mid-block between SW Alder & SW Washington Streets, 3rd floor fire escape, 12 feet from building.
AFTER-MALL SITES	
B2	East side SW Fifth Avenue, mid-block between SW Alder & SW Washington Streets, 3rd floor level.
B3	Same location as Site B2.

TABLE AX-4

SOURCE B - SITE B1
STATISTICAL NOISE LEVELS (dBA)
BEFORE-MALL
ON-MALL

TIME	L_1	L_{10}	L_{50}	L_{90}	L_{eq}
6:48 - 7:00 am	81	75	69	64	71.3
7:25 - 7:37	84	78	72	66	73.97
7:40 - 8:00	83	79	73	70	74.78
8:14 - 8:34	81	77	72	66	73.2
8:40 - 9:00	82	76	71	67	72.3
9:14 - 9:34	80	75	70	66	71.54
9:40 - 10:00	79	75	71	66	71.68
10:05 - 10:25	79	74	69	65	70.14
10:35 - 10:55	79	74	69	65	70.45
11:05 - 11:25	80	75	70	67	71.93
11:30 - 11:50	79	75	70	66	71.33
12:05 - 12:25 pm	81	75	69	66	71.45
12:38 - 12:58	80	74	70	67	71.3
1:05 - 1:25	79	74	71	67	71.44
1:32 - 1:52	82	75	70	67	73.00
2:00 - 2:20	80	75	71	67	71.8
2:30 - 2:50	81	75	70	66	71.86
3:08 - 3:28	82	77	72	68	73.16
3:30 - 3:50	79	74	70	66	71.23
4:00 - 4:20	79	75	70	66	71.33
4:29 - 4:49	82	77	73	69	73.77
4:55 - 5:15	82	77	73	70	73.9
5:25 - 5:45	80	76	71	67	71.9

$L_{eq}(12) = 72.2$

AFTER-MALL SOURCES

Source B: Same as above.

Sites B2 and B3 provide after-Mall noise measurement data. Statistical noise levels for Site B2 are presented in Table AX-5 and for Site B3 in Table AX-6.

After-Mall Site B2 noise measurements were recorded by DEQ procedures (20) from 7:03 a.m. to 4:13 p.m. on Thursday, April 6, 1978, from the third floor of the Yeon Building on SW Fifth Avenue. The site was located mid-block between SW Alder and SW Washington Streets, on the east side of the street. Construction of the Transit Mall was completed by this date, and buses were operating one-way southbound (uphill) on SW Fifth Avenue.

TABLE AX-5

SOURCE B - SITE B2
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
ON-MALL

TIME	L_1	L_{10}	L_{50}	L_{90}	L_{eq}
7:00 - 8:00 am	82	77	70	66	74.2
8:00 - 9:00	81	76	69.5	66	73.1
9:00 - 10:00	80.5	75	68	64	71.8
10:00 - 11:00	79.1	74	69	65	71.4
11:00 - 12 noon	80.5	75	69	65	72
12:00 - 1:00 pm	81	75	69	66	72.3
1:00 - 2:00	82	75	70	66	73.1
2:00 - 3:00	80	74	69	65	72
3:00 - 4:00	83	76	70	66	73.8

$L_{eq}(12)$ = approximately 72.7

After-Mall Site B3 shared the same location as Site B2. Noise measurements were taken by standard DEQ procedures (20) from 7:00 a.m. to 7:00 p.m. on Wednesday, April 22, 1981.

TABLE AX-6

SOURCE B - SITE B3
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
ON-MALL

TIME	L_1	L_{10}	L_{50}	L_{90}	L_{eq}
7:00 - 8:00 am	84	78	71	66	75.4
8:00 - 9:00	83	77	70	67	73.8
9:00 - 10:00	82	76	70	67	73.9
10:00 - 11:00	81	75	70	67	72.4
11:00 - 12 noon	82	75	69	67	73.5
12:00 - 1:00 pm	81	75	70	67	72.6
1:00 - 2:00	81	75	70	67	72.5
2:00 - 3:00	81	75	70	67	72.9
3:00 - 4:00	82	76	70	67	73.2
4:00 - 5:00	83	77	72	68	74.8
5:00 - 6:00	83	78	72	67	75.3
6:00 - 7:00	81	75	69	65	72.5

$L_{eq}(12) = 73.6$

<u>Source C:</u> <u>The City of Portland Urban Noise Survey</u>, U.S. EPA, March 1979.

The City of Portland recorded noise measurements at 17 sites downtown in 1979 while under contract to the U.S. Department of Housing and Urban Development to conduct a noise survey in the downtown area. The overall work program encompassed three major elements:

- o The measurement of variations of the downtown community noise environment based on continuous 24-hour monitoring and short duration noise samples.

- The measurement of bus noise levels within and adjacent to the downtown Transit Mall using nighttime simulated bus traffic and actual daytime operations.
- The design of a model for predicting the City noise environment and for testing abatement strategies for compliance with the U.S. Department of Housing and Urban Development (HUD).

Results of the first work element provide after-Mall data useful for this Noise Impacts study. The 17 sites were selected for the HUD noise survey on the basis of their proximity to proposed redevelopments for the purpose of comparison with HUD noise standards for housing. Noise measurements were continuously recorded and calibrated every 24 hours from a stationary reference location at each site, and supplementary 15-minute samples were taken at four different points very near the reference locations. Measurements were made in January and February of 1979. Of the seventeen measurement sites, only six were selected for this Noise Impacts study, and in each case, the noise measurements recorded at the stationary reference location were the figures utilized.

The 24-hour monitor was placed at the most convenient location for each site. Generally, the microphone was placed from 14 to 39 feet above the ground and at least 4 feet from a building facade. The microphones were part of a weatherproof B & K 4921 Outdoor Microphone System.

The monitoring equipment included a digital recorder, a weatherproof Metrasonics db 602. The recorder stored values of L_{eq}, L_{90}, L_{50}, and L_{10} for each 30-minute interval (at four sites, 15-minute intervals were used) during the 24-hour period. System calibration was performed at the beginning and end of each 24-hour measurement period.

Two (C1, C21) of the six selected sites were located on the Mall and four (C8, C9, C10, and C14) were located off the Mall. All measurements were taken from a second or third floor level, and all sites were located at mid-block points. The locations of the six sites are illustrated in Figure 2 on page 32 of this report, and their location descriptions are found on Table AX-7 in this section. Tables AX-8 through AX-13 present the statistical noise levels for the six sites.

TABLE AX-7

SOURCE C
SITE* LOCATION DESCRIPTIONS
AFTER-MALL
ON-MALL AND OFF-MALL

ON-MALL SITES	LOCATION DESCRIPTION
C1	East side SW Fifth Avenue, mid-block between SW Morrison & SW Yamhill Streets, 2nd floor fire escape.
C21	East side of SW Fifth Avenue, mid-block between SW Alder & SW Washington Streets, 3rd floor fire escape.
OFF-MALL SITES	
C8	East side Broadway, mid-block between W. Burnside & NW Couch Streets, 3rd floor fire escape.
C9	North side of SW Washington Street, mid-block between SW Sixth Avenue and SW Broadway, 2nd floor ledge.
C10	South side SW Madison Street, mid-block between SW Sixth Avenue & SW Broadway, 2nd floor fire escape.
C14	South side of SW Taylor Street, mid-block between SW Alder & SW Washington Streets, 3rd floor fire escape.

*Microphone at all sites was 4 to 5 feet from the building.

TABLE AX-8

SOURCE C - SITE C1
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
ON-MALL

PERIOD	TIME	L_{10}	L_{50}	L_{90}	L_{eq}
Day	11:00 - 11:15 am	73	66	62	71
	11:15 - 11:30	73	67	62	71
	11:30 - 11:45	72	67	63	70
	11:45 - 12 noon	73	67	63	71
Peak	4:30 - 4:45 pm	75	69	64	73
	4:45 - 5:00	77	70	66	75
	5:00 - 5:15	77	71	65	75
	5:15 - 5:30	79	73	69	76
Evening	9:00 - 9:15 pm	66	60	54	65
	9:15 - 9:30	64	59	55	63
	9:30 - 9:45	75	66	54	74
	9:45 - 10:00	68	59	55	67
Night	11:30 - 11:45 pm	73	66	60	70
	11:45 - 12 midnight	67	62	58	65
	12:00 - 12:15 am	70	66	62	68
	12:15 - 12:30	65	66	56	63

TABLE AX-9

SOURCE C - SITE C21
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
ON-MALL

PERIOD	TIME	L_{10}	L_{50}	L_{90}	L_{eq}
Day	11:00 - 11:15 am	73	67	63	71
	11:15 - 11:30	72	66	63	70
	11:30 - 11:45	72	65	63	70
	11:45 - 12 noon	72	67	63	70
Peak	4:30 - 4:45 pm	76	69	65	74
	4:45 - 5:00	75	69	65	73
	5:00 - 5:15	77	72	69	75
	5:15 - 5:30	76	70	66	74
Evening	9:00 - 9:15 pm	65	60	56	63
	9:15 - 9:30	70	64	58	68
	9:30 - 9:45	72	62	57	69
	9:45 - 10:00	65	59	56	63
Night	11:30 - 11:45 pm	71	60	55	67
	11:45 - 12 midnight	63	58	55	62
	12:00 - 12:15 am	72	66	61	69
	12:15 - 12:30	73	69	65	71

TABLE AX-10

SOURCE C - SITE C8
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
OFF-MALL

PERIOD	TIME	L_{10}	L_{50}	L_{90}	L_{eq}
Day	11:00 - 11:30 am	70	66	64	76
	11:30 - 12 noon	69	66	64	68
Peak	4:30 - 5:00 pm	71	67	65	70
	5:00 - 5:30	69	66	64	68
Evening	9:00 - 9:30 pm	67	63	60	65
	9:30 - 10:00	67	63	60	66
Night	11:30 - 12 midnight	66	62	58	65
	12:00 - 12:30 am	66	61	57	64

TABLE AX-11

SOURCE C - SITE C9
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
OFF-MALL

PERIOD	TIME	L_{10}	L_{50}	L_{90}	L_{eq}
Day	11:30 - 12 noon	70	66	63	68
Peak	4:30 - 5:00 pm	71	66	64	69
	5:00 - 5:30	71	67	64	69
Evening	9:00 - 9:30 pm	69	63	60	66
	9:30 - 10:00 pm	69	63	59	67
Night	11:30 - 12 midnight	67	61	58	65
	12:00 - 12:30 am	67	61	58	64

TABLE AX-12

SOURCE C - SITE C10
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
OFF-MALL

PERIOD	TIME	L_{10}	L_{50}	L_{90}	L_{eq}
Day	11:00 - 11:30 am	72	67	64	70
	11:30 - 12 noon	71	67	64	70
Peak	4:30 - 5:00 pm	70	66	64	69
	5:00 - 5:30	70	67	64	69
Evening	9:00 - 9:30 pm	66	60	57	65
	9:30 - 10:00	66	61	57	64
Night	11:30 - 12 midnight	63	56	53	62
	12:00 - 12:30 am	64	56	52	63

TABLE AX-13

SOURCE C - SITE C14
STATISTICAL NOISE LEVELS (dBA)
AFTER-MALL
OFF-MALL

PERIOD	TIME	L_{10}	L_{50}	L_{90}	L_{eq}
Day	11:30 - 12 noon	72	67	64	73
Peak	4:30 - 5:00 pm	73	69	64	71
	5:00 - 5:30	73	69	65	72
Evening	9:00 - 9:30 pm	70	64	62	69
	9:30 - 10:00	71	65	62	68
Night	11:30 - 12 midnight	71	64	62	69
	12:00 - 12:30 am	69	63	61	66

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