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Agency

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Noise

# Noise and Urban Pedestrian Areas

United States
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NOISE AND PEDESTRIAN AREAS

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# Executive Summary

This study consists of three reports which treat the subject of noise within the context of urban pedestrian areas. The main concern of the study is noise mitigation, although its contents cover a wide range of topics related to noise in the urban environment. The first report provides a description of existing noise mitigation techniques which have application to pedestrian improvement areas. The second report summarizes the actual application of noise mitigation techniques to pedestrian areas based on the results of a questionnaire sent to pedestrian projects throughout the country. The second report also includes the formulation of noise abatement criteria for the design of Broadway Plaza, a proposed pedestrian project in New York City. The third report analyzes actual noise levels and attitudes by pedestrians toward noise in several public plazas in New York City based on actual noise monitoring and attitudinal surveys conducted in the plazas.

The first report, "Noise Mitigation Techniques for Pedestrian Areas: State-of-the Art," is intended to serve local governments as a planning guide to noise mitigation techniques appropriate to pedestrian improvements. Although extensive research has been done on noise mitigation and on pedestrian areas, little analysis has been done treating the two subjects together. As a consequence, the noise mitigation techniques which have potential for applicatic in pedestrian areas have been drawn from a variety of other applications.

Noise in urban areas is varied and comes from many sources simultaneousl} However, noise can be categorized according to the three parts of its journey as a sound wave, viz., (1) at its source; (2) along its path, and (3) at the point where it is heard or "received." Noise mitigation techniques for pedestrian areas, which are examined in this first report of this study, can be similarly grouped into these three headings. A fourth category has been added to include those measures which do not attempt to directly control noise through physical means but rather through institutional or regulatory measures.

These four categories are further divided according to application of each type of noise mitigation technique. For example, noise mitigation techniques applicable to source noise include: mandating or selecting quiet equipment; modifying an existing source of noise; enclosing the source; noise management procedures for source noise; site design for source noise, and development of alternative noise sources. The subject of noise mitigation techniques along the path of noise transmission is discussed under the headings of: shielding and buffering. Mitigation techniques applicable to noise at the point where it is heard or received are best understood by the term "isolation". Finally, institutional methods of noise mitigation are presented under two general headings: 1. funding and 2. public awareness campaigns. The classifications of mitigation techniques used here is not intended to establish a strict framework for urban noise, which is not susceptible in all cases to such neat categorization. Rather, it is one way in which noise can be understood so that appropriate mitigation techniques can be more easily identified.

The second report, "The Application of Noise Mitigation Techniques in Pedestrian Areas," goes beyond the conceptual treatment of noise as presented in the first report to an understanding of the environment of the pedestrian area. The concern of this report is to determine how noise has actually been treated in the planning, design and/or operation of pedestrian areas which have been or are being constructed in the United States. A questionnaire was prepared and sent to eighteen malls throughout the country under the aegis of the United States Conference of Mayors. Sixteen malls answered the questionnaire and an analysis of the results is included here. The analysis showed that nearby surface transportation vehicles are the major contributors to the noise levels in and around pedestrian areas. Another major source of noise is construction equipment. Efforts to mitigate the noise from these sources include rerouting vehicles away from the pedestrian area,the use of masking noise to prevent unwanted sound intrusion, retrofitting buses and construction equipment, the use of temporary enclosures around construction equipment, limiting the hours during which construction is permitted and purchasing quieter construction equipment.

Very little was done by the malls surveyed to use design elements as sound attenuators. Only a few malls monitored the noise before the mall was built and only one monitored noise after construction was completed. On the whole, the use of noise mitigation techniques appeared not to have been of critical concern to the surveyed malls. A notable exception was the Portland Mall, which was selected for analysis as a case study because of its various efforts to mitigate noise through design as well as through operational and engineering means. The case study on the Portland Mall included in this report reveals that the major contributor to noise levels on the Portland Mall is the diesel bus. The City of Portland has undertaken a bus retrofit program in an effort to quiet bus noise.

The last part of this report formulates noise abatement criteria for Broadway Plaza, a proposed pedestrian project in New York City. The schematic design of the project was analyzed and suggestions were made for possible noise mitigation measures. Operational procedures for vehicular traffic were also recommended for the purpose of controlling noise. The recommendations will be evaluated in terms of their feasibility for implementation in the project in light of the project's objectives and such factors as cost.

The main focus of the third report, "An Evaluation of Noise and Urban Spaces," was to determine if certain design elements commonly found in public spaces have any effect on the reduction of noise. To accomplish this, several public plazas in New York City were monitored for noise. Based on this study, several factors appear to have some effect on the reduction of noise levels, viz., changes in site elevation, distance from the noise source and walls positioned between the source and recipient of noise.

Such elements as benches, statues, trees, shrubbery and other vegetation have little effect on the attenuation of noise. Furthermore, tall buildings around the pedestrian area cause sound to reverberate and noise is unable to dissipate in that type of environment. Based on these findings, a nomograph and calculation methodology were developed to assist designers and planners in projecting noise levels and speech interference levels for pedestrian projects. In addition, a methodology was developed based on traffic and design factors as a means for projecting noise levels for individual pedestrian projects. This methodology will provide project planners and designers with a better understanding of the results of various operational and design factors on potential noise propagation and, consequently, on the relative quiet of the proposed space.

This report also considers the sensitivity and awareness of noise by the people using pedestrian spaces. A survey was developed to determine how pedestrians perceive noise in a public outdoor space in relation to their use of that space and compared with other environmental problems. The attitudinal survey indicated that the majority (63 percent) of plaza users were either not bothered or only somewhat bothered by plaza noise. When asked which plaza design element would best reduce noise, 34 percent of those daytime users surveyed selected trees. In reality, the most effective means for mitigating noise in an outdoor plaza is a wall which, if placed between a noise source and a noise recipient, can serve as a barrier. However, only 13 percent of daytime users favored using walls as a design element. The surveys also showed that most people interviewed visited the space between three and five times a week, with most of the visits occurring during lunch hours. The activity enjoyed by many was "people watching." Most tended to stay between 15 and 30 minutes and many expressed a desire for more landscaping, in the form of trees and waterfalls, in these public spaces.

This study introduces the subject of noise in the urban environment and the range of noise mitigation possibilities suitable for public pedestrian spaces. The intent of the study is twofold: to serve as an introduction to the subject of noise and urban pedestrian areas as well as an impetus for continued exploration.

# I. Noise Mitigation Techniques for Pedestrian Malls: State-of-the-Art

## 1.0 INTRODUCTION

The information compiled in this report is being done to aid in understanding which noise mitigation techniques are appropriate in the planning, design, construction and operation of pedestrian-related projects. Noise can be categorized according to the three parts of its journey as a sound wave, viz., (1) at the source; (2) along the path, and (3) at the point where it is heard or "received." Noise mitigation techniques for pedestrian areas, which shall be examined here, can be similarly grouped into these three headings. A fourth category has been added to include those measures which do not attempt to directly control noise through physical means but rather through institutional or regulatory means.

Although the subjects of noise mitigation and pedestrian areas are not new concepts, there is little data that treat the two of them together. Consequently, the techniques discussed below have been drawn from a variety of applications but have potential for application to pedestrian areas.

Within the first three major categories of noise control, similar techniques of noise mitigation have been grouped together. Where appropriate, existing applications of the technique are included.

Chapter 2.0, which examines "Mitigation Techniques at the Source of Noise," includes six generic techniques appropriate to pedestrian areas. They are: (1) mandating or selecting quiet equipment; (2) modifying an existing source of noise; (3) enclosing the source of noise; (4) noise management procedures for source noise; (5) site design for source noise; (6) development of alternative noise sources.

Chapter 3.0, "Mitigation Techniques Along the Path of Noise Transmission," includes two generic techniques: (1) shielding, and (2) buffering.

Chapter 4.0, which discusses "Mitigation Techniques at the Receiver End of Noise," explores the technique of isolation.

Chapter 5.0, "Institutional Methods of Noise Control," incorporates mitigation measures which do not attempt to control noise through strictly physical means.

## 2.0 MITIGATION TECHNIQUES AT THE SOURCE OF NOISE

All noise originates from a source; in urban areas it emanates from many sources at once. In these areas, pinpointing exact sources of certain noises may become quite involved, given the number of noises that are heard simultaneously from different sources (e.g., bus, truck, auto) and even from the same source (e.g., bus exhaust, bus transmission, bus tires).

It is also important to realize that each type of noise may have its own peculiarities. Low frequency noise may pose different problems for noise control than high frequency noise. Impact noise associated with a loud sound of short duration is not the same as ambient or background noise level, which is a continuous type of noise ranging across a broad band spectrum.

There are several generic techniques to control noise at its source. They are (1) mandating or selecting quiet equipment; (2) modifying an existing source of noise; (3) enclosing the source; (4) noise management procedures for source noise; (5) site design for source noise; and (6) development of alternative noise sources.

### 2.1 Mandating or Selecting Quiet Equipment

An obvious way to mitigate noise levels is to purchase the quietest model possible of the equipment needed for the pedestrian area.

The U. S. Environmental Protection Agency (USEPA) has instituted a program to regulate the permissible noise levels emanating from certain new products which that agency considers major contributors to noise. Manufacturers of these products must meet the noise level regulation in order to market their goods. Some affected product lines are: portable air compressors, medium and heavy trucks, and pavement breakers. Future candidates for noise control are: autos and air conditioning units. A complementary part of this regulatory program is the requirement that all Federal government agencies purchase the quietest model of equipment which is available and suitable for their use.

Several cities are undertaking a similar approach. For example, the City of Portland is in the process of purchasing quieter buses to help decrease the noise levels along the length of their mall. However, since specific noise levels are not indicated on the purchase specification, it is not known how they will compare with current bus models in service use. This effort is independent of a bus retrofit program which is discussed in Chapter II.

Similar strategies involving product selection can be employed for pedestrian improvement areas. Land owners whose properties abut a pedestrian mall may voluntarily agree to install the quietest possible equipment needed for the safe and efficient operation of their buildings or machinery. Another possibility is that a mall association or operator may institute a maximum decibel limit for noise from participating or abutting properties. This could present difficulties if noise emitted from unregulated sources, e.g., passing vehicles, is greater than the established limit. A third illustration of this technique is the voluntary purchase by the mall association of equipment needed to maintain and operate the mall.

2.2 Modifying an Existing Source of Noise

If it is impossible to acquire quiet models of equipment, modifying that equipment to reduce its noise may be possible. This technique involves physically altering the source itself. This technique is best illustrated in the efforts made to control noise from subways, vehicles and construction and building equipment.

The program for subway equipment modification, instituted by the New York City Transit Authority, aims to reduce noise in the transit system by 10 dBA within ten years through modifications to the rails, braking system and wheels of existing equipment.

Subway noise, audible through sidewalk ventilation chambers, can be significantly intrusive in pedestrian areas. The ventilation chambers may be prime candidates for the application of noise mitigation techniques. Appropriate techniques related to subway ventilation chambers will be discussed below in the section related to path noise. As is the case with all of these techniques, it should be mentioned early that the expense associated with their application may make such efforts feasible for only those pedestriar sites where the area impacted by the noise is significant enough for the technique to be cost-effective.

Various efforts are underway to modify vehicular noise. The Washington Metropolitan Area Transit Authority, in conjunction with the U.S. Department of Transportation (DOT) sponsored a project to reduce the noise emanating from its bus fleet. The project demonstrated the need to work on modifications to the engine, exhaust, intake and cooling systems of the coaches to reduce noise. In addition, DOT has established a TRANSBUS program with the objective of designing a state-of-the-art transit coach. Part of the total project is the attainment of an exterior noise level in the 75 decibel (dBA) range. Another part of the quiet bus program instituted by the City of Portland has been to modify the bus engine compartments of its existing fleet and to install retrofit noise reduction packages, which consist of turbocharging the engine, new mufflers, resonators, revised tail pipes and engine compartment absorption.

Noise emanating from construction and building machinery contribute to the increase in outdoor noise levels. The retrofit of such equipment with such sound attenuators as mufflers, silencers and filters would help to modify the source noise contributed by that equipment to reduce its effect on pedestrian areas and on adjacent facilities. Proper handling and maintenance of the equipment prevents parts from wearing out and avoids the situation of raising noise levels unnecessarily. The institution of a program that regularly inspects and maintanins the working order of such equipment is a step in this direction.

### 2.3 Enclosing the Source of Noise

If the selection or modification of source noise is impossible, another technique involves enclosing the noise source to keep the noise from escaping into the surrounding environment. Enclosures are sound insulating structures designed for the total containment or exclusion of a sound field.

Many types of sound resistant enclosures are manufactured to conform to a wide variety of shapes and sizes. A most popular method of enclosure material uses sheet steel for the external insulation surface. This is normally lined with approximately 2 inches of non-flammable absorbent material. Such material can be made for a variety of uses as acoustic screens, partial enclosures, hoods or even large weather-resistant buildings. The rule concerning enclosures is that no apertures should exist that will permit sound leakage.

The most logical consequence of this technique for pedestrian mall areas is to encase any noise source on or adjacent to the site for the purpose of inhibiting its sound field from escaping into the surrounding environment. Noise from machinery located on buildings adjacent to the pedestrian mall may be prime candidates for such a technique. Also, covering the loading bays of delivery trucks is another application of such a technique.

## 2.4 Noise Management Procedures for Source Noise

When the techniques discussed above are considered impractical and the noise level still persists, operational controls may help to remedy the situation. Noise management procedures may not actually eliminate the measurable sound, but could help to prohibit, schedule and/or redirect noise from sensitive areas, including the pedestrian area and, perhaps, adjacent facilities or buildings.

An example of outright prohibition exists in many municipal noise ordinances. A case in point is the prohibition of noise in the establishment of a hospital zone or school zone. The creation of auto restricted zones with a complete prohibition of vehicles can be an effective measure in reducing noise levels in pedestrian areas.

Limiting or scheduling noise to certain hours is an example of the time-of-day management technique. As an example, many airports do not permit takeoffs and landings during nighttime hours when the possibility of interference with the sleep of the affected populace exists. In the case of pedestrian areas, a parallel example can be made by limiting the time when noise-producing sources, such as delivery trucks, are allowed in or near pedestrian areas. Another possibility is to limit construction activity, which is a major irritant to nearby people, to certain times of the day. The times of permissible noise activity may be able to coincide with periods of user inactivity. Thus, truck deliveries to the pedestrian sites could be limited to nighttime or early morning hours. Likewise, maintenance equipment could also be scheduled for use at times when the pedestrian area is least populated.

Management procedures may be used to direct noise away from sensitive areas. For instance, the Federal Aviation Administration (FAA) has instituted flight procedures for aircraft takeoffs and landings in some areas. Takeoff and approach paths are planned to take advantage of the least sensitive areas around some airports. A similar strategy can be utilized for pedestrian areas. The rerouting of traffic around sensitive areas may reduce noise levels there. In addition, traffic management procedures can be instituted to control traffic flow, speed and turning movements. Realizing that acceleration and braking activity can cause increased levels of noise, the use of signalization and other traffic aids can help to prevent excess vehicle starting and stopping, illegal or hazardous turns causing sudden braking, congestion and driver frustration which results in the use of horns.

Another dimension to noise management is instituting procedures for user operations. Considerate use of noise-producing equipment by its operators can alleviate much noise. A case in point is the FAA's strategy with respect to aircraft operation. FAA has advocated such measures as reduced thrust settings near the ground and the use of minimum certified flaps to reduce aerodynamic drag in an effort to decrease noise levels through user controls. While this approach may prove diffucult to implement for the myriad of users of a pedestrian area, visual reminders in the form of signs or traffic control devices, such as signalization, may be indirectly effective in controlling the operation of noise sources by their users. A more direct approach is to institute training programs that instruct operators of noisy equipment in ways to use their equipment more quietly (e.g., bus driver training programs).

## 2.5 Site Design for Source Noise

If noise control is considered early enough in a project, site planning and design can be instrumental in reducing noise. The placement of noise sources and selection of the materials used for site construction and design can help to reduce noise levels.

In designing a pedestrian area, consideration should be given to those parts of the site where pedestrian activity will take place as well as to adjacent land uses which could be sensitive to noise emanating from the mall itself. In this way, sources of noise can be placed far enough away from these activity nodes or sensitive areas as possible.

In another vein, the type of materials used for the construction of the site is important. An example of this is road surfacing. The roughness of the roadway adjacent to a pedestrian area may raise the noise level due to tire-roadway friction. The United States Environmental Protection Agency and the Federal Highway Administration are currently studying this problem. Secondly, a wet roadway surface can raise the noise level. With this in mind, roadway surfaces may be designed to produce faster runoff and to be made of material that dries more quickly. Within the pedestrian mall itself, consideration can be given to the materials used for building facades and the mall's pavement. For example, concrete reflects sound resulting in the reverberation of sound waves and the further propagation of the noise. Orienting facades of such hard material to reflect sound away from noise sensitive areas or treating them with sound absorbent materials may be successful applications of this approach.

The use of vegetation can have a positive psychological effect on the users of pedestrian areas by way of creating the effect of a serene ambience or by visually shielding actual noise sources. It has been demonstrated that sound measurements taken in front of and behind a hedge row results in a difference of approximately one decibel. Since the human ear can only detect differences in the sound pressure level of 3-5 decibels, it can be seen that moderate amounts of vegetation per se do not attenuate noise to any noticeable extent. However, creative use of vegetation materials can create a feeling of a quieter area and contribute to the perception of a more pleasant surrounding.

## 2.6 Development of Alternative Noise Sources

Creating another sound that masks the undesirable noise is a technique to drown out unwanted noise sources. This technique, however, should never be used to drown out noise which may be hazardous to a person's hearing. Sounds are masked only by rival sounds that are quite near them in pitch. Effective masking, therefore, requires a broad band source of masking noise if the situation requires predicting the frequency range in advance or dealing with broad band interference. Therefore, the criteria for producing a masking noise are: (a) to create a steady sound of a low intensity with a wide band frequency distribution void of any pure tones, (b) to produce an omnidirectional source, and (c) to provide the masking noise with the ability to override intruding noise without becoming annoying itself.

Masking noise has taken the form of fountains, artificial waterfalls, and piped-in music. Of these, the most effective seems to be the waterfall, where the natural splashing sound is of sufficient intensity to mask less agreeable noise. The introduction of masking noise in pedestrian areas is possible in the form of artifical waterfalls in certain areas. The masking noise could be effective in its immediate surrounding environs, where sitting, eating or reading activities may be desired. The effect of the masking noise will be lost, however, the further a user of the pedestrian area travels away from it. Some piped-in music for certain activities such as outdoor cafes may prove successful as a masking noise depending upon the sound intensity of rival noises.

## 3.0 MITIGATION TECHNIQUES ALONG THE PATH OF NOISE TRANSMISSION

An airborne sound field, once established, travels through a medium (e.g., air, water), before reaching a receiver of that sound. The sound is said to travel along a path. In the case of pedestrian areas, the medium is air. Sound waves, once introduced into the air, can be refracted, diffracted, reflected, diffused or dissipated. Of these, diffraction and dissipation are most susceptible to noise mitigation for pedestrian improvement areas through the techniques of shielding and buffering. The principle of sound diffraction will be discussed in the context of the technique of "shielding"; the principle of sound dissipation in conjunction with the technique of "buffering."

### 3.1 Shielding

Diffraction occurs when the sound waves become bent around a solid object or barrier. Once emitted from a source the sound waves travel until they strike the barrier. Depending on the height, size and composition of the barrier, part of the sound wave hits the barrier and a path loss occurs. The other part of the wave becomes bent as it moves over the barrier, thereby suffering a path loss as well. The effect of this path loss is a reduction of the decibel level.

The composition, configuration and placement of shields or barriers determine their effectiveness. The greater the diffraction of the sound waves, the more effective the barrier becomes. Barriers can either be natural or artificial. Artificial barriers have been placed adjacent to highways in some areas to block noise emanating from highway traffic. In some areas, buildings housing daytime activities, such as office buildings, have been placed between heavy traffic arteries and residential dwellings to prevent noise from intruding on the residential areas at night. Natural barriers, such as berms and hills, have also been used effectively to block sound in highway designs.

Screening has been substituted in some cases for barriers. However, lightweight material is not an effective substitute for a barrier structure. Conventional barriers consist of three construction elements - a foundation, a supporting structure and sound absorbing material. Construction of sound absorbing barriers requires material which is capable of absorbing penetrating sound energy and transforming that sound energy into heat. Stone wool panels, for instance, 50mm in thickness with a density of 100Kg/m , have proven effective against road traffic noise. A sound reflecting wall is erected as part of the barrier behind the absorbing material so double penetration is possible as the sound wave first penetrates the material then reflects back through it. An intermediate air gap is provided between the absorbing elements and the reflecting backwall to improve performance. An effective barrier can reduce noise levels by 5-15 dBA.

Barriers, ideally, should not have apertures along their lengths which permit noise seepage. While they have proven effective when placed alongside highways, the use of such continuous structures along roads adjacent to busy pedestrian areas probably is, in most cases, impractical. However, other objects may be used in similar fashion as barriers in pedestrian areas, although their effectiveness will not be as significant. For instance, the placement of bus shelters or taxi stands can be utilized as partial barriers against traffic noise, with their shelter sides facing away from the traffic. Mall furniture, sculptures, table umbrellas may be used, although they may be of marginal benefit in attenuating noise. The use of these and various other objects can be positioned in many ways to provide for some relief against noise levels. The significant intrusion of subway noise through sidewalk ventilation chambers was alluded to above. Treating the walls of these chambers with absorption material may help to transform the ventilation chamber into a sound attenuator. The useful application of commonly found objects in pedestrian malls for noise mitigation purposes is limited only by the physical constraints of the site and the imagination of the designers. Such objects can be used in conjunction with trees, shrubs, berms and isolated standing walls to create a more serene type of environment.

3.2 Buffering

As a sound wave begins to travel away from its source, its intensity decreases until, at a certain distance, the sound is not heard. Increasing the distance between noise source and noise receiver is termed buffering. One of the physical properties of sound is its decreasing intensity with distance (dissipation property). Doubling the distance between a point source of noise (e.g. siren) and the receiver of noise in an "open sound field" may decrease the sound pressure level by 6 decibels; from a line source (roadway) the rule of thumb is that the sound pressure level decreases by 3 decibels when the distance is doubled. However, in most urban areas, the "open field" is non-existent as buildings and other objects reflect sound, causing further sound propagation.

Buffering has been used in the areas of land use planning and zoning. Buffer zones have often been required between different types of abutting land uses to protect against nuisances and encroachments. Purchases of land for easements and excess land acquisitions are other land use measures that may be applicable in buffering pedestrian areas from noise intrusions. However, given the density of development usually surrounding pedestrian areas in center cities, any forms of the above examples of buffering may be expensive, cumbersome to accomplish, and impractical for significant reductions in noise levels based on the dissipation properties of sound.

## 4.0 MITIGATION TECHNIQUES AT THE RECEIVER END OF NOISE

Once noise has been emitted from a source and has travelled through a medium along its path, it remains to be heard or felt by a person or an object. The primary technique to mitigate noise at that point involves isolating the "receiver."

### 4.1 Isolation

Isolation at the point where noise is heard or "received" is similar to the enclosure technique for source noise. Just as the noise source was enclosed in that technique, the receiver is similarly isolated.

For pedestrian areas, an example of this technique would be to isolate any programmed activities (i.e., the dispensing of tourist information) in enclosed structures if verbal communication could be adversely affected by surrounding noise sources.

Exterior areas requiring quiet for pedestrian activities might also be partially isolated from adjacent noise sources through changes in site elevation. By creating partially enclosed pedestrian levels below the level of the noise source or by locating the source of noise in a depressed area (e.g. a roadway cut), the receiver's exposure to the sound waves is decreased. The cost of constructing such site elevation changes, however, may outweigh the benefits derived from a lower noise level.

As a last resort, ear plugs are a classic example of noise isolation practiced on an individual basis.

## 5.0 INSTITUTIONAL METHODS OF NOISE CONTROL

### 5.1 Funding

Strategies which do not attempt to control noise through strictly physical means could be categorized as institutional methods of noise control. One such strategy is to incorporate specific project elements for noise attenuation in the funding process. The Department of Housing and Urban Development (HUD) for instance, has the authority to withhold funds to build or rehabilitate residential dwellings in areas containing unacceptable noise levels. HUD has defined such areas. Likewise, HUD can recommend certain measures to influence the reduction of noise levels in other areas where noise is considered problematic but less than unacceptable. The funding inducement is also present in this case.

Funding can also be used directly to support research on state-of-art noise mitigation techniques, as is presently occurring in many areas of noise control in the United States and foreign countries.

### 5.2 Public Awareness Campaigns

Another method of noise control relies upon familiarizing the public with the potential ill effects of noise through public awareness campaigns. Short film clips, attractively designed signs and posters that would also decorate an area, are some applications of this technique which are appropriate to pedestrian areas and would help bring attention to the noise issue.

## 6.0 CONCLUSION

Existing in the environment around urban malls are many types of noises with their own peculiar characteristics. These various sounds are emitted from a multitude of sources. The emitted sound waves are influenced by the presente of solid objects, wall finishes, site topography, absorbent materials, distance and meteorological conditions. Given the number of variables affecting noise propagation, designers of pedestrian areas concerned about noise attenuation have the option of dealing with noise by employing one or a series of noise mitigation techniques, depending upon the specific characteristics of noise propagation and the objectives of the mall itself. In the case of bus noise, for example, the rerouting of bus routes around the mall, the purchase of the quietest model of buses, retro-fitting existing buses with sound absorbent material, the placement of bus stops away from sensitive areas, and the installation of bus stop shelters to provide some form of barrier between the noise source and pedestrians are noise mitigation alternatives which can be used individually or in combination to address this particular noise problem. It is difficult to predict the effectiveness of one technique over another. Each mall, its character and its resources will be different. Consequently, the ways to deploy the above techniques for noise attenuation, of necessity, reflect that diversity.

# II. The Application of Noise Mitigation Techniques in Pedestrian Malls

## 1.0 INTRODUCTION

The purpose of this report is to synthesize and present information obtained from sixteen transit/pedestrian malls in the United States on the extent to which noise mitigation measures have been incorporated into their planning, design, construction and operation. A second purpose is to apply the findings to a case study. The sixteen malls on which information was obtained are:

1. Lexington Mall - Baltimore, Maryland
2. State Street Mall - Chicago, Illinois
3. Stoneplace Mall - Dallas, Texas
4. River City Mall - Louisville, Kentucky
5. Mid-America Mall - Memphis, Tennessee
6. Lincoln Road Mall - Miami Beach, Florida
7. Nicollet Mall - Minneapolis, Minnesota
8. Chestnut Street Transitway - Philadelphia, Pennsylvania
9. East Liberty Mall - Pittsburgh, Pennsylvania
10. Portland Mall - Portland, Oregon
11. Westminster Mall - Providence, Rhode Island
12. Exchange Street Mall - Raleigh, North Carolina
13. Market Street - San Francisco, California
14. Occidental Mall - Seattle, Washington
15. Gallery Place - Washington, D. C.
16. Library Place - Washington, D. C.

The report is divided as follows:

Chapter 2.0 presents background information on each of the malls. The first section of this chapter consists of one-page summaries of the physical and operational characteristics of each mall, together with a description of the context in which the mall was built (e.g. land use). The second section contains a summary of what were considered potential noise issues and/or problems suggested by the background material collected on each of the projects and indicates how this information was used to structure a noise questionnaire for distribution to the sixteen malls.

Chapter 3.0 focuses on the responses to the questionnaire. The noise questionnaire was intended to determine the extent to which noise was considered in the planning, design, construction and operation of the malls and any mitigation measures which were used to address an identified noise problem. Once developed, the questionnaire was sent to the cities representing the malls by the United States Conference of Mayors. The third chapter is, therefore, divided into two sections. The first section records the responses to each question in both a tabulated and narrative form. The second section offers some conclusions based on an evaluation of the responses and regarding the consideration given by the malls to noise.

Chapter 4.0 presents a case study analysis of the Portland Mall in Portland, Oregon. The case study identifies the various efforts taken to mitigate noise on the Mall through design, operation and engineering.

The last chapter, 5.0, examines a proposed pedestrian project in New York City with respect to possible noise mitigation techniques; the project is presently in the design stage.

## 2.0 BACKGROUND INFORMATION ON SIXTEEN MALLS

### 2.1 Overview

In order to provide an overview of the sixteen malls, a summary sheet was developed which was intended to highlight information on each project, as well as on the project's surrounding environment. For the most part, the information sought was thought to have some bearing on noise. This included the physical characteristics of the project, such as the length, width, area, number of blocks and the types of design features of each mall. Under the category of operational characteristics, information was included on the availability and type of programmed activities, as well as vehicular usage (e.g., transit, traffic, loading and emergency vehicles). The category of "context" was intended for information on the types of adjacent thoroughfares, the population of the Central Business District, the transportation modes used to gain access to the CBD, and types of land uses adjacent to the mall. Lastly, a short summary is provided for each mall to highlight salient features. The overview data is included below. The sources of information for the summary sheets are listed in the bibliography at the end of this section.

## MALL

| | |
|---|---|
| NAME | LEXINGTON MALL |
| LOCATION | BALTIMORE, MD |
| DATE COMPLETED | 1974 |

PHYSICAL CHARACTERISTICS

| | |
|---|---|
| SIZE | |
| LENGTH: | 650' |
| WIDTH : | 62' |
| AREA : | 40,300 SQ FT |
| BLOCKS: | 2 |
| DESIGN ELEMENTS | Trees at grade, landscaping, benches, bollards, street lights , new paving. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | N/A * |
| TRAFFIC/TRANSIT ACCESS | |
| TRANSIT : | None |
| TRAFFIC : | None |
| LOADING : | 6:00 A.M. to 10:00 A.M. |
| EMERGENCY : | Any time |

## CONTEXT

| | |
|---|---|
| ADJACENT STREETS | N/A |
| CBD POPULATION AND DATE | 905,759 in 1970 |
| ADJACENT LAND USE | CBD Retail |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 41% | 37% | 2% | 0% | 5% | 15% |

## SUMMARY

The two-block Lexington Mall is designed with new paving, pedestrian lighting, seating, trees and planters. The mall serves as a link between the office and retail cores in downtown Baltimore, with an additional block extension planned to link the mall with a proposed subway entrance in the retail center.

* N/A = Information not available.

# MALL

| | |
|---|---|
| NAME | STATE STREET MALL |
| LOCATION | CHICAGO, IL |
| DATE COMPLETED | 1979* |

PHYSICAL CHARACTERISTICS

SIZE

| | |
|---|---|
| LENGTH: | 4,000' approximately |
| WIDTH : | 4 blocks = 120'; 5 blocks = 100' |
| AREA : | 435,550 SQ FT |
| BLOCKS: | 9 |
| DESIGN ELEMENTS | Trees in planters, various sculptures and fountains, bus shelters, escalators to subway, sidewalk cafes, new sidewalk paving, new lighting, heated and lighted newstands, canopies over bus waiting areas. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | Plans include activity programming. |

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | Buses (one lane each way, alternating lay-bys) underground subway. |
| TRAFFIC : | None; cab stands on cross streets. |
| LOADING : | On cross streets. |
| EMERGENCY : | Any time. |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 3,366,951 in 1970 |
| ADJACENT LAND USE | CBD retail core. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A |

# SUMMARY

State Street Mall, a transit mall to be completed in 1979, is planned to include unique design features on each of the nine blocks; these furnishings include fountains, sculpture, sidewalk cafes, and art display cases. Programming for the mall is a key element of the plans, with activity areas included in the design.

Transit is also an important aspect of the mall with buses in both directions and boarding bays, plus the subway directly beneath with access by escalator and stair to the Mall. The Loop elevated is nearby.

* Projected completion date.

# MALL

| | |
|---|---|
| NAME | STONEPLACE MALL |
| LOCATION | DALLAS, TX |
| DATE COMPLETED | 1965 |
| PHYSICAL CHARACTERISTICS | |
| SIZE | |
| LENGTH: | 200' |
| WIDTH : | 50' |
| AREA : | 10,000 SQ FT |
| BLOCKS: | 1 |
| DESIGN ELEMENTS | Trees in planters, benches, lighting. |
| OPERATION CHARACTERISTICS | |
| ACTIVITY PROGRAMMING | N/A |
| TRAFFIC/TRANSIT ACCESS | |
| TRANSIT : | None |
| TRAFFIC : | None |
| LOADING : | From side streets. |
| EMERGENCY : | Any time. |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | One major thoroughfare at each end of the mall. |
| CBD POPULATION AND DATE | 844,401 in 1970 |
| ADJACENT LAND USE | CBD office and retail. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 87% | 13% | 0% | 0% | 0% | 0% |

# SUMMARY

Stoneplace Mall is the smallest mall of this study. The one-block street was de-mapped to facilitate traffic flow along the two major avenues at either end, and a pedestrian mall was built to fill that empty space. The mall serves primarily as a mini-park for downtown office workers.

# MALL

| | |
|---|---|
| NAME | RIVER CITY MALL |
| LOCATION | LOUISVILLE, KY |
| DATE COMPLETED | 1973 |

PHYSICAL CHARACTERISTICS

SIZE

| | |
|---|---|
| LENGTH: | 2,815' |
| WIDTH : | 60' |
| AREA : | 168,900 SQ FT |
| BLOCKS: | 3 |

DESIGN ELEMENTS — Many plantings and trees, variety of seating, shelters, kiosks, children's climbing blocks and stage fixtures built into mall in several places, new paving. 80% of mall is open space and unfurnished.

OPERATION CHARACTERISTICS

ACTIVITY PROGRAMMING — Children's programs.

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | None. |
| TRAFFIC : | None. |
| LOADING : | 6:00 P.M. - 10:00 A.M. |
| EMERGENCY : | Any time. |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | N/A |
| CBD POPULATION AND DATE | 361,472 in 1970 |
| ADJACENT LAND USE | CBD retail. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 85% | 15% | 0 | 0 | 0 | 0 |

# SUMMARY

The three-block pedestrian River City Mall in downtown Louisville is 80% open space. The filled areas contain a variety of seating as well as trees and ground plants. There are large, flexible, multi-purpose shelters and information kiosks on two of the three blocks. Use of the mall by families is encouraged by including children's shows and climbing blocks.

## MALL

| | |
|---|---|
| NAME | MID-AMERICA MALL |
| LOCATION | MEMPHIS, TN |
| DATE COMPLETED | 1977 |

PHYSICAL CHARACTERISTICS

SIZE

| | |
|---|---|
| LENGTH: | 4,000' |
| WIDTH : | varies |
| AREA : | N/A |
| BLOCKS: | 10 |
| DESIGN ELEMENTS | Described as the "Longest Pedestrian Mall"; trees at grade, plantings, reflecting pool, large fountains, kiosks, performance platforms, banners, sculpture, pavilions. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | Elaborate schedule, music over kiosk loudspeakers. |

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | Free tram. |
| TRAFFIC : | Two blocks for limited traffic; two serpentine lanes form the roadbed. |
| LOADING : | Cross streets and back alley system |
| EMERGENCY : | Any time. |

## CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 623,000 in 1970 |
| ADJACENT LAND USE | CBD retail, office, government. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A |

## SUMMARY

The Mid-America Mall is part of a greater city scheme for the revitalization of Memphis. The Civic Center provides an anchor for the Mall at one end; at the other end are two blocks of"semi-mall" where two lanes are provided for general traffic. A free tram runs the length of the mall.

Design includes seating areas, covered waiting stations, a large fountain near the Civic Center, various water sculptures, pavilions, kiosks, and platforms for performances.

## MALL

| | |
|---|---|
| NAME | LINCOLN ROAD MALL |
| LOCATION | MIAMI, FL |
| DATE COMPLETED | 1960 |

PHYSICAL CHARACTERISTICS

| | |
|---|---|
| SIZE | |
| LENGTH: | 3,000' |
| WIDTH : | 100' |
| AREA : | 300,000 SQ FT |
| BLOCKS: | 8 |
| DESIGN ELEMENTS | Plantings and trees at grade down center of mall; canopies and covered arcades adjacent to storefronts. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | N/A |
| TRAFFIC/TRANSIT ACCESS | |
| TRANSIT : | An electric mini-bus runs end to end. |
| TRAFFIC : | None |
| LOADING : | From side streets. |
| EMERGENCY : | Any time |

## CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 87,072 Date unavailable. |
| ADJACENT LAND USE | Retail |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 60% | 30% | 0 | 10% | 0 | 0 |

## SUMMARY

Lincoln Road Mall is geared toward tourists, who are its principle customers, with a mini-bus running from end to end during days and some evenings. Clusters of plantings and exotic trees shade the center of the mall; canopies and covered arcades shade the sides.

# MALL

| | |
|---|---|
| NAME | NICOLLET MALL |
| LOCATION | MINNEAPOLIS, MN |
| DATE COMPLETED | 1967 |

PHYSICAL CHARACTERISTICS

| | |
|---|---|
| SIZE | |
| LENGTH: | 3,300' |
| WIDTH : | 80' |
| AREA : | 264,000 SQ FT |
| BLOCKS: | 8 |
| DESIGN ELEMENTS | Trees at grade, fountains, sculpture, new paving, bus shelter/kiosk combination includes benches, displays, telephones, and piped-in music; serpentine transit lanes, skyways; removal of all overhanging signs; new paving with snow melting mats; 15 feet of clear walking area beside building line. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | Music over kiosk loudspeakers. |
| TRAFFIC/TRANSIT ACCESS * | |
| TRANSIT : | Bus, mini-bus, taxi: one lane in each direction. |
| TRAFFIC : | None |
| LOADING : | From side streets, rear access, and a tunnel system. |
| EMERGENCY : | Any time |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets |
| CBD POPULATION AND DATE | 434,500 in 1970 |
| ADJACENT LAND USE | CBD retail core, near office core. |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 42.6% | 50.8% | 0 | 0 | 3% | 3.6% |

# SUMMARY

Nicollet Mall is the most widely publicized of the study malls. Desire for retail improvement provided the original impetus for creating the transit mall, although a 51% increase in bus volumes is foreseen by 1985.

Most noted for its unique system of skyways (which will connect with future parking and subway facilities), and a serpentine transitway, the Nicollet plan also incorporates fountains, sculptures, a four-sided clock, and multi-purpose bus shelters which have benches, telephones, informational displays, and loudspeakers for piped-in music. The mall was constructed of hard materials such as copper, bronze, granite, brick and terrazo. The trees at grade are sparse along its length.

* Pedestrian volume: 12,800 before mall; 13,600 after mall (av. per side/block/12 hrs)
Pre-mall traffic volume: 6,800 (per side/block/12 hours)
Bus volume at peak hour: Estimated 20 per hour in each direction before the mall, 60 per hour in each direction after the mall.

# MALL

| | |
|---|---|
| NAME | CHESTNUT STREET TRANSITWAY |
| LOCATION | PHILADELPHIA, PA |
| DATE COMPLETED | 1975 |

PHYSICAL CHARACTERISTICS

| | |
|---|---|
| SIZE | |
| LENGTH: | 5,600' |
| WIDTH : | 60' |
| AREA : | 336,000 SQ FT |
| BLOCKS: | 12 |
| DESIGN ELEMENTS | Trees at grade, planters, bus shelters, special newsstands, ornamental light fixtures, information columns, benches, corner curbs flush with street, widened sidewalks, new brick paving. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | N/A |
| TRAFFIC/TRANSIT ACCESS * | |
| TRANSIT : | Bus, taxi; two lanes. |
| TRAFFIC : | Two blocks of the 12. One block is open to taxis; the second block is open to general traffic for access to parking lots. |
| LOADING : | From side streets; rear access; night loading on mall. |
| EMERGENCY : | Any time. |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 1,950,089 in 1970 |
| ADJACENT LAND USE | CBD retail core. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 26.9% | 26.2% | 2.7% | 30.2% | 0.3% | 3.7% |

# SUMMARY

Pedestrian scale is emphasized in the Chestnut Street Transitway. Plans for this mall developed out of the need to ease projected Bicentennial traffic conjestion. The two transit lanes, one in each direction, are for buses only on ten of the twelve mall blocks, with one block allowing taxis access to a hotel, and the other block allowing general traffic access into parking lots. New signal timings will facilitate bus flow. Furnishings are few along the widened sidewalks, thus permitting high pedestrian volumes.

* Pedestrian volumes: After transitway, 3016/block side/hour during peak periods - on major blocks.
Pre-mall traffic volumes: 14,000 (one way, daily).
Bus volumes at peak hour: 43 before transitway, 52 in each direction after transitway.

# MALL

| | | | |
|---|---|---|---|
| NAME | EAST LIBERTY MALL | | |
| LOCATION | PITTSBURGH, PA | | |
| DATE COMPLETED | 1969 | | |
| PHYSICAL CHARACTERISTICS | | | |
| SIZE | Broad | Penn | Highland |
| LENGTH: | 900' | 1400' | 1400' |
| WIDTH : | 50' | 100' | 70' |
| AREA : | 283,000 SQ FT | | |
| BLOCKS: | 14 | | |
| DESIGN ELEMENTS | Interconnecting transitways along three streets; trees and shrubbery in above grade planters; numerous benches and shelters/display units; lighting fixtures, new paving. | | |

OPERATION CHARACTERISTICS

ACTIVITY PROGRAMMING — N/A

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | Bus, mini-bus; transitway connecting three streets. |
| TRAFFIC : | One block of Highland open to traffic, due to lack of rear loading access. |
| LOADING : | Rear access, plus one block of Highland. |
| EMERGENCY : | Any time. |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | N/A |
| CBD POPULATION AND DATE | 525,275 in 1970 |
| ADJACENT LAND USE | CBD retail. |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 80% | 18% | 1% | 0 | 0 | 1% |

# SUMMARY

Three streets interconnected as a transitway comprise the East Liberty Mall in downtown Pittsburgh. Buses, mini-buses and taxis are permitted on the transitway.

Design of the fourteen blocks emphasize pedestrian comfort with landscaping in small planters, numerous benches, and shelters that serve as display units.

# MALL

| | |
|---|---|
| NAME | PORTLAND MALL |
| LOCATION | PORTLAND, OR |
| DATE COMPLETED | 1978 |
| PHYSICAL CHARACTERISTICS | |
| SIZE | Two parallel Avenues: |
| LENGTH: | 2800' each (5600' total) |
| WIDTH : | 80' |
| AREA : | 448,000 SQ FT |
| BLOCKS: | 11 each - 22 total |
| DESIGN ELEMENTS | Transitway, trees, above-grade plantings, sculpture, fountains, trip planning kiosks, bus shelters; clear area for pedestrians passageway adjacant to building line; vending machines, lighting, special benches, concession booths, bollards. |
| OPERATION CHARACTERISTICS | |
| ACTIVITY PROGRAMMING | Outdoor fairs. |
| TRAFFIC/TRANSIT ACCESS ** | |
| TRANSIT : | Two one-way bus lanes. |
| TRAFFIC : | One lane for three out of every four blocks. |
| LOADING : | Loading and taxi bays on side streets. |
| EMERGENCY : | Any time |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 381,000 in 1970 |
| ADJACENT LAND USE | CBD retail, office, government. |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | 21% | N/A | N/A | N/A | N/A |

# SUMMARY

Portland Mall, scheduled for completion this year, is actually two 11-block transit malls on adjacent parallel one-way streets. High bus volumes are anticipated because the City plans to reroute bus lines onto or near the mall. Two bus lanes per mall street are planned, with general traffic permitted in a third lane on three out of every four blocks. Platooning of buses and special timing of traffic signals will facilitate traffic flow.

Portland has included many pedestrian amenities in their design such as trip-planning, kiosks (with free information phones, and video screens), sculptures, fountains, trees, vending machines at the end of each block, and bus shelters.

** Pedestrian volumes: 686 on Sixth Avenue, 444 on Fifth Avenue (average hourly volume mid-morning and mid-afternoon, per side, per block).

Traffic Volume: Less than 14,000 daily

Bus Volumes: Peak hour (before mall/projected): Sixth Avenue (85/207); Fifth Avenue (85/211).

# MALL

| | |
|---|---|
| NAME | WESTMINSTER MALL |
| LOCATION | PROVIDENCE, RI |
| DATE COMPLETED | 1965 |

PHYSICAL CHARACTERISTICS

| | | | |
|---|---|---|---|
| SIZE | Two sections: | "A" | "B" |
| LENGTH: | | 950' | 316' |
| WIDTH : | | 60' | 60' |
| AREA : | 75,960 SQ FT | | |
| BLOCKS: | 8 Total = | 6 | 2 |

DESIGN ELEMENTS: The two sections (6- and 2- blocks) separated by one block that is open to general traffic, contain lighting fixtures concealed in the planters, benches, illuminated trees and a sound system.

OPERATION CHARACTERISTICS

ACTIVITY PROGRAMMING: N/A

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | None |
| TRAFFIC : | None, except for the one middle block. |
| LOADING : | 6:00 P.M. to 7:00 A.M. weekdays |
| EMERGENCY : | Any time |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets |
| CBD POPULATION AND DATE | 179,116 in 1970 |
| ADJACENT LAND USE | CBD - retail |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 79% | 17% | 0 | 1% | 0 | 3% |

# SUMMARY

Westminister Mall is part of a larger city plan to encourage urban revitalization. The Mall is situated along eight of nine blocks of Westminster Street in Providence. The two- and six-block pedestrian configuration is split by one block, along which general traffic is permitted for access to the parking structure on that block. The six-block section was designed to complement the older, more austere architecture which surrounds it, while the two-block section is more modern and monumental. A sound system is incorporated into the above-grade planters.

# MALL

| | |
|---|---|
| NAME | DOWNTOWN MALL |
| LOCATION | RALEIGH, NC |
| DATE COMPLETED | 1975 |

PHYSICAL CHARACTERISTICS

SIZE

| | |
|---|---|
| LENGTH: | N/A |
| WIDTH : | N/A |
| AREA : | N/A |
| BLOCKS: | 3½ blocks |
| DESIGN ELEMENTS | Gazebo, large sculpture, trees, bus shelter and outdoor seating beneath shade trees, amphitheatre seating 300, mural wall, reflecting pools, two fountains, clock/bell tower, lawns, new paving. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | Possible activities planned for the gazebo. |

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | None: cross streets only. |
| TRAFFIC : | None |
| LOADING : | None; service access only. |
| EMERGENCY : | Any time |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 121,577 in 1970 |
| ADJACENT LAND USE | Capitol Bldg.,commercial, retail,office, government. |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A |

# SUMMARY

The Downtown Mall will complement the planned State Government Mall that will join the State Capitol with a high-rise office building. Other nearbv malls are anticipated by the City.

## MALL

| | |
|---|---|
| NAME | MARKET STREET |
| LOCATION | SAN FRANCISCO, CA |
| DATE COMPLETED | N/A |
| PHYSICAL CHARACTERISTICS | |
| SIZE | |
| LENGTH: | N/A |
| WIDTH : | N/A |
| AREA : | N/A |
| BLOCKS: | N/A |
| DESIGN ELEMENTS | Sidewalk widening, new pavement. |
| OPERATION CHARACTERISTICS | |
| ACTIVITY PROGRAMMING | N/A |
| TRAFFIC/TRANSIT ACCESS | |
| TRANSIT : | Bus, underground light rail rapid transit (LRRT), BART. |
| TRAFFIC : | Limited |
| LOADING : | N/A |
| EMERGENCY : | Any time |

## CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 715,674 in 1970 |
| ADJACENT LAND USE | CBD retail, office. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A |

## SUMMARY

Market Street is an important transit hub in downtown San Francisco, where above and below grade local transit systems interface with BART, the San Francisco area rail system.

# MALL

| | |
|---|---|
| NAME | OCCIDENTAL MALL |
| LOCATION | SEATTLE, WA |
| DATE COMPLETED | 1973 |
| PHYSICAL CHARACTERISTICS | |
| SIZE | |
| LENGTH: | 560' |
| WIDTH : | 85' |
| AREA : | 47,600 SQ FT |
| BLOCKS: | 2 |
| DESIGN ELEMENTS | Trees at grade, street furniture, overhead wiring removed. |
| OPERATION CHARACTERISTICS | |
| ACTIVITY PROGRAMMING | Open air concerts, art exhibits, vending carts. |
| TRAFFIC/TRANSIT ACCESS | |
| TRANSIT : | None |
| TRAFFIC : | None |
| LOADING : | 7:00 A.M. - 10:00 A.M. |
| EMERGENCY : | Any time |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | N/A |
| CBD POPULATION AND DATE | 550,000 in 1974 |
| ADJACENT LAND USE | Seattle's Pioneer Square Historic District. |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| 75% | 22% | 0 | 9 | 2% | 1% |

# SUMMARY

The Occidental Mall in the Pioneer Square Historic District of Seattle was planned with outdoor activities in mind, with vending carts, open air concerts and art exhibits scheduled in the summer months. The mall is also a primary pedestrian thoroughfare to the Domed Stadium to the south.

# MALL

| | |
|---|---|
| NAME | GALLERY PLACE |
| LOCATION | WASHINGTON, D.C. |
| DATE COMPLETED | 1977 |

PHYSICAL CHARACTERISTICS

| | |
|---|---|
| SIZE | |
| LENGTH: | Approximately 450' |
| WIDTH : | Approximately 125' |
| AREA : | 56,250 SQ FT |
| BLOCKS: | 1 |
| DESIGN ELEMENTS | Trees at grade, raised plantings, two fountains and row of fountains at grade down the center, sculpture which doubles as seating, slab seating; wide and spacious area. |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | Elaborate schedule |
| TRAFFIC/TRANSIT ACCESS | |
| TRANSIT : | Midi-bus (although no road bed). |
| TRAFFIC : | None |
| LOADING : | None |
| EMERGENCY : | Any time |

# CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 756,510 in 1970 |
| ADJACENT LAND USE | National Portrait Gallery, retail. |
| ACCESS TO CBD | |

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A |

# SUMMARY

The Washington D.C. "Streets for People" is an extensive plan to pedestrianize F and G Streets over a period of time. Gallery Place is the first block on F Street; it is one of the first pedestrian spaces to be implemented as part of the "Streets for People" plan. Amenities include information kiosks (with video screens), raised plantings, trees at grade, two fountains, a row of at-grade "fountains" down the center of the mall, and matching granite sculpture and bollards which double as seating. A temporary stage is available for outdoor programs. A mini-bus runs along the perimeter of this block. The Arrowstreet planning process, which included subjective noise evaluation by users, found the pre-mall street noisy.

## MALL

| | |
|---|---|
| NAME | LIBRARY PLACE |
| LOCATION | WASHINGTON, DC |
| DATE COMPLETED | 1977 |

PHYSICAL CHARACTERISTICS

SIZE

| | |
|---|---|
| LENGTH: | Approximately 450' |
| WIDTH : | Approximately 75' |
| AREA : | 33,750 SQ FT |
| BLOCKS: | 1 |
| DESIGN ELEMENTS | Two rows of trees at grade, raised plantings, sunken seating areas, benches (wood and rock slab). |

OPERATION CHARACTERISTICS

| | |
|---|---|
| ACTIVITY PROGRAMMING | Extensive schedule. |

TRAFFIC/TRANSIT ACCESS

| | |
|---|---|
| TRANSIT : | None. |
| TRAFFIC : | None. |
| LOADING : | N/A |
| EMERGENCY : | Any time. |

## CONTEXT

| | |
|---|---|
| ADJACENT STREETS | Cross streets. |
| CBD POPULATION AND DATE | 756,510 in 1970 |
| ADJACENT LAND USE | Library, smaller institutional buildings. |

ACCESS TO CBD

| AUTO | BUS | TAXI | TRAIN | BICYCLE | PEDESTRIAN |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A |

## SUMMARY

Library Place, on G Street, is the second of two blocks to have been built thus far in Washington D.C.'s "Streets for People" plan. Like Gallery Place, programming is emphasized. However, the design is different, with sunken seating areas, raised plantings, two rows of trees, and various benches. There is no transit along this block, and the Arrowstreet study which sampled user attitudes, found this pre-mall street quiet.

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## 2.2 Formulation of the Noise Questionnaire

The background information on the malls became the basis for structuring a questionnaire of noise in each mall. An analysis of information obtained on each project made it appear obvious that there was no simple way to generally classify the malls. Some malls were purely pedestrian-oriented while others contained provisions for traffic or transit or both. Similarly, some malls were of considerable length while others were one or two blocks long. Some contained a wide range of diverse design elements while others did not. Nevertheless, it was felt that there were several aspects in common to all.

First, each mall was situated in or near an urban area of high activity - the central business district. Because of this, it was inferred that each mall was affected by a similar environment. As a result, questions were developed to determine the various sources of noise to which each mall was subjected in order to determine if similar environments contained similar noise sources.

Second, it was apparent that each mall had incorporated various design elements. Consequently, it was inferred that these design elements may have some bearing on attenuating noise by acting as barriers or shields to block noise emanating from noise sources and that our questionnaire should explore this possibility.

Third, many of the malls contained provisions for either allowing vehicular traffic on the mall or diverting traffic around it. Since it was deduced that traffic is a major contributor to noise, several questions were developed to determine the impact of such noise.

Finally, since the malls were situated in or near intense urban development, a great deal of pedestrian traffic could be generated. In this respect, questions were structured to determine the implications of noise on the pedestrians (receivers of noise) by way of the pedestrian complaints and the existence of less attractive areas in the mall due to noise.

The inferences that were drawn from the background material gathered on the malls helped to structure the questionnaire, which is the subject of the next chapter.

## 3.0 SYNTHESIS OF NOISE DATA COLLECTED FROM SIXTEEN MALLS IN THE U. S.

### 3.1 Data Collection Process

Various methods of data collection were examined. It was determined that a questionnaire was the most useful survey instrument. The flexibility of the questionnaire enabled the project staff to satisfy a wide range of objectives.

The objectives of the questionnaire were to survey the extent to which the subject of noise was considered in the design, planning, construction and operation of the malls and the measures which were taken to mitigate it. Additional objectives of the questionnaire related to the identification of noise sources, the use of design features for noise attenuation and the impact of noise on the users of the malls.

The questionnaire was distributed by the United States Conference of Mayors (USCM) to eighteen malls in the United States. The selection of the malls was intended to provide a cross-section of the malls in the country. A list of contacts for the malls was supplied to the USCM. The list represented a diverse group; it consisted of city planning officials, city engineers, mall administrators, project directors, officials of the Chambers of Commerce and consultants. Initially, only one questionnaire was sent to each mall. In cases where there was no response, follow-up phone calls were made and a second questionnaire was sent to the appropriate contact. Information on sixteen of the eighteen malls was finally collected by way of written response or telephone interview.

The text of the questionnaire reflects the study's objectives. The questionnaire was divided into four parts:

The first part focused on sources of noise. Seven questions were developed to determine: (a) if sources of noise were identified in the planning and design of the mall; (b) what sources were considered problematic;

(c) what measures, if any, were taken to reduce or control noise at its source; and (d) if sources of noise were not identified in the planning stages, whether any have been identified since operations began.

The second part of the questionnaire concentrated on obtaining information on techniques to control noise along the path of sound transmission. The objective was to determine if any design elements were considered for use as a means of attenuating the noise between the location of noise sources and the location of noise receivers. Five questions were designed to obtain data related to the kinds of barriers that may also have been incorporated as design features, the types of materials used for them and the use of buffer areas to separate noise sources and noise receivers.

The third part concentrated on gathering information about the noise recipient. To ascertain what mitigation measures were considered at the point where noise is felt or heard, four questions were formulated to determine (a) if there were less attractive areas in the mall due to noise; (b) if certain configurations of building facades were utilized to help reflect sound away from activity noises; (c) if sound absorbing material was used; and (d) if there were user complaints about noise in the mall area.

The final part of the questionnaire contained administrative questions. Questions were developed to obtain diverse information, such as whether noise measurements were taken, whether an environmental impact statement was submitted, whether any public awareness campaigns about noise for the mall have been established and whether a noise consultant was retained.

The questionnaire is presented below, together with a tabulation showing the responses selected by the malls and a brief narrative summarizing the response pattern.

3.2 Noise Questionnaire and Results

A. SOURCE NOISE

1. WERE POTENTIAL SOURCES OF NOISE IDENTIFIED BEFORE OR DURING THE PLANNING AND DESIGN PHASE OF YOUR MALL? YES 8 NO 8
IF NO, SKIP TO QUESTION 5.

The responses of the sixteen malls were evenly divided between affirmative and negative - eight malls responded "yes" and eight "no". Those respondents who answered "yes" represented the malls in the cities of Memphis, Philadelphia, Portland, Minneapolis, Chicago, Pittsburgh and Washington, D.C. (This last respondent answered the questionnaire for the two Washington, D.C. malls simultaneously). If a pattern to the responses was apparent, there seemed to be a correlation between the identification of noise sources and those malls that made provisions for vehicular use of the mall. Those malls that were strictly pedestrian-oriented were more likely to answer "no" to this question.

2. IF ANSWER TO 1 IS YES, KINDLY CHECK THE GENERIC AREA (S) WHERE NOISE SOURCES WERE IDENTIFIED AS PROBLEMATIC:

A. 8 SURFACE TRANSPORTATION
B. 2 SUBSURFACE TRANSPORTATION
C. 0 AIRPLANE FLYOVER
D. 0 BUILDING NOISES (E.G., FANS, VENTILATING UNITS, AIR CONDITIONING UNITS)
E. 3 NUISANCE TYPE NOISE GENERATED FROM MALL ACTIVITY (E.G., MALL ADVERTISING DISPLAYS, LOUDSPEAKERS, SPECIAL EFFECTS TO ENHANCE MALL'S CHARACTER, ETC.)
F. 1 NOISE GENERATED BY HUMAN ACTIVITY (E.G., LOUD CONVERSATION, YELLING, PORTABLE RADIO/STEREOS, ETC.)
G. 3 CONSTRUCTION NOISE INVOLVING THE MALL'S DEVELOPMENT
H. 0 OTHER (PLEASE SPECIFY) ______________

Of the eight that responded affirmatively to Question 1, the generic area most frequently cited in the responses to Question 2 was surface transportation. The next two areas most frequently checked were construction noise and noise related to the mall's activity. Noise emanating from subsurface transportation was considered problematic in the two Washington, D.C. malls.

3. IN ORDER TO BE MORE SPECIFIC, THE GENERIC AREAS OF QUESTION 2 ARE SEPARATED INTO THEIR SUBSTITUENTS BELOW WHERE APPROPRIATE. KINDLY CHECK THE SPECIFIC TYPE OF NOISE SOURCE, WITHIN THE CORRESPONDING GENERIC AREA MARKED ABOVE, THAT WAS IDENTIFIED AS PROBLEMATIC.

A. SURFACE TRANSPORTATION: CAR 6, BUS 8, TRUCK 5, TAXI 2, EMERGENCY VEHICLES 0, RAILROAD 0
B. SUBSURFACE TRANSPORTATION: SUBWAY 2, UNDERGROUND ROADWAY 0
C. BUILDING NOISES: VENTILATING FANS 0, AIR CONDITIONING UNITS 0, TRANSFORMERS 0, GENERATORS 0, OTHER (PLEASE SPECIFY) ______
D. MALL ACTIVITY NOISE: ADVERTISING DISPLAYS 0, LOUDSPEAKERS 3, SPECIAL ACTIVITY AREA, E.G., OUTDOOR THEATRE 0, SPECIAL DESIGN EFFECTS, E.G., WATERFALLS, TOWER CLOCKS, PUMPED-IN MUSIC (PLEASE SPECIFY) Record Stores
E. OTHER (PLEASE SPECIFY) ______

The specific type of surface transportation that was checked most frequently as a noise problem was buses, followed by cars and trucks. Taxis were only cited twice as being problematic.

With respect to mall activity noise, loud speaker systems and record stores were regarded as significant noise producing sources.

In the subsurface transportation category, subway noise was cited by the Washington, D.C. respondent.

The reader should note that construction noise, while considered problematic in Question 2, was not further delineated in this question for the sake of simplicity.

4. WERE ANY OF THE FOLLOWING NOISE REDUCTION MEASURES INCORPORATED INTO THE MALL'S DEVELOPMENT TO ATTENUATE SOURCE NOISE? KINDLY DESCRIBE.

A. 2 NOISE SOURCE (S) WAS PHYSICALLY MODIFIED ______

B. 1 NOISE SOURCE (S) WAS ENCLOSED ______

C. 1 NOISE SOURCE (S) WAS LIMITED TO CERTAIN TIMES OF THE DAY ______

D. 5 NOISE SOURCE (S) WAS GIVEN AN ABATEMENT PROCEDURE THAT HELPED TO ATTENUATE NOISE WITHOUT PHYSICALLY MODIFING IT IN ANY WAY. ______

E. 1 OTHER Noise Regulations

In response to 4a, two malls (Portland and Chicago) indicated that the purchase of new, quieter bus models was being made (Portland) or being considered (Chicago). The new buses would contain design modifications to provide for quieter operation.

For 4b, Portland required the use of temporary enclosures around noise-producing equipment during the construction phase of its mall. The effectiveness of such enclosures was not reported.

In response to 4c, Portland restricted the use of construction equipment to certain times of the day.

The responses to 4d were varied. Minneapolis reported the use of a maintenance program for its mall buses to keep them in good operating condition. By maintaining the buses in proper working order, worn and pitted parts are replaced to avoid making unnecessary noise. In a different vein, Philadelphia and Pittsburgh responded to "d" by reporting that most vehicular traffic was diverted around the mall area. Although the source noise was not physically altered, the source (most vehicular traffic) was redirected away from the sensitive area. Raleigh, North Carolina and Washington, D.C. made use of an alternate noise source to mask the annoying type of noise with a more pleasing type of sound. The type of noise source used in these instances was the splashing of waterfalls or water fountains.

In response to 4e, Memphis reported the use of noise regulations that limited the level of sound that could be produced by a source of noise in the mall.

5. IF NOISE SOURCES WERE NOT IDENTIFIED IN THE PLANNING AND DESIGN PHASE, HAVE ANY BEEN IDENTIFIED AS PROBLEMATIC SINCE OPERATION OF THE MALL? YES 2 NO 14

6. IF SO, WHAT SOURCES OF NOISE HAVE BEEN IDENTIFIED AS PROBLEMATIC? Bus noise and store loudspeakers

Of the eight malls that responded negatively to question 1, the question which seeks to identify noise sources during mall design and planning, two malls responded affirmatively to Question 5, which tries to identify noise sources apparent since operation. Raleigh and Louisville indicated that a noise source has been identified since operation. Raleigh responded that buses created a noise problem where they crossed the mall at street intersections. Louisville cited the use of store loudspeakers as problematic. Louisville has effectively dealt with their problem administratively with the cooperation of the mall's businessmen.

7. WAS CONSIDERATION GIVEN TO SET NOISE "LIMITS" FOR ANY EQUIPMENT, MATERIAL, MACHINERY, ETC. WHICH USERS OF THE MALL WOULD NOT PURCHASE OR USE IF SUCH LIMITS WERE SURPASSED? YES 2 NO 14

Two malls responded affirmatively to this question. As indicated above, Memphis made use of a city ordinance to set noise limits on noise sources. The other mall to answer "yes" was Portland.

B. NOISE TRANSMISSION ALONG THE PATH

8. WERE DESIGN CONSIDERATIONS (IN THE FORM OF BUFFERING, E.G., SHIELDING BY WAY OF PHYSICAL BARRIERS OR INCREASING THE DISTANCE BETWEEN NOISE SOURCE AND NOISE RECEIVER) GIVEN TO THE ATTENUATION OF NOISE AS IT PASSED THROUGH AIR FROM NOISE SOURCE TO NOISE RECEIVER? YES 5 NO 11

Five malls answered 'yes' to this question. Raleigh, Portland, Pittsburgh and the two Washington, D.C. malls were among those respondents which utilized design features which were thought to help attenuate noise between the noise source and the receiver of noise.

9. IF SO, WHAT KIND OF PATH BUFFERING WAS USED?

A. 4 A PURPOSEFULLY POSITIONED ARTIFICIAL BARRIER
B. 0 USE OF A NATURAL BARRIER (HILL, BERM, ETC.)
C. 0 USE OF OTHER BUILDINGS
D. 0 INCREASING THE DISTANCE BETWEEN NOISE SOURCE AND NOISE RECEIVER
E. 2 USE OF VEGETATION
F. 0 PURCHASE OF EASEMENTS
G. 0 EXCESS ACQUISITION OF LAND TO PROVIDE FOR BUFFER ZONES
H. 3 OTHER (PLEASE SPECIFY)

Of the five responses to Question 8, four out of the five cited the use of some form of barrier to attenuate sound. The barrier took the form of raised planters with vegetation or water fountain structures. Two malls cited the use of vegetation to attenuate noise. Raleigh and the two Washington, D.C. malls checked "h" above and noted the use of pleasant masking noises to compete with the unwanted, intruding noises.

10. IF ARTIFICIAL BARRIERS WERE USED, WHAT TYPE OF MATERIALS WERE THEY MADE OF? ______________________

Precast stone was the material cited by Raleigh and the two Washington, D.C. malls for the planters and fountain structures. Portland utilized temporary plywood enclosures around heavy machinery during its construction phase as its barrier material.

11. IF BUFFER DISTANCES WERE UTILIZED, WHAT DISTANCES WERE CONSIDERED ADEQUATE FOR YOUR PURPOSE? ______________

This question was not answered by any of the malls. Evidently, since all of the selected malls are in densely populated urban areas, an inference can be drawn that there is little opportunity to amass space between noise source and noise receiver in these areas for the purpose of dissipating noise.

12. WERE ANY SPECIFIC MATERIALS USED ELSEWHERE IN THE MALL FOR EITHER THE ABSORPTION OR REFLECTION OF SOUND WAVES?
YES __2__ NO __14__

IF SO, WHAT MATERIALS WERE USED AND DO YOU CONSIDER THEM EFFECTIVE? ______________________

The respondent from the two Washington, D.C. malls addressed this question. The materials used there to assist in absorbing or reflecting sound waves were the different types of vegetation used in landscaping the planters.

C. NOISE AT THE RECEIVER END

13. WOULD YOU SAY THAT THERE ARE "LESS ATTRACTIVE" AREAS OR LESS UTILIZED AREAS OF YOUR MALL WHERE THE REASONS FOR SUCH UNDERUTILIZATION CAN BE ATTRIBUTED TO EXPOSURE TO "ANNOYING" NOISE (IRRESPECTIVE OF THE FACT THAT ANNOYING NOISE DIFFERS FROM INDIVIDUAL TO INDIVIDUAL?)
YES __2__ NO __14__

Two mall respondents indicated the possibility that less attractive areas existed in the mall due to noise. It is of interest to note that both indicated the fact was due to bus noise. Raleigh indicated that those street intersections where buses crossed the mall were likely candidates for "less attractive" status. The respondent from Portland deduced that there probably were such sites because outdoor cafes were planned for some mall areas but the bus noise was considered too annoying at the time for such a use.

14. WERE CERTAIN BUILDING CONFIGURATIONS UTILIZED OR DESIGN LAYOUTS CREATED AS A RESULT OF NOISE CONSIDERATIONS?
YES __3__ NO __13__

IF SO, WHAT DESIGN LAYOUTS OR BUILDING CONFIGURATIONS WERE CONSIDERED? ____________

The respondent for the two Washington, D.C. malls addressed this question by indicating that the positioning of planters and the use of vegetation would help absorb the sound reflecting from building facades and store glass windows. Raleigh's response also indicated that consideration was given to noise in the positioning of their planters.

15. WAS IT NECESSARY TO CONSIDER SOUND ABSORBING MATERIAL TO INSULATE BUILDINGS OR STRUCTURES IN THE MALL FROM NOISE?
YES __0__ NO __16__

Of the mall respondents who chose to answer this question, all of the responses were negative.

16. HAVE THERE BEEN ANY COMPLAINTS ABOUT NOISE LEVELS BY USERS OF THE MALL? YES __6__ NO __10__

Several of the mall respondents indicated that there have been general complaints about noise levels; additional comments varied from occasional general complaints to specific complaints. Among the specific complaints were bus noise (Philadelphia) and loudspeakers (Louisville).

D. ADMINISTRATIVE

17. WERE ANY OF THE FOLLOWING CONSIDERED OR USED IN CONJUNCTION WITH THE MALL'S OPERATION TO DISCOURAGE NOISE? KINDLY CHECK.

A. __1__ PUBLIC AWARENESS CAMPAIGNING ABOUT NOISE
B. __0__ LITERATURE DISTRIBUTION ON NOISE
C. __0__ FILM CLIPS
D. __0__ SIGNS
E. __1__ OTHER (PLEASE SPECIFY) ____________

The respondent from the Pittsburgh mall indicated that a public awareness campaign about noise was considered at some time. Memphis checked "e" above, citing the use of a City noise ordinance to discourage noise associated with the mall's operation.

18. WERE THERE ANY NOISE MEASUREMENTS TAKEN TO DETERMINE NOISE LEVELS BEFORE CONSTRUCTION OF THE MALL? YES 3 NO 13

AFTER CONSTRUCTION OF THE MALL? YES 1 NO 14

There were three malls that had taken noise measurements before construction - Philadelphia, Portland and Chicago. Only one, Portland, has taken such measurements since beginning its operations. The respondent from Chicago noted that Chicago's mall is still in its construction phase and, therefore, noise monitorings after construction could not be addressed at this point.

19. WAS THERE AN ENVIRONMENTAL IMPACT ASSESSMENT DRAFTED FOR YOUR MALL THAT CONSIDERED THE NOISE ISSUE?
YES 4 NO 12

Three malls drafted an environmental impact statement - Philadelphia, Portland and Chicago. Seattle's response indicated that a Declaration of Non-Significant Impact was made for Phase 2 of its mall but was not necessary for Phase 1.

20. WAS A CONSULTANT RETAINED TO ADDRESS NOISE MATTERS?
YES 1 NO 15

IF SO, DID IT PROVE COST EFFECTIVE IN YOUR ESTIMATION?
YES 1 NO -

Portland retained a consultant to address the noise issue and considered it effective. In the case of the two Washington, D.C. malls, a consultant was retained to do a pre-design survey, of which noise was a component. However, no indication was made that there was a consultant used to specifically address the noise issue there.

21. DO ANY MUNICIPAL CODES COVER THE PROBLEM OF NOISE IN YOUR MALL? YES 11 NO 5

IS IT EFFECTIVE? YES 11 NO 0

IS ENFORCEMENT OF SUCH A CODE A SERIOUS PROBLEM?
YES 0 NO 11

Eleven of the malls were located in cities which had some type of municipal code which addressed noise. However, there was no consistent type of ordinance found among the eleven responses. Some cities had a nuisance ordinance while others prescribed noise performance standards in their zoning codes. Each of the eleven malls which indicated some type of noise code also indicated that the code was effective in controlling noise. No serious enforcement problem was cited by the eleven.

## 3.3 Evaluation of Noise Mitigation Efforts by the Selected Malls

Based on the information received, several conclusions and inferences can be made concerning identified noise patterns and noise mitigation efforts practiced by the sixteen selected malls.

1. Surface transportation vehicles on or adjacent to malls create the most serious noise problem. The surface transportation vehicle which appears to contribute most to this noisy condition is the bus. Even the mall in Raleigh, which is pedestrian-oriented but allows for bus crossings at side streets, has cited problems with noise at those intersections. The search for quieter bus models is being undertaken for the malls in Chicago and Portland.

2. Noise involved with construction of a mall also creates a serious problem. Efforts to cope with this type of noise has centered around enclosing the noise-producing equipment with temporary structures and limiting the construction to certain hours of the day.

3. Besides purchasing quiet equipment, enclosing a noise source and limiting noise to certain hours of the day, the rerouting of traffic away from the mall was considered by some of the mall respondents as a way of controlling noise at its source. The question that remains to be answered is whether or not the diverted traffic is seriously affecting those areas which are now receiving the increased volume of traffic.

4. Another noise mitigation effort, which has been considered effective by some of the mall respondents, is masking noise.

The use of waterfalls has been cited as a way to create a more pleasant type of sound which blocks the intruding and more annoying types of noise. However, while masking noise may be effective for the immediate area adjacent to the waterfall, its effect is reduced the further away one travels from it. Secondly, the sound must be one of sufficient intensity to function properly as a masking noise.

5. It appears that very little has been done to use various design features in malls as sound attenuation possibilities. Several malls have relied on the use of vegetation and above-ground planters as shields to block noise as it passes through the air from noise source to noise receiver. However, moderate use of vegetation alone is not enough to substantially reduce noise and, depending on their size and construction, isolated planters may not have much of an effect either. Based on the responses to the questionnaire, it still remains to be seen whether or not design features such as mall furniture, bus shelters, isolated standing walls, etc. can be effectively designed into the mall layout for sound attenuation purposes.

6. It appears that very little space is available at the sites of the malls to act as a buffer area between noise source and noise receiver. The distances between a noise source and the pedestrian receiver of noise appears to be close at the malls. In such a case, it would be difficult to design a mall where noise sources could be positioned far enough away from sensitive areas so that a buffer zone could be created.

7. Very few malls measured existing noise levels. In those malls that did, only Portland has done it on a before and after basis. This could imply that, in many cases, noise was not a serious concern in the design and operation of the mall. Furthermore, only one mall used a noise consultant (Portland).

8. Several malls appear to rely on citywide ordinances to help enforce noise levels in the mall area. The effectiveness of such municipal ordinance lies in proper enforcement. Essentially, the effort at noise reduction through such means becomes administrative in nature rather than the consequence of mall planning or design.

9. In reviewing all the responses by the selected malls, it appears that, even in those malls that identified noise as problematic, the use of noise mitigation techniques was not of critical concern. This was most obvious in cases where the mall was pedestrian-oriented and where the development of the mall was accomplished prior to the requirements of an environmental impact review process. The more recently planned malls were more likely to consider noise mitigation techniques in their development. However, even in many of these cases, evidence does not seem to support an active effort to forcefully mitigate noise in the malls. Portland, with its noise mitigation program, which shall be discussed in Chapter 4.0, appears to be the exception rather than the rule in this regard.

10. From the responses, it would also appear that the attenuation of noise in central city areas was not among the primary objectives for mall development either. It would appear that the overall

objectives for constructing the mall would more likely be linked to encouraging economic development, area beautification, or comprehensive traffic programs than to the creation of a quieter environment for central city areas.

11. Finally, evidence would indicate that, given the nature of the urban mall *per se* and the intensity of activity surrounding it, noise continues to be a problem and that past efforts to attenuate it need to be supplemented with more information about noise mitigation techniques, increased awareness about noise on the part of urban designers and more resources to accomplish the task.

## 4.0 A CASE STUDY - PORTLAND, OREGON

### 4.1 Setting

The problem which noise poses to mall users and neighboring businesses and the efforts which have been made to mitigate noise are best illustrated in the Portland Mall in Portland, Oregon. A detailed examination of such a specific project as Portland, and the noise issues and problems related to it, should afford a better understanding of noise abatement strategies in the context of actual factors and decisions affecting a project's planning, design and operation.

### 4.2 Description of the Portland Mall

Early transportation studies, performed for the City of Portland by private consultants, recommended the consolidation of the downtown bus network. Almost all of the buses which operated in the downtown area were to be routed to and through a transit mall. The transit mall was planned for two major downtown streets - Fifth and Sixth Avenues between Burnside and Madison Streets - a distance of approximately eleven blocks on each avenue for a total of twenty-two blocks (Figure 1). The implementation of the mall was part of a larger effort by Tri-Met, the principal mass transportation carrier in Portland, to provide more effective transit service to the overall metropolitan area.

Several alternatives were considered for the design of the transit mall. The approved design provided for two exclusive bus lanes on each avenue, plus a third for mixed traffic use on sixteen of the total twenty-two blocks. As bus volumes increase in the future, private autos would be further restricted from using the mall and higher transit capacity would be achieved.

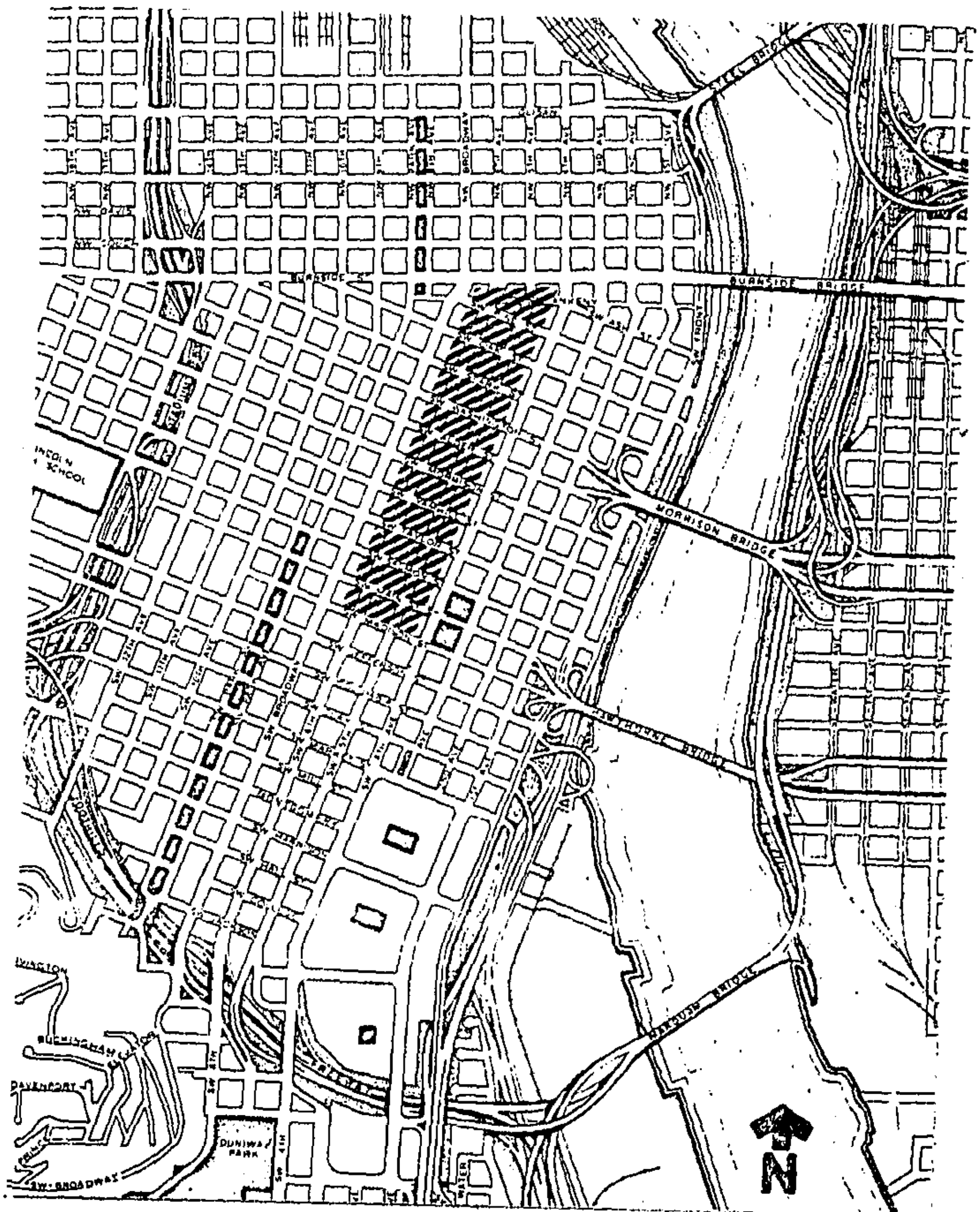



**Figure I**

**Project Location in Downtown Portland**

Source: U.S. Department of Transportation, Urban Mass Transportation Administration, Final Environmental Impact Statement, Fifth and Sixth Avenues Transit Mall, Portland, Oregon, December 1975, p. (1-B)2.

The basic configuration of the mall is a system of two parallel high-capacity transit lanes. Sixth Avenue, the western half of the mall, carries transit vehicles northward; Fifth Avenue, the eastern half, carries southbound traffic. Most of the routes serving the metropolitan area of Portland eventually travel along the mall. The mall also includes about twenty bus stops in each direction of the eleven-block mall. Crosstown streets are open to traffic, and non-transit vehicles may turn onto the transit mall on eight of the eleven blocks on each avenue. Extended sidewalks at certain locations act as barriers to prevent complete through-movement of non-transit vehicles. Surface facilities for transit passengers include sheltered waiting areas with seating, widened sidewalks, route and schedule information via television monitors, bus stop markers, route identification maps and phones which communicate with a transit information center. Other design features, not specifically related to transit travel, have been incorporated into the design of the mall as well. They include street landscaping, consisting of shade trees and granite planters which contain a wide variety of seasonal flowers and foliage, special brick paving with a surface pattern designed to accent and delineate pedestrian areas, street furnishings including elaborate drinking fountains, water fountains, kiosks, bulletin boards, display cases, concession booths, benches, bollards, lighting, flagpoles, traffic signage and traffic signalization. All of these elements are designed to project a visually attractive environment, supportive of pedestrian and transit-related activity.

### 4.3 Noise and the Transit Mall

#### Planning Considerations

Noise was perceived as a potential problem in the planning phases of the mall. The major contributor of noise was considered to be vehicular traffic - specifically buses. Because Fifth and Sixth Avenues were heavily trafficked, noise levels were high in the area before the implementation of the mall. With the addition of more diesel buses on the two corridors, increased noise levels were predicted.

The Environmental Impact Statement (EIS) of the mall investigated several mass transit alternatives in relation to their noise impacts. Beside the diesel bus alternative, a trolley system, a light rail system, a mixture of a diesel and trolley system and a no-build alternative were evaluated. The no-build alternative was evaluated in terms of the mixture of traffic that was present in the area before mall implementation. These alternatives were analyzed in terms of four noise criteria: pedestrian speech interference, hotel room sleep interference, office background noise standards and courtroom background noise criteria. Noise measurements were taken at four sites on Fifth and Sixth Avenues and at eight sites on the adjoining cross streets east and west of the proposed mall. Table 1 identifies the location of these sites and their respective statistical noise levels.

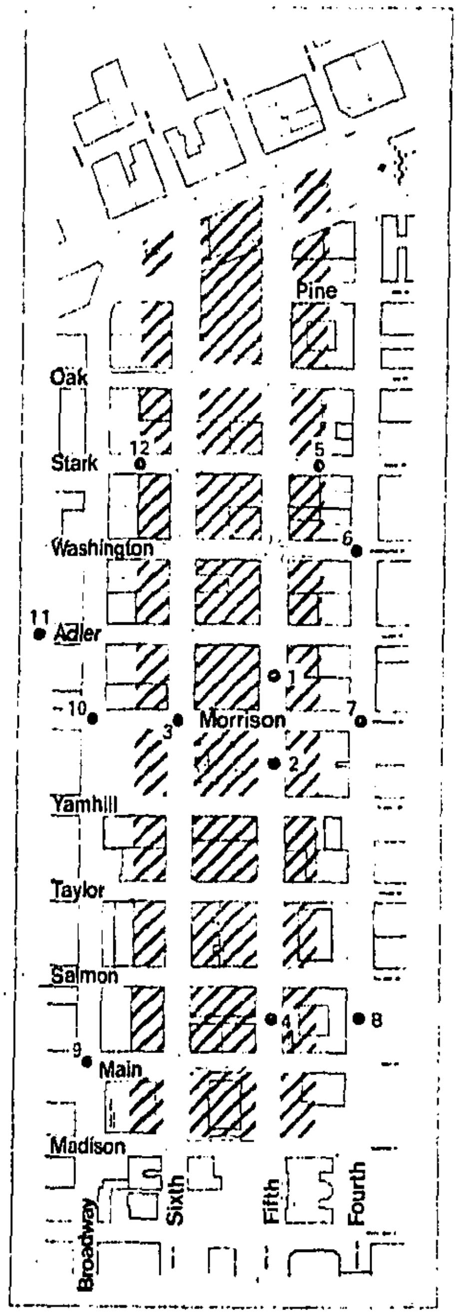
The alternative to increasing the use of diesel buses on the mall would, according to the EIS, increase pre-mall noise levels to beyond the standards contained in the four noise criteria. The EIS showed that only a switch to a different type of transit mode (e.g. from diesel bus to a trolley system) would improve noise conditions on the mall. However, this alternative required a significant capital investment and was, therefore, abandoned in favor of less costly solutions that may be available in the design and/or operation of the project.

Design Considerations

Several design possibilities to mitigate noise were considered. In examining these possibilities, the primary objective of the mall had to be kept in mind. It was, above all, a transit mall for buses - designed to make access to the downtown area more attractive and convenient. An

TABLE 1: EXISTING STATISTICAL NOISE LEVELS (dBA) AND SITE LOCATIONS KEY

| On Mall Sites | Time | $L_{90}$ | $L_{50}$ | $L_{10}$ | $L_1$ | $L_{eq}$ |
|---|---|---|---|---|---|---|
| 1 | Day | 60 | 64 | 72 | 80 | 69 |
| | Evening | 55 | 61 | 69 | 78 | 66 |
| | Night | 51 | 57 | 64 | 73 | 61 |
| | Peak Hour | 61 | 66 | 74 | 83 | 71 |
| 2 | Day | 62 | .71 | 77 | 80 | 73 |
| | Evening | 52 | 58 | 64 | 70 | 61 |
| | Night | 51 | 57 | 64 | 70 | 60 |
| | Peak Hour | 64 | 72 | 83 | 87 | 78 |
| 3 | Day | 65 | 68 | 72 | 79 | 70 |
| | Evening | 58 | 64 | 71 | 76 | 67 |
| | Night | 51 | 55 | 63 | 70 | 60 |
| | Peak Hour | 62 | 67 | 71 | 77 | 63 |
| 4 | Day | 62 | 68 | 74 | 80 | 70 |
| | Evening | 62 | 68 | 79 | 84 | 74 |
| | Night | 53 | 59 | 70 | 79 | 67 |
| | Peak Hour | 61 | 69 | 78 | 83 | 73 |
| Off Mall Sites | | | | | | |
| [illegible] | [illegible] | 63 | 67 | 71 | 76 | 69 |
| | Evening | 52 | 59 | 66 | 74 | 63 |
| | Peak Hour | 63 | 68 | 74 | 60 | 71 |
| 6 | Day | 66 | 72 | 78 | 86 | 75 |
| | Evening | 59 | 65 | 72 | 84 | 71 |
| | Peak Hour | 67 | 73 | 80 | 87 | 76 |
| 7 | Day | 62 | 69 | 75 | 83 | 72 |
| | Evening | 56 | 62 | 75 | 82 | 71 |
| | Peak Hour | 61 | 66 | 74 | 81 | 71 |
| 8 | Day | 61 | 64 | 70 | 78 | 67 |
| | Evening | 55 | 59 | 69 | 75 | 64 |
| | Peak Hour | 62 | 67 | 73 | 79 | 70 |
| 9 | Day | 58 | 64 | 73 | 82 | 70 |
| | Evening | 57 | 64 | 72 | 80 | 69 |
| | Peak Hour | 62 | 68 | 74 | 82 | 71 |
| 10 | Day | 61 | 66 | 72 | 79 | 69 |
| | Evening | 59 | 66 | 75 | 82 | 71 |
| | Peak Hour | 63 | 69 | 76 | 85 | 74 |
| 11 | Day | 60 | 64 | 71 | 82 | 69 |
| | Evening | 46 | 50 | 57 | 64 | 54 |
| | Peak Hour | 62 | 67 | 74 | 84 | 72 |
| 12 | Day | 61 | 66 | 72 | 77 | 63 |
| | Evening | 56 | 60 | 65. | 73 | 63 |
| | Peak Hour | 66 | 72 | 78 | 82 | 74 |




Source: Tables 5 and 6, Robin M. Towne Associates, Environmental Noise Study, Portland Transit Mall, January, 1975.

unavoidable byproduct of bus traffic is noise. Furthermore, there was not a vast amount of open space between the transit lanes and the pedestrian walkways and building lines. In some areas of the mall the presence of tall buildings would create a canyon effect where noise can reverberate.

One design possibility was to acoustically treat the facades of the abutting buildings. However, this would prove costly and ineffective because there were large window areas on the building facades and there was little space left for acoustical treatment.

The use of acoustical barriers placed between the bus lanes and the sidewalks was also explored but considered untenable for several reasons. A barrier several feet high placed on the ground may prove effective in absorbing and diffracting noise, such as is created by bus exhaust, which emanates from underneath the bus. However, the exhaust stacks on most of Portland's fleet are directed skyward from the top rear of the bus and a barrier lower than the noise source would have little effect in this case. Secondly, an effective barrier should have no gaps in its length. Such a situation would clearly interfere with pedestrian and passenger circulation.

The use of extensive vegetation was also considered ineffective. The lack of space to plant vegetation in addition to the amount of vegetation necessary to substantially reduce noise argued against the pursuit of this alternative. Similarly, the use of masking noises, in the form of waterfalls, was considered ineffective. While a waterfall may be useful for a small area, it would not be viable given the extensive size of the Portland Mall.

The bus shelters along the mall were prime candidates for acoustical treatment. They are oblong in shape and semi-enclosed structures. Access to each shelter is from either the curb or sidewalk. The north and south ends of each structure are rounded and enclosed with transparent material. The top of each shelter is made of the same transparent material. For noise mitigation purposes, the side of the shelter adjacent to the sidewalk could be closed off. However, the resulting three-sided enclosure was more expensive to construct and less convenient to pedestrian access.

In short, there was little that could be, and, in fact, was done with respect to designing the mall to attenuate noise given the purpose and physical constraints of the project.

Operation Considerations

As the mall was phased into operation, the number of buses began to increase on Fifth and Sixth Avenues. As a result of the increased bus volumes, the noise levels began to rise. Shopkeepers initiated complaints about the noise. The cause of their annoyance was primarily the buses, specifically the noise associated with bus acceleration. The increased noise levels also affected the ability of mall users to carry on conversations at normal voice levels in the vicinity of bus traffic and also posed a possible hazard to hearing. Of importance in this latter consideration is the time spent at the mall by the average person. In addition, the increase in the noise was significant enough to prohibit the U.S. Department of Housing and Urban Development (HUD) from funding housing units along the busy downtown corridor. Confronting the noise problem from a different direction, Tri-Met examined operational strategies on the mall to decrease noise levels.

Since there seemed to be a correlation between increased bus volumes and increased noise levels on the mall, it was logical to assume that decreasing the number of buses along the mall would serve to lower the noise levels. With this in mind, Tri-Met began to examine different routing possibilities for buses entering and leaving the downtown area. The results of the analyses are not complete at this writing. However, while such an operational measure may appear effective with respect to noise, it would be difficult to simultaneously accommodate extensive rerouting in light of the fact that the purpose of the transit mall is to consolidate transit access and to expand such service should the demand for transit services grow in the future.

An operational measure that has been implemented is a bus operator education program. This program is aimed at instructing the bus driver on how to operate his bus in as quiet a manner as possible. Another operational consideration examined was traffic signalization. The use of a progressive signal system on the mall as opposed to a simultaneous signal system has been briefly explored. No conclusive evidence on the noise curtailment effects of the two systems has been documented to prove which system, if either, has a more positive effect in reducing noise. The theory behind the use of either type of signal system is to minimize the starting and stopping of buses at traffic lights as they travel the length of the mall. The progressive system was first used on the mall. The simultaneous system is presently in effect.

Engineering Considerations

Much of Portland's efforts at noise attenuation have concentrated on engineering approaches to quiet bus noise. This approach has the advantage of treating noise before it is created rather than attenuating it after it is already present in the environment by means of design and/or operational considerations. Source control measures are now being undertaken by the bus fleet operator, Tri-Met. Tri-Met has made several alterations on test buses in a noise retrofit program with funding for the demonstration program provided by a grant from the US Department of Transportation-Urban Mass Transportation Administration as well as from the US Environmental Protection Agency. Tri-Met has installed a turbocharger on the engines of its test buses. The installation of this device has resulted in a reduction in the engine noise and exhaust noise level. Tri-Met has also padded the engine compartment on these buses with a 1½ inch thick material that is soft, rugged, and easily bent. It consists of a 10 $oz/ft^2$ lead septum sandwiched between two blankets of glass fiber. The composite is protected by a lightweight waterproof aluminized glass cloth. The lead serves as a sound barrier and the glass fiber blankets reduce echoing. Tri-Met is also experimenting with installing belly pans underneath the engine compartment as a noise mitigationtechnique. The final design of these pans is not yet complete. Another measure, undertaken by Tri-Met, has been to retrofit the exhaust system of its test buses with new mufflers. Several retrofit buses were tested during 1979; these experimental efforts have thus far resulted in a 4.5 dB decrease in the noise level of the buses.

At the present time, Tri-Met has not requested funding for retrofitting their bus fleet. If and when this comes about, Tri-Met expects to retrofit approximately 15 buses per month. A new type of bus transmission is under investigation which would reduce the need for full throttle on acceleration, allowing the bus to move more smoothly with less engine RPM and, consequently, less engine noise. Tri-Met has also investigated the use of trolley bus operations within their system to provide for quieter transit operations in the future.

Continued Monitoring

While the engineering effort continues, Portland is involved in a program to monitor noise in the central business district with funds provided by the U.S. Environmental Protection Agency and the U.S. Department of Housing and Urban Development. Part of the program is to develop an urban noise model capable of predicting noise levels in an urban environment. The program has produced preliminary noise monitoring data as of this writing. Some of this preliminary information has been included in this report to provide a rough estimate of the changes in the noise levels of the mall on a before-and-after basis. While a significant amount of monitoring has occured outside the confines of the mall for purposes of the urban noise model, two main locations have been included below. The main locations are on Fifth Avenue at the intersections of Morrison and Adler Streets. Each main location was composed of four monitoring sites positioned at different strategic points. The two locations are in close proximity to locations 1 and 2 of Portland's EIS., which have been included above in Table 1. Table 2 compares the preliminary post-mall noise level data with the pre-mall data of the EIS.

Table 2

Pre- and Post-Mall Noise Data for Two Locations

(Average $L_{eq}$: Day and Night)

| | Location | Pre-Mall (EIS) Data | Post-Mall Data* |
|---|---|---|---|
| | | $L_{eq}$ dBA | $L_{eq}$ dBA |
| A. | Fifth Avenue and Morrison Street | Day 73<br>Night 60 | 69-75.3<br>56-69 |
| B. | Fifth Avenue and Adler Street | Day 69<br>Night 61 | 71-75.2<br>66.4-70.7 |

*These are preliminary results only and represent the range of the four monitoring sites at each location.

Because the locations of the monitoring sites are not identical for the pre- and post-mall monitoring, strict comparisons should not be made. However, these results do seem to indicate that the presence of the mall has served to increase noise levels in the area. At Fifth Avenue and Morrison Street, where noise levels were initially high, the noise level has increased slightly during the daytime hours. What appears to be more of a problem is the increase in the noise level in those areas of the mall which were subject to less noise before the mall was constructed; these are now similar to or higher than the more noisy pre-mall locations. Aggravating this situation further is the increased night-time noise levels, which do not help the City to meet its housing objectives in the downtown area. A further consideration are the peak hour noise levels, which would presumably raise the noise levels on the mall even higher than those indicated on Table 2, although for brief periods of time during the day.

## 4.4 Summary

From Portland's experience, it appears that the most advantageous way to solve the noise problem is at the source of the noise. Portland's best strategy is to retrofit its buses. Retrofitting Portland's fleet appears possible but expensive. To assist Portland in the future, the purchase of newer, quieter buses to replace its older buses will help to decrease the noise levels further. To implement design and/or operational techniques to reduce noise does not appear to be as effective. The use of barriers, re-routing schemes, etc., may prove to be costly and only marginally effective, as well as possible obstacles to pedestrian access and circulation, which are objectives of the project. On the other hand, the 4.5 dB decrease associated with Tri-Met's total retrofit effort would substantially help to decrease the noise to levels that are more in keeping with the objective of protecting against noise-induced hearing loss and preventing undue annoyance and disturbances caused by excessive bus noise.

## 5.0 FORMULATION OF NOISE ABATEMENT DESIGN CRITERIA - BROADWAY PLAZA, NEW YORK

Broadway Plaza is proposed as a series of three pedestrian plazas and a transitway to be built in the heart of Times Square in New York City. The project is currently in the final design phase with construction scheduled to begin in the Spring of 1931. It was of interest to this study of noise and pedestrian areas to identify potential noise mitigation measures from the perspective of the design of a specific project, although the feasibility of incorporating these techniques will ultimately depend upon their conformance with project objectives.

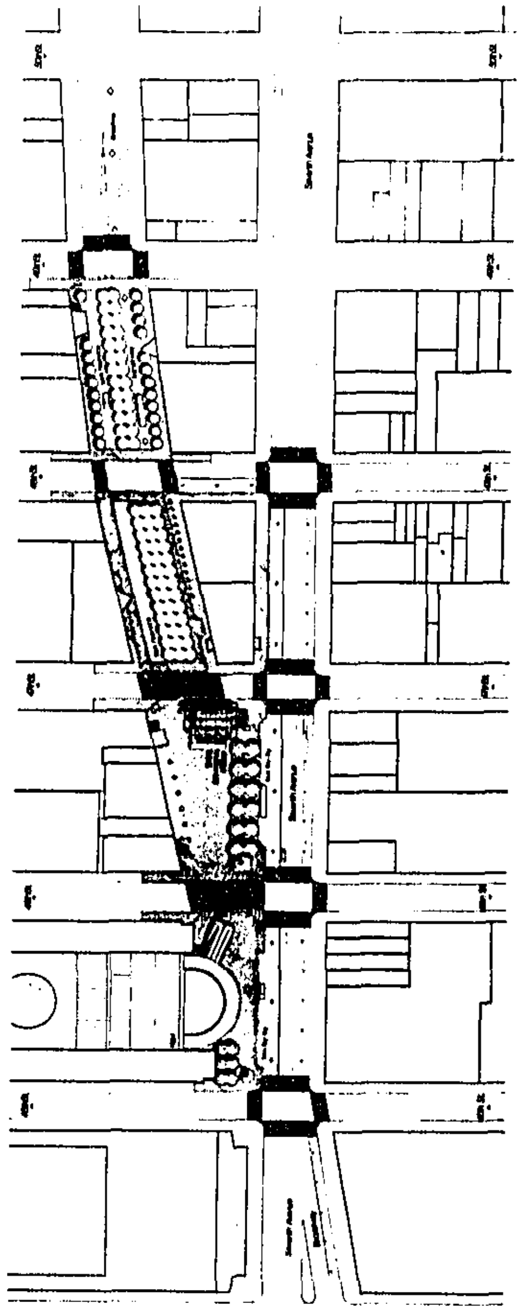
Section 5.1 summarizes the design and operational features of the proposed Broadway Plaza; Section 5.2 analyzes the potential significance for noise mitigation of certain of these design elements; Section 5.3 suggests criteria for the location of physical elements to reduce noise; and Section 5.4 offers operational guidelines for vehicular movement for the purpose of controlling noise.

### 5.1 Description of Broadway Plaza

Broadway Plaza is a proposed pedestrian/transit mall in the heart of Times Square and the Theater District in New York City. Broadway Plaza will be created by closing Broadway to traffic between 45th and 48th Streets and replacing the portion of the street now used for automobiles with new paving. Since crosstown traffic will be allowed to continue across 46th and 47th Streets, Broadway Plaza will, in effect, consist of three pedestrian plazas. A transitway on Broadway between 48th and 49th Streets will introduce a series of operational measures designed to give preferential treatment to transit vehicles to Columbus Circle. The transitway will be continued along the eastern edge of the pedestrian plazas between 48th and 45th Streets.

The southernmost plaza between 45th and 46th Streets will include new paving, trees and the existing monument to George M. Cohan, which is presently

# Broadway Plaza



## 48th-49th Streets Transitway

- Sidewalks remain at same width.
- Dual roadway with landscaped center median.
- Buses routed on eastern roadway.
- Taxi and service vehicles use western roadway.
- Bus stop on center median.
- Trees, information kiosks.

## 47th-48th Streets Plaza C

- Right-of-way for emergency access and service vehicles.
- Trees, lights, sculpture and information kiosks.

## 46th-47th Streets Plaza B

- Times Square Theater and Information Center (TKTS; Tourist and Transit Information; Military).
- Outdoor stage for programmed entertainment.
- Special boarding area and lay-by for buses.
- Father Duffy monument.
- Trees, banners, kiosks.

## 45th-46th Streets Plaza A

- Adjacent to proposed Times Square Hotel (Enclosed sidewalk cafe; escalators to retail areas).
- Special boarding area and lay-by for taxis (Taxi information and dispatch operation).
- George M. Cohan monument.

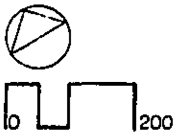



**Figure 2**
**Broadway Plaza Site Plan**

located on Duffy Square. The eastern edge of the plaza would be reserved for taxis, with a special lay-by providing taxi information and a dispatch operation. A new fifty-story hotel has been proposed for the western edge of this plaza and would include an enclosed sidewalk cafe and escalators leading from street level to retail areas on the third and fourth floors.

The middle and largest of the plazas between 46th and 47th Streets will include a complete transit, tourist and theater information center which will also incorporate TKTS, the half-price ticket booth presently located on Duffy Square. This multi-functional center will also have an outdoor stage for programmed entertainment. A special boarding area and lay-by for transit vehicles will be designated along Seventh Avenue between 46th and 47th Streets. In addition to new paving, this plaza will include trees, banners, information kiosks and the existing monument to Father Duffy.

The plaza between 47th and 48th Streets will have retail shops on either side of the block. It has been designed to include shade trees, lights, information kiosks and sculpture. A continuous twenty-foot right-of-way will be provided for emergency access and service vehicles.

The transitway on Broadway between 48th and 49th Streets is designed as a dual roadway with transit vehicles and the existing Broadway bike lane to be routed on the western roadway. A landscaped center median will incorporate a bus stop as well as information kiosks and shade trees. The transitway will continue across 48th Street and down Seventh Avenue to 45th Street and provide access to the block-long lay-bys for buses and taxis provided by the two adjacent plazas.

Broadway Plaza also includes the introduction of a series of operational measures and traffic management strategies designed to provide priority treatment for transit vehicles along Broadway, north of the Plaza, and simultaneously encourage non-transit vehicles to diversion routes. These measures include signal changes, as well as a motorist guidance system.

## 5.2 Potential Significance of Design Elements for Noise Mitigation

Several of the identified design elements can serve a function in attenuating noise. Although suggestions will be made here for utilizing these design features of the Plaza for noise attenuation, the final design of any of the discussed elements would be subject to the inherent tradeoffs between cost, purpose and function.

The first opportunity for noise mitigation lies in the bus and taxi shelters. In effect, these physical elements could act as potential noise barriers for Plazas A and B. The design of the shelters should be continuous along as much of the two plazas as possible. The shelter should be of significant height not only to block the noise that emanates from near-ground vehicle exhaust systems, engine compartments, suspension systems and transmissions but to provide the barrier effect against the exhaust systems of heavier trucks, which are located well above the ground. The tops of the shelters should be turned inward at an angle toward Seventh Avenue rather than parallel to the street surface to provide for more barrier surface. The shelter can be constructed of a transparent material, such as Lexon. This material would be preferable to plexiglass, since it has a higher density. There are several advantages to such shelters. They would be transparent, thereby allowing visual access between areas inside and outside of the Plaza. Secondly, the use of a high-density plastic should reduce some of the noise. Thirdly, the shelters would be located near the noise sources with the further advantage in that limited space on the Plaza would be needed to accommodate them. The disadvantages of a continuous shelter along a block front are that it would significantly interfere with pedestrian circulation at the edge of Plazas A and B, and that it would prohibit easy access to and from the buses and taxis.

Along the eastern edge of Plazas A and B are located subway ventilation gratings. Noise from the subways underneath the Plaza emanates from these gratings. Noise from these gratings can be abated through the installation of either a prefabricated sound trap or acoustically lined sheet metal ducts. The sound trap can be installed below the street grade, which would not interfere with pedestrian circulation. The sheet metal ducts could be installed above street level and can be designed as a series of three foot to four foot oval or cylindrical ducts extending from the grating of an angle of 135° which could direct any escaping noise away from activity areas. The duct work could be designed attractively, as well as color coordinated, with other furnishings and structures on the Plaza although such ducts would be clearly unusual forms for a pedestrian area.

The TKTS booth and information center could be acoustically insulated to facilitate communication inside the structure. The area designated for ticket purchases or other areas designated for communication outside of the structure can be oriented away from the traffic side of the structure. In this way, the structure itself can act as a noise barrier while performing its other functions.

The roadways adjacent to the mall may be candidates for noise mitigation. Potholes and poorly-fitting manhole covers add to the fluctuating noise levels when passed over by moving vehicles. A smooth roadway surface may prevent the clanking and thudding of vehicle suspension systems and provide for quieter tire-road surface interaction.

Other design elements, thus far identified, used above or in concert with each other may have minimal effectiveness as sound attenuators. A series of barriers, placed one after another, does not much improve the effectiveness of a single, well-positioned and constructed barrier. Therefore, it may not prove cost-effective to locate a series of barriers that, for example, may consist of a line of bus shelters placed in front of a series of bulletin boards or kiosks which are then positioned in front of a line of shade trees when a continuous "front line" barrier may provide the most significant reduction in noise levels. The effectiveness of isolated sculptures, kiosks or monuments will have a negligible effect in decreasing noise. Isolated trees or vegetation used to accent plaza appearance will not help to decrease noise levels either, although they may promote the psychological impression of a more serene type of environment. The introduction of a masking noise (e.g. a waterfalls) may prove effective in drowning vehicular noise in areas immediately adjacent to it, but its effects are quickly diluted the farther away one travels from it.

Depressions in plaza elevation would help to decrease noise in the depressed areas. The depressed or sunken area, in effect, becomes isolated from the noise pathway. However, this is impossible in the case of Broadway Plaza since such a change in site elevation, which would be necessary for noise abatement purposes, would interfere with subway tunnels and the utility infrastructure as well as prove a serious impediment to pedestrian circulation in such a heavily traversed area as Times Square.

The transitway between 48th and 49th Streets presents certain noise issues. It will be used by buses, taxis and service vehicles. Although a median strip will be positioned in the center of the road to separate transit and paratransit vehicles, this element will have little effect on reducing noise. Since traffic will be present on both sides of the median, even a barrier constructed along its entire length will not provide much assistance in reducing the noise there.

5.3 <u>Criteria for the Location of Physical Elements to Reduce Noise</u>

Based on the parameters outlined in the previous section, several criteria can be established to locate design elements for noise mitigation on Broadway Plaza.

1. Those design elements that can serve a function in attenuating noise should be located as near as possible to the source of noise. In the case of Broadway Plaza, the primary noise source will be vehicular. Consequently, the eastern edge of the plaza (e.g. along Seventh Avenue) could be considered the primary location for the installation of design elements that may help to attenuate noise.

2. In the case of using physical elements as barriers, a series of barriers will not increase the effectiveness over one, well-positioned barrier. Therefore, emphasis should be placed on designing and locating physical elements to provide for one "line of defense" against noise intrusions rather than dispersing physical elements throughout the plaza for noise attenuation purposes.

3. Physical elements should be placed between the source of noise and the potential receivers of noise (e.g. plaza users).

4. Activity programming and events should be positioned as far away as possible from noise sources, since noise attenuates with distance.

5. Changes in site elevation (e.g. depressions in the site's topography) can create areas which are less noisy. Depressed areas would be even more effective against noise if positioned

as far as possible from noise sources.

6. Areas where conversation is desired can be partially isolated by the use of design elements when those elements can be placed between the noise source and conversation areas.

7. Building structures, and particularly their facades, can be treated acoustically to prevent sound reverberation.

8. Areas where such activities as eating or reading are desired and where conversation is not required can be treated with masking noises.

9. Isolated and stationary noise sources (e.g. air conditioning units) can be enclosed or partially enclosed to prevent noise from intruding into an area.

10. Buildings or other structures can be oriented away from noise sources, thereby utilizing the structure itself as a noise barrier.

11. Design elements can also be a means of bringing the noise problem to the attention of the public. Signs and other visual reminders to encourage quiet could be attractively designed and located in those areas of the plaza intended for conversation, reading, etc.

12. Non-permanent fixtures might be investigated for use as temporary sound barriers for use during those times when outdoor events are scheduled. These temporary fixtures could be placed to partially enclose an activity area during performances and

disassembled afterwards. The location for the temporary structures would depend upon the specific acoustical needs of the event.

### 5.4 Operational Guidelines for Vehicular Movement for Noise Control

The guidelines set forth below pertain to the design of vehicular movement in the area of Broadway Plaza. Since vehicular traffic is the major contributor of noise in the area, operational techniques to control the flow, movement and composition of the traffic may prove fruitful for noise control purposes. For this reason, the following guidelines are proposed.

1. Traffic signals on Seventh Avenue should be coordinated to stop traffic either above 47th Street or below 45th Street, and not adjacent to the major pedestrian areas. This would prevent many vehicles from idling at traffic lights adjacent to the plaza and, more importantly, minimize the noise of vehicle acceleration at the beginning of the green cycle.

2. Traffic signals between 48th and 45th Streets on Seventh Avenue should be set to accommodate as steady a flow of traffic on Seventh Avenue as possible and to minimize interruptions in the vehicular flow patterns.

3. Seventh Avenue should be kept clear of double parked vehicles to provide for a steady flow of vehicular traffic during green cycles.

4. Vehicles on the crosstown streets in the area of the plaza should be stopped behind the building line.

5. Traffic signals along the transitway at the intersections of 48th Street and Broadway and 48th Street and Seventh Avenue should be coordinated so that buses can make the double turn in one signal phase, thereby avoiding double acceleration from rest.

6. Trucks should be encouraged to make their deliveries during those times of the day when the plaza is least utilized by pedestrians.

7. Non-transit vehicles should be prohibited from using the Seventh Avenue transitway in order to minimize conflicts with bus movements.

8. Through traffic (especially trucks) should be encouraged to seek alternate routes south other than Seventh Avenue. The use of signage and other traffic aids can be helpful in this regard.

9. Bus operators should be encouraged to operate their vehicles in as quiet a manner as possible. Signage that reminds people not to use horns and to avoid sudden braking and accelerating may be useful.

10. Markings for traffic lanes should be clearly visible so that weaving and merging are kept to a minimum.

Several of the elements and operating guidelines which have been suggested above as having potential for noise mitigation have already been included as part of Broadway Plaza; these include the use of the eastern edge of the Plaza for the location of design elements and the program of signage and signalization proposed as part of the traffic diversion. A combination of both design and operational measures, as discussed above, is expected to reduce the noise levels in and around Broadway Plaza.

# III. An Evaluation of Noise and Urban Spaces

## 1.0 INTRODUCTION

### 1.1 Project Objectives

The purpose of this study is to evaluate the relationship between urban pedestrian plazas and ambient noise levels. Seven pedestrian plazas in New York City were selected as representative case studies. At each of the seven plazas a noise measurement study was conducted to determine the "noise climate" during daytime and evening hours of maximum use. Since noise affects the plaza user, an attitudinal survey to determine the users' profile and sensitivity to noise was included in the study.

The study was begun with the assumption that pedestrian plaza noise could originate from any source. It was found that noise sources other than surface transportation were not likely to affect a plaza. Of the two types of surface transportation noise, motor vehicle traffic would be more common to an urban pedestrian plaza than rail. The other major aspects of this study, noise abatement measures and a method for estimating plaza noise levels, deal with traffic as the major source of noise.

An attitudinal survey was conducted at five of the seven selected plazas. The intent of the survey was twofold: (1) to determine the profile of a typical pedestrian plaza user and (2) to determine the plaza users' awareness and sensitivity to noise. Noise abatement measures for plaza design were evaluated. The design elements examined in this study were a combination of those design elements found in the pedestrian plazas studied and noise reduction techniques used for other types of architectural design. These design elements typically include barriers, plantings and vegetation, waterfalls and fountains, seating placement, and multilevel designs.

The final phase of the study was the design of a method to estimate plaza noise levels. In this method, a nomogram is used to determine traffic noise levels for three categories of vehicles: autos, medium trucks/buses, and heavy trucks. Once the traffic noise level has been determined, noise attenuation due to barriers, blockage from buildings, vegetation and depressed and elevated plaza design are considered. By using this method, the plaza designer can determine the plaza noise level due to one or more roadways and its impact on speech communication within the plaza.

1.2 Selection of Pedestrian Plazas

Seven pedestrian plazas in New York City were selected to serve as representative case studies for the noise and attitudinal surveys. The selection criteria was based on a cross section of plaza design and plaza use parameters. A chart comparing plaza features (Table 1) was used to select the seven plazas from a preliminary list of 24 plazas (AMRA, 1978). Two of the seven plazas were excluded from the attitudinal survey because of their infrequent use.

The pedestrian plazas selected were:

Seagram Plaza - Park Avenue between 52nd Street and 53rd Street

Rockefeller Center - Fifth Avenue between 49th Street and 50th Street

Lincoln Center - Columbus Avenue between 62nd Street and 65th Street

General Motors Plaza - Fifth Avenue between 58th Street and 59th Stree

Grand Army Plaza - Fifth Avenue between 58th Street and 59th Street

Plaza 400 - First Avenue between 55th Street and 56th Street

KLM Plaza - Madison Avenue between 49th Street and 50th Street

Table 1

Criteria for Plaza Selection

| | KLM Plaza | Seagram Plaza | Plaza 400 | General Motors Plaza | Grand Army Plaza | Rockefeller Center | Lincoln Center |
|---|---|---|---|---|---|---|---|
| **A. Proximity to different surface transportation:** | | | | | | | |
| a. auto traffic only | | X | | | | | |
| b. auto and bus traffic | X | | X | X | X | X | X |
| c. truck routes | X | | X | X | X | | X |
| d. subway | | | | | | | |
| **B. Adjacent land uses:** | | | | | | | |
| a. residential/commercial | | | X | X | X | | X |
| b. commercial/office | X | | | | | X | |
| c. office only | | X | | | | | |
| d. recreational/comm/ office | | | | | X | | X |
| **C. Adjacent streets/avenues:** | | | | | | | |
| a. one street | | | | | | | |
| b. two streets (parallel) | | | | | | | X |
| c. two streets (perpendicular) | | | | | | | |
| d. three streets | X | X | X | X | | X | |
| e. four streets | | | | | X | | |
| **D. Mall/adjacent structures** | | | | | | | |
| a. open plaza area | | | | | X | | |
| b. partially enclosed without canyon | | X | | X | | | |
| c. partially enclosed with canyon | X | | X | | | X | X |
| d. fully enclosed | | | | | | | |
| **E. Traffic aids adjacent to plaza:** | | | | | | | |
| a. traffic lights | X | X | X | X | X | | X |
| b. bus shelters & taxi stands | | | | | | | |
| **F. Topography** | | | | | | | |
| a. above grade | | X | | | | | |
| b. below grade | | | | | | | |
| c. at grade | | | | | X | | X |
| d. multi-level | X | | X | X | | X | |
| e. gradual grade change | X | | X | | | | |

Table 1 (continued)

| | KLM Plaza | Seagram Plaza | Plaza 400 | General Motors Plaza | Grand Army Plaza | Rockefeller Center | Lincoln Center |
|---|---|---|---|---|---|---|---|
| G. Geometry | | | | | | | |
| a. rectangular | | X | | X | X | X | |
| b. circular | | | | | | | |
| c. triangular | | | | | | | |
| d. L-shaped | | | | | | | |
| e. U-shaped | X | X | X | | | | X |
| H. Design features-presence of: | | | | | | | |
| a. masking noise | | X | | X | X | X | X |
| b. barriers (isolated standing walls) | | | | | | | X |
| c. mall furniture | | | | X | X | X | |
| d. vegetation (by sample size comparison only) | | | | | | | |
| 1. heavy vegetation | | | | | | X | |
| 2. light vegetation | X | X | X | X | X | | X |
| 3. no vegetation | | | | | | | |
| e. absorbtive materials &/or finishes | | | | | | | |
| I. Pedestrian thoroughfare | | | | | | | |
| a. presence of | X | X | X | X | X | X | X |
| b. absence of | | | | | | | |

Source: AMRA, 1978.

1.3 <u>Description of Plazas</u>

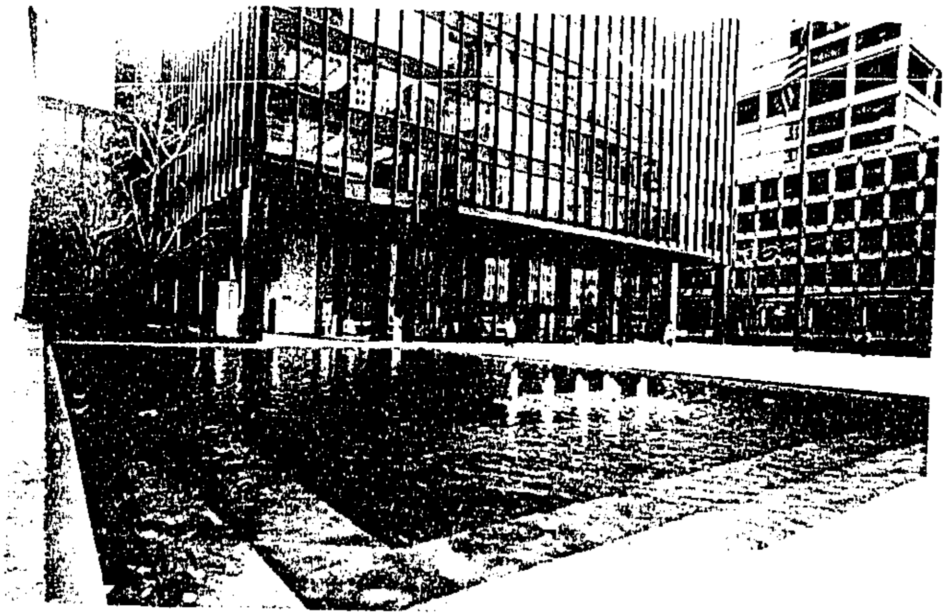
The design features of each of the pedestrian plazas selected for this study are as follows:

<u>Seagram Plaza</u>

The bronze and bronze-glass tower Seagram Building designed by Mies van der Rohe in the 1950's reintroduced the idea of "plaza" to New York. Occupying the full block on Park between 52nd and 53rd Streets, the Seagram Plaza (Figure 1) is large and open with some furniture and foliage; two fountains are situated at either end. The Plaza is two meters (m) (six feet (ft) ) above grade, somewhat separated from street activity.

<u>Rockefeller Center</u>

The flagship RCA building rises directly from Rockefeller Center Plaza (Figure 2) which not only provides scale to this complex but functions as a pedestrian enclave for tourists, shoppers and workers in nearby offices. Rockefeller Plaza is a multi-level pedestrian space which encompasses and overlooks the sunken center area which is transformed from an outdoor cafe in summer to an ice skating rink in winter. This sunken plaza, set back from the street, is accessible via the Channel Gardens, a gently sloped, fountained space with lush seasonal foliage. Flanked by low-scaled shops, the Gardens offer seating facilities from which to view both internal plaza events and Fifth Avenue activities.



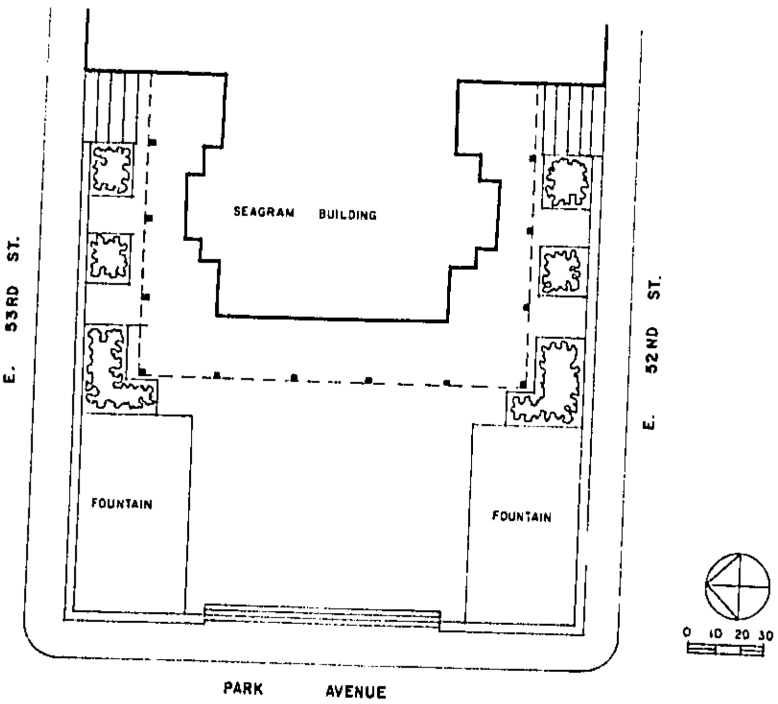



**FIGURE 1 SEAGRAM PLAZA**

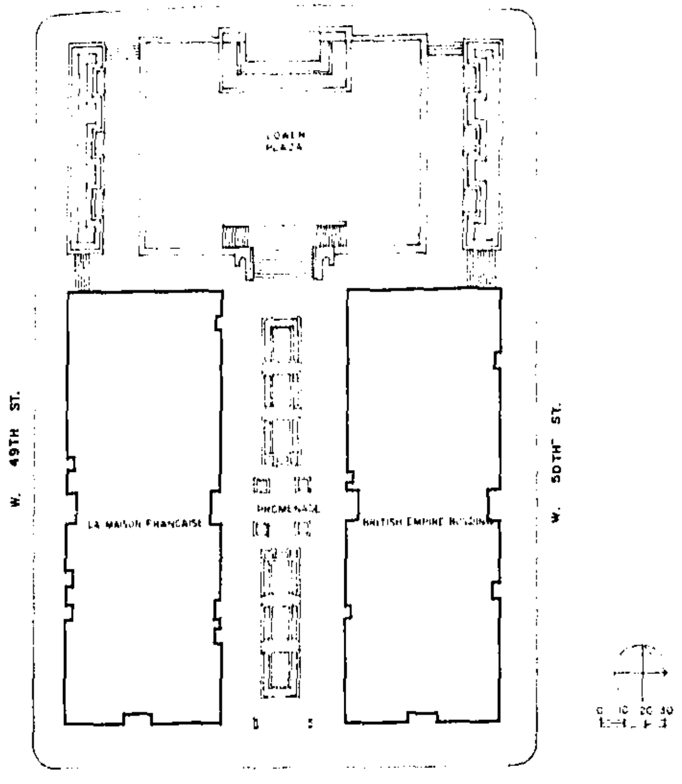


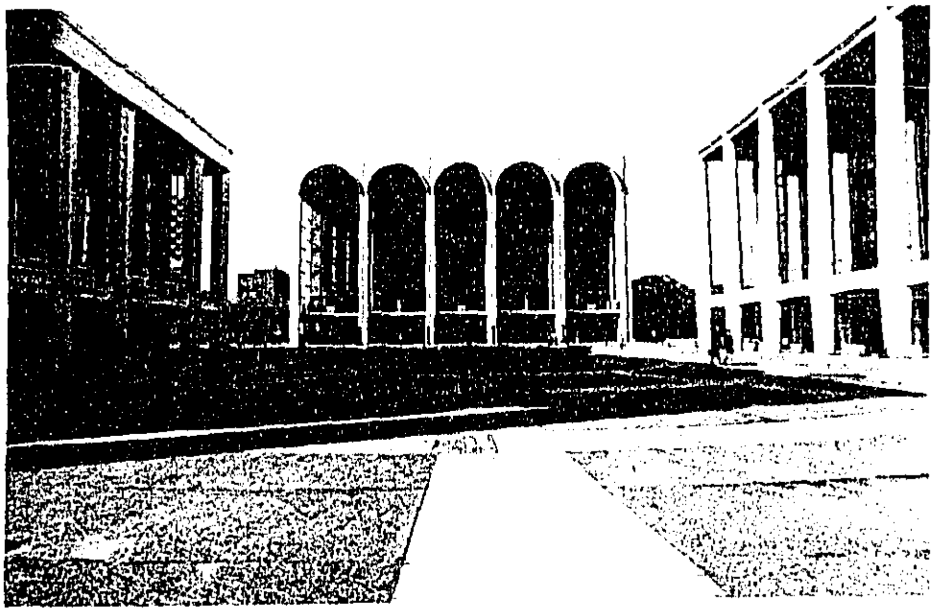

**FIGURE 2 ROCKEFELLER CENTER**

Lincoln Center

For purposes of this project the Lincoln Center Plaza (Figure 3) encompasses the system of pedestrian spaces including the main open space contained by Philharmonic Hall, the State Theatre and the Metropolitan Opera as well as Damrosch Park at the southwestern corner of the complex and the smaller plaza space in front of the Library and Museum of Performing Arts in the northwest corner. The main plaza is a paved, spacious court; the only furniture is the fountain situated in the middle of the plaza around which opera and theatre goers congregate before and after performances. During the summer months an outdoor cafe is set up along the south side of Avery Fisher Hall. To the south of the Met is Damrosch Park, a space for free outdoor events. This park includes a flat, intricately paved center section surrounded by an edge of formal landscaping. On the other side of the Met is a small plaza in front of the Library/Museum Building; ample seating facilities surround a reflecting pool.

General Motors Plaza

The bi-level General Motors Plaza (Figure 4) occupies the full block between 58th and 59th Streets. Attached to the relatively new (1968) General Motors tower the U shaped upper plaza is regularly punctuated by stone slab seating facilities and lightly vegetated planters. This portion of the plaza is at street level and offers an opportunity for building workers or passersby to lunch or people watch in Manhattan's exclusive Plaza Hotel district. The sunken central space is flanked by premier quality retail facilities. During warm weather this below grade portion of the plaza houses a popular outdoor cafe.



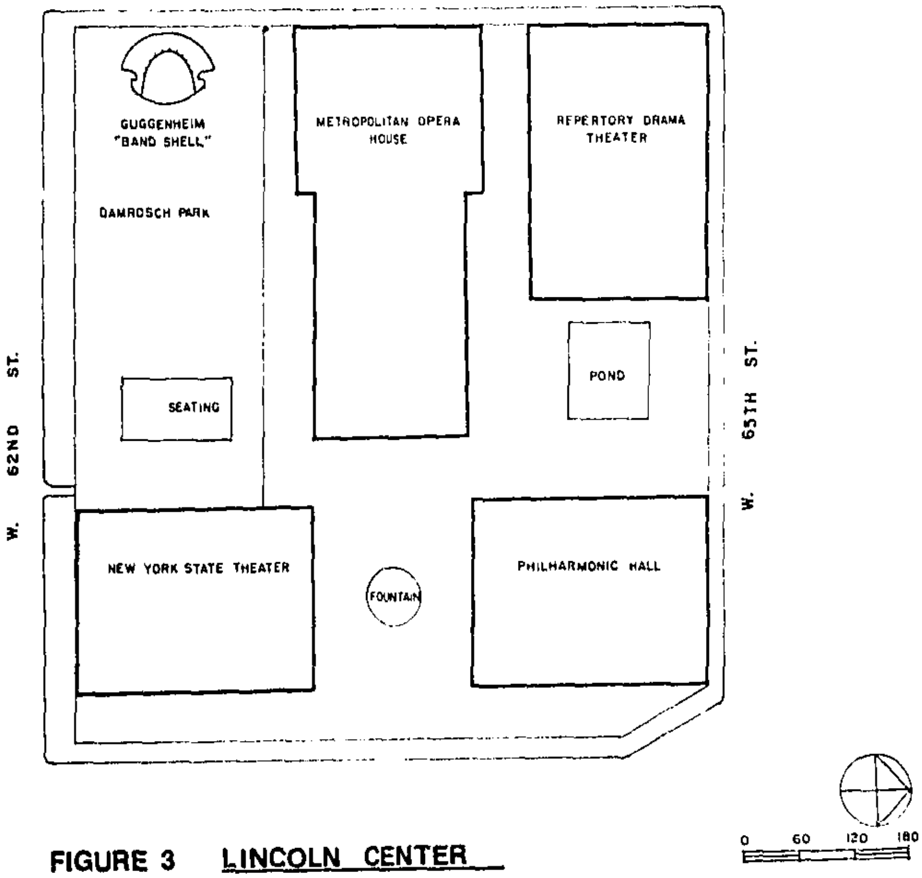
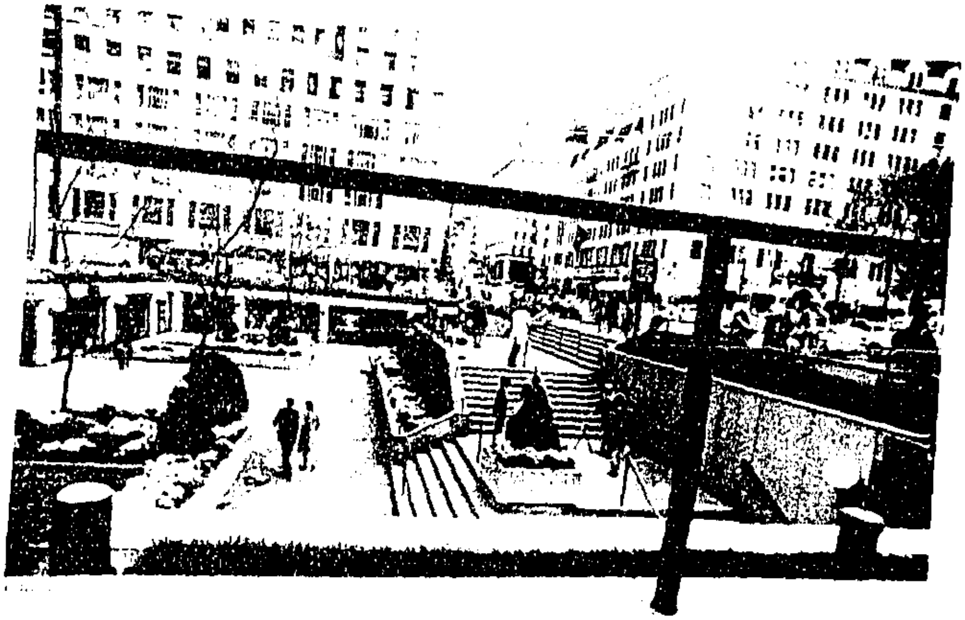



**FIGURE 3** LINCOLN CENTER



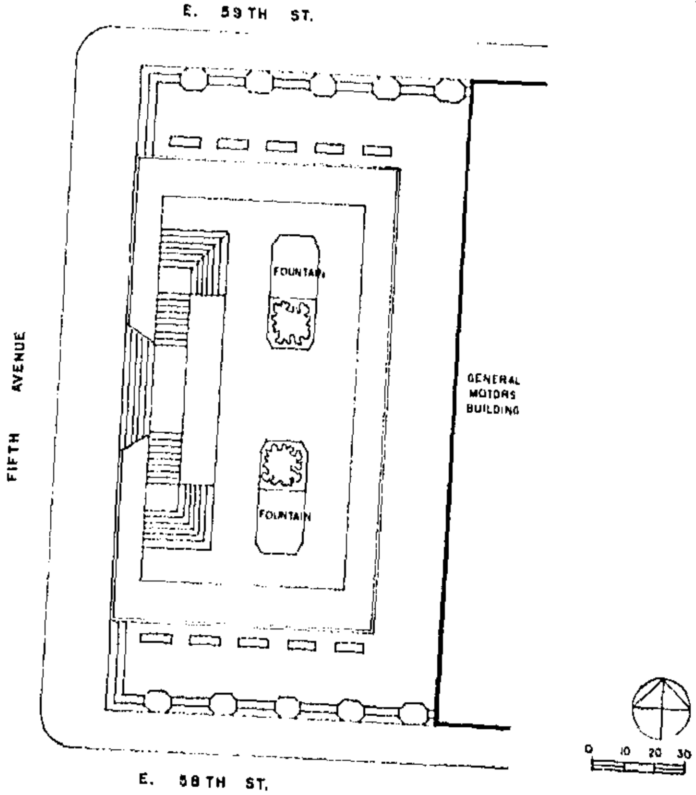



FIGURE 4 GENERAL MOTORS PLAZA

Grand Army Plaza

Located in Manhattan's most exclusive shopping-hotel-office area at the edge of Central Park, Grand Army Plaza (Figure 5) is the first of New York's two public urban plazas. It is a pedestrian plaza which is not a part of a private building complex as are the other plazas in this study. The plaza is an island, surrounded completely by streets and contained by buildings of varied architecture and function. It is bisected by 59th Street. To the south of the pedestrian space is ornamented by varied paving and trees enclosing the Pulitzer Fountain. Although some seating facilities are provided, many pedestrians relax along the fountain rim. To the north of 59th Street there is a short mall lined by benches and light foliage. At the northernmost point of the mall stands a 1903 statue of General Sherman atop a multi-tiered pedestal.

Plaza 400

Plaza 400 (Figure 6) is a public open space which was developed in conjunction with the residential complex at 400 E. 56th Street. The open space is multi-level with the below grade portion along First Avenue. The plaza is fitted with vegetation and seating. A large fountain is located at the entrance of the plaza.

KLM Plaza

The KLM Plaza (Figure 7) is continguous with Madison Avenue between 49th and 50th Streets. The plaza is depressed from sidewalk level and a defined boundary separates the open space from the sidewalk. The plaza has no furnishings or trees, however, a sitting area for pedestrians is provided by the steps and barrier wall which circle the perimeter of the buildinp on three sides.

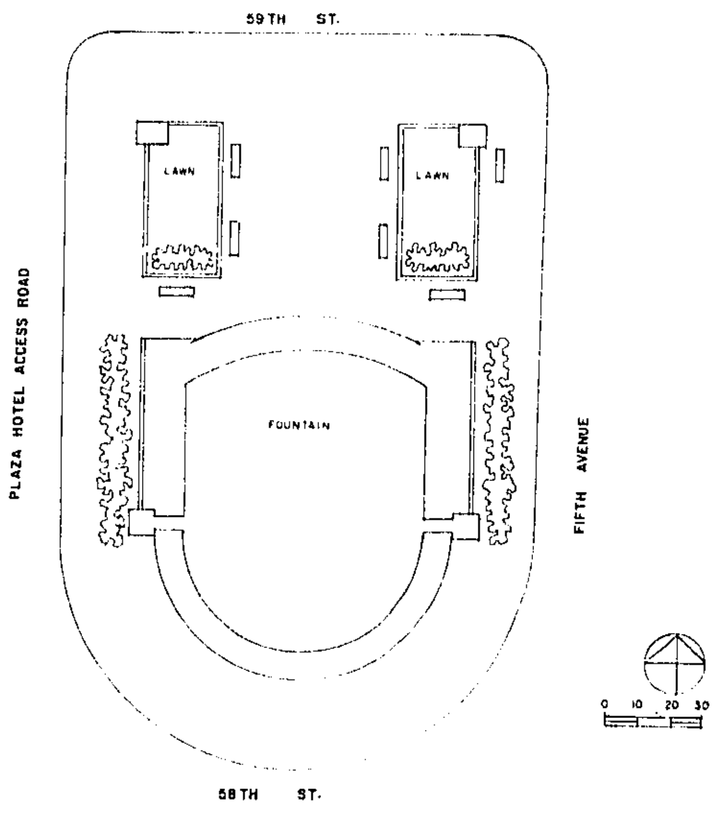
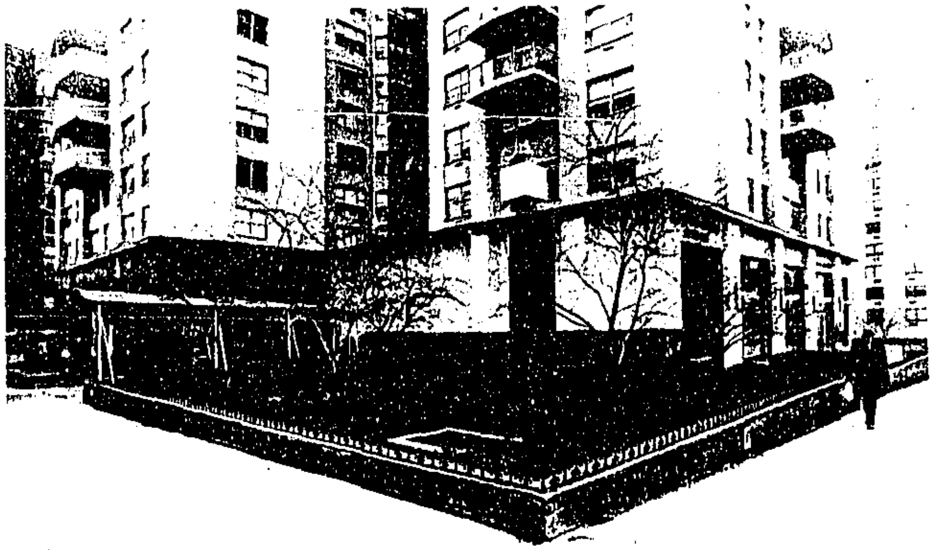



**FIGURE 5 GRAND ARMY PLAZA**



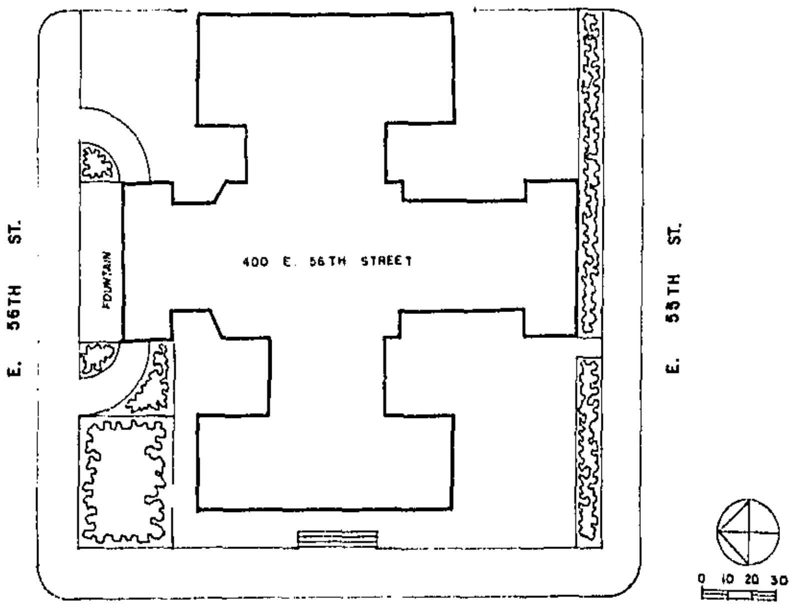
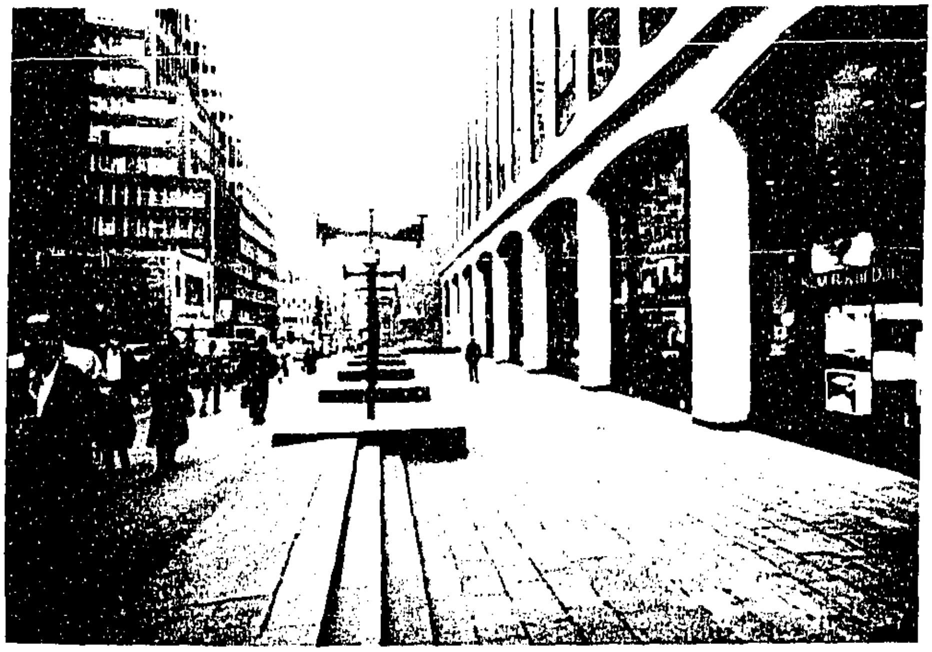



FIGURE 6 PLAZA 400



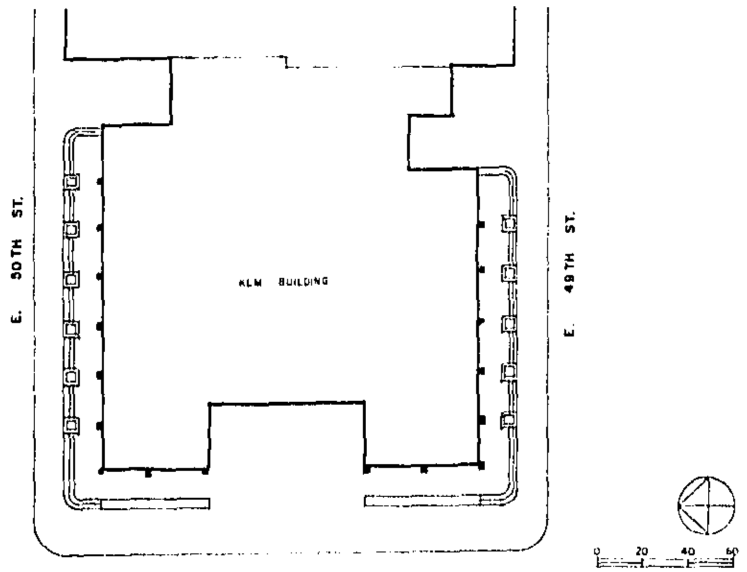



**FIGURE 7 KLM PLAZA**

## 1.4 Study Components

An attitudinal and noise measurement survey was conducted at those plazas selected for case study. Plaza 400 and KLM Plaza were excluded from an attitudinal survey. Due to their design and location they are infrequentl used by pedestrians. They were included in the noise measurement survey in order to study the noise propagation of Plaza 400's multilevel design and determine the noise level of KLM Plaza which is exposed to a high volume of regular and express bus service along Madison Avenue.

The attitudinal survey was designed to determine the profile of the plaza users and their awareness and sensitivity to noise. An integral part of the survey was the observation of how each plaza is used, noting any favored areas of occupancy.

The noise measurement survey was conducted to determine the noise levels of each plaza during the hours of maximum pedestrian use (11 am to 3 pm for daytime use and 4 pm to 8 pm for evening use).

The data obtained from the attitudinal and noise measurement survey was used to determine the following:

- the effect of plaza design on traffic noise propagation.
- noise attenuation measures that can be incorporated in the design of a plaza.
- a calculation methodology for the plaza designer which will estimate the level of traffic noise within a plaza.
- the effect of noise on pedestrian use of the space.

## 2.0 ATTITUDINAL SURVEY

### 2.1 Development of a Questionnaire

The attitudinal survey (Table 2) consists of ten questions, the first five of which are designed to determine the profile of the plaza users: frequency of visits (Q1), the time of day of visit (Q2), factors which influence the time of day a user would visit the plaza (Q3), users' main activity in the plaza (Q4) and the length of visit (Q5).

In past noise studies there was concern about biased or sensitized answers developing if the respondent knew, at the time of the questioning, that noise was the specific subject of the survey (Wyle, 1977). It was also found that more respondents claim to be disturbed by noise when the investigation's purpose is not disguised and the respondent knows the attitudinal survey is concerned with his reaction to noise (Wyle, 1977). The introduction of the word "noise" was delayed in the questionnaire until after the investigation of the plaza user's profile.

It is important to find out how a user ranks noise among other environmental conditions such as air quality, uncleanliness, crowding and traffic (Q7). The first question in which "noise" is used asks if the user is aware of noise in the plaza (Q8) and, if so, can he identify the source of the noise (Q8a).

To determine the user's perception of plaza noise levels (Q9) an opinion "thermometer" is used with the top designated as "extremely noisy" and the bottom designated as "not noisy at all." A similar opinion "thermometer" is used to determine if the user is bothered by plaza noise (Q9a). This allows the respondent to make an independent judgement which is not constrained by pre-assigned intermediate annoyance intervals. The last inquiry of the questionnaire gave the plaza user an opportunity to select a plaza design feature which could best alleviate noise annoyance (Q10).

Table 2

Attitudinal Survey

1. How often do you visit the plaza weather permitting?

   a. 3-5 times per week
   b. 1-2 times per week
   c. every other week
   d. once a month
   e. less than once a month

2. What time do you usually visit the plaza?

   a. morning
   b. during work breaks
   c. lunch
   d. after work
   e. evening
   f. other

3. What influences what time of day you visit the plaza?

   a. crowds at the plaza
   b. climate/sunshine
   c. special scheduled events
   d. other

4. What do you mainly do when you visit the plaza?

   a. eat
   b. talk with friends
   c. read
   d. people watch
   e. other

5. How long do you stay?

   a. less than 15 minutes
   b. 15-30 minutes
   c. 30-45 minutes
   d. 45 minutes - 1 hour
   e. over 1 hour

6. What conditions would you like to see changed to make your visits more pleasant?

   a. more seating
   b. shielding from sun, rain, wind
   c. better maintenance
   d. aesthetic improvements, such as trees, waterfalls, plaza furniture
   e. program events
   f. other

7. Which of the following affect you most when you're in the plaza?

   a. air quality
   b. noise
   c. uncleanliness
   d. crowding
   e. surrounding traffic

8. Were you aware of noise in this plaza prior to this interview?

   a. yes
   b. no

8a. Can you identify the source of this noise?

   a. traffic
   b. construction
   c. aircraft
   d. internal activities
   e. building equipment
   f. other

9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy

|  | a | b | c | d | e |  |
|---|---|---|---|---|---|---|
| not noisy at all | 1 | 2 | 3 | 4 | 5 | extremely noisy |

9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered.

|  | a | b | c | d | e |  |
|---|---|---|---|---|---|---|
| not bothered at all | 1 | 2 | 3 | 4 | 5 | extremely bothered |

10. Which of the following do you feel could best alleviate noise annoyance?

   a. trees
   b. plaza furniture
   c. waterfall
   d. piped in music
   e. barrier wall
   f. other

## 2.2 Conducting the Survey

The attitudinal survey was conducted at five pedestrian plazas in New York City during the month of October, 1978. General Motors, Grand Army and Seagram Plazas were sampled during the lunch period (11am-3pm). Rockefeller Center and Lincoln Center were sampled during this same lunch period and again during the evening (4pm-8pm). Each question had five possible responses.

The sample size required to detect a given "true" difference between percentages (or proportions) was determined prior to the survey by the method of Sokal and Rohlf (1969). The analyses were required to be 90% certain of detecting a significant difference between responses to each question when a difference did exist; and to be 95% certain of not concluding that there was a significant difference between responses to a question when there was no difference. Applying these criteria to the method of Sokal and Rohlf a sample size of at least 79 observations was needed.

Each potential respondent was advised that the survey was an effort to obtain information on the users of pedestrain plazas and the results would be incorporated into the design and construction of future plazas. For the most part, the survey was performed orally; however, in small group situations, respondents themselves were allowed to fill out the questionnaire in the presence of the interviewer. Respondents were instructed only to select one answer per question. The questionnaire was completed in under ten minutes.

## 2.3 Observations of Plazas

The personnel conducting the attitudinal surveys were asked to observe how the plazas were used. They were to observe any noticeable occupancy trends in a plaza due to sunlight, seating or other factors.

The observations for the plazas surveyed are as follows:

### Seagram Plaza

Here, largely without exception, plaza users were office workers on their lunch break. Peak activity occurred during the 12 noon to 2 pm period in two distinct hourly cycles. Distribution of users throughout the plaza was strongly related to the presence of sunlight. At the time of the survey Seagram Plaza had early afternoon sun first felt in the northwest corner; accordingly, the heaviest concentration of users occured in this area along both the Park Avenue steps and the northern periphery of the plaza around the fountain. Small groups of users opted for seats along the wall in other sections of the plaza. Lack of foliage and comfortable seating arrangements were regarded as definite drawbacks to plaza usage.

### Rockefeller Center

During the day, user composition was limited essentially to a combination of tourists and office workers on lunch breaks. On the day of the survey, the majority of plaza users congregated on the upper plaza overlooking the ice rink to watch a special skating programmed event. Benches in the channel gardens were occupied primarily by plaza users eating lunch. A small number of pedestrians walking through the area stopped there for a short rest. The upper portion of the gardens fronting on Fifth Avenue was used more consistently presumably due to the strength of the sun and proximity to Fifth Avenue sights.

In the evening the user group was largely composed of tourists and metropolitan area residents who were in the vicinity and whose visit to the plaza was a secondary activity. Distribution of users throughout the plaza was similar to the daytime pattern with the majority of pedestrians overlooking the skating rink and the remainder in small groups on benches in the Channel Gardens.

Lincoln Center

Daytime users at Lincoln Center seemed to favor the smaller scaled, more intimate spaces at the rear of the complex rather than the major plaza. Damrosch Park and the plaza in front of the Library and Museum of Performing Arts, self-contained and essentially removed from the street, appeared conducive to longer visits and more solitary types of activities including reading, studying, writing, sunning. Visits of shorter duration and walk-throughs tended to sit at the fountain in the main plaza area. Because of Lincoln Center's location and special function, user composition was perhaps most diverse at this plaza; the range of users included nearby office workers and residents, tourists, students and members of the performing arts community. The volume of users remained more or less constant.

During the evening survey period user composition and usage patterns differed significantly from the daytime survey. For the most part, evening plaza usage was associated with attendance at a Center performance. The peak activity period occurred between 7 pm to 8 pm directly before curtain time. Users congregated around the fountain and near the theaters; usage of Damrosch Park and the Library/Museum plaza was sharply curtailed.

General Motors Plaza

GM Plaza was used almost exclusively by the lunch time office worker either from the GM Building itself or surrounding buildings. Small groups of users occupied seating facilities on the upper plaza and along Fifth Avenue. The limited duration of the visits was presumably due to unfavorable weather conditions on the day of the survey. A small number of users, generally on their way to and from the GM Building, preferred to stand along the railing overlooking the lower plaza. Virtually no plaza activity occurred in the below grade level due to lack of seating facilities at this time of year. Use of below grade level was primarily for access to and from retail shops.

Grand Army Plaza

Directly across Fifth Avenue at Grand Army Plaza user composition varied to include a fair number of tourists and passing pedestrians as well as office workers on their lunch break. This difference in user composition between Grand Army Plaza and nearby GM Plaza could possibly be attributed to a combination of the following factors:

- the relatively informal structure of Grand Army Plaza
- its ample and varied seating spaces and more diverse visual environment
- the perception of Grand Army Plaza as a public space rather than an extension of an office building.

With the exception of a marked preference for seating at the multi-tiered base of the statue at the north end of Grand Army Plaza, the distribution of users was generally even throughout the plaza.

## 2.4 Survey Results

Responses from the survey questionnaire were used to develop descriptions of plaza use and profiles of plaza users. The survey results for the aggregate daytime and evening responses are presented in Appendix A and are summarized below:

Daytime User: The typical daytime user visits the plaza during the lunch period at least once a week for approximately one half hour. While the typical user may eat lunch at the plaza and in fact engage in several activities during the visit, his main activity is people-watching (33 percent). Favorable climate or sunshine conditions are by far the most significant influence on the actual time for the visit (58 percent). Not one environmental factor appeared to adversely affect the daytime user; the responses were split evenly among the environmental factors.

On the whole, typical users found the plazas lacking in aesthetics (e.g. trees, waterfalls, etc.) (28 percent) and seating facilities (25 percent).

Evening Users: As would be expected, the evening plaza user differed from the daytime user in time of visit and frequency of use. Typically, the evening user visits the plaza after work or during evening hours (73 percent combined) for approximately one half hour. Unlike the daytime user, the evening user visits the plaza infrequently, generally less than once a month (39 percent). Evening plaza use, particularly at Lincoln Center, appears to be associated with waiting for a scheduled performance to begin. Here again, people watching is the primary activity (31 percent).

With respect to environmental factors, the evening plaza user is affected to the greatest degree by crowding (27 percent). Lack of seating (35 percent) was found to be a plaza's greatest overall deficiency.

On the whole the survey results indicate that pedestrians use these plazas for short visits usually in conjunction with another purpose such as eating lunch, waiting for an event, etc. In those plazas sampled during both daytime and evening hours, two distinct user patterns emerged. Rate of use among the daytime group is significantly higher, presumably due to the fact that the group is largely composed of nearby office workers who have greater opportunities for repeated use. Evening users on the other hand may visit the plaza only when they have another reason to be in that particular area.

The attitudinal survey results with regard to a user's awareness and sensitivity to noise are discussed in Chapter III-4.0.

## 3.0 Noise Measurements

### 3.1 Measurements of Procedures

Noise measurements were recorded at each of the seven selected pedestrian plazas as follows:

| Plaza | Time | Date |
|---|---|---|
| Seagram Plaza | 11 am-3 pm | October 23, 1978 |
| Rockefeller Center | 11 am-3 pm | October 24, 1978 |
| | 4 pm-8 pm | November 1, 1978 |
| Lincoln Center | 11 am-3 pm | October 25, 1978 |
| | 4 pm-8 pm | October 25, 1978 |
| General Motors Plaza | Noon -2 pm | October 26, 1978 |
| Grand Army Plaza | Noon -2 pm | October 27, 1978 |
| Plaza 400 | 11 am-3 pm | October 30, 1978 |
| KLM Plaza | 4 pm-6 pm | October 30, 1978 |

Noise measurements were recorded on magnetic tape and analyzed at a later time. The measurements were made using two microphone locations. One microphone remained stationary throughout the survey period. The other microphone was moved to different locations throughout the plaza every 20 to 30 minutes.

Two microphone locations were used in order to determine the sound propagation within each plaza as it relates to the following:

- distance from noise source.
- sound reflections from wall, floor and other surfaces.
- effects of occupancy.
- masking effect of waterfalls.
- free standing barriers.
- vegetation.

A list of the noise monitoring instrumentation is presented in Table 3. Noise levels were recorded by using a one inch diameter microphone fitted with a windscreen. The signal from the microphone was passed to a precision sound level meter where it was A-filtered. Recording the noise through the A-weighted network increased the dynamic range of the instrumentation. The signal output from the sound level meter was recorded by the magnetic tape recorder. In the field, a calibration signal of 114 dB at 1000 HZ was recorded on the tape.

Measurements were not made if:

- street pavement was not generally dry
- winds were greater than 12 miles per hour (mph)
- non-typical noises such as construction, sirens, and unusual pedestrian activity occured.

Table 3

Noise Instrumentation

| Type | Manufacturer | Model |
|---|---|---|
| Sound Level Calibrator | Gen Rad<br>Gen Rad | 1562-A<br>1567 |
| Windscreen | Gen Rad | For ½" & 1" microphones |
| Microphones | Gen Rad<br>Gen Rad | 1961-9601<br>1962-9601 |
| Sound Level Meter | Gen Rad<br>Gen Rad | 1565B<br>1933 |
| Tape Recorder | Nagra Kudelski<br>Nagra Kudelski | SJS<br>IV-Stereo |
| Graphic Level Recorder | Bruel & Kjaer | 2306 |
| Noise Level Analyzer | Bruel & Kjaer | 4426 |
| Headphone | Beyer Dynamics | DT98A |

## 3.2 Selection of Measurement Locations

Each of the seven plazas were selected for their design characteristics and their different sources of noise intrusion. Measurement locations (Figures 8 through 14) were selected to evaluate the plaza design characteristics as described below:

Seagram Plaza - Two water fountains provide masking for the traffic noise from Park Avenue. The traffic is predominantly cars with an occasional bus. There are very few trucks other than four wheel vans.

Rockefeller Center - The entrance on Fifth Avenue leads into a long and narrow plaza with high rise buildings on both sides. There are fountains within the plaza and benches for seating. The traffic noise from Fifth Avenue consists mostly of cars and buses. The narrow width of the plaza with its adjoining buildings provides a "canyon effect" sustaining the noise levels of the traffic and the internal plaza noise of fountains and people. This is the only plaza surveyed which has programmed events.

Lincoln Center - The plaza is bordered on three sides by buildings with the fourth side as the plaza entrance. There is a single large fountain at the center of the plaza. Due to the size of the plaza and the spacing of the buildings there is no canyon effect. There are smaller pedestrian areas set back from the main plaza area which was tested to determine its barrier effect in reducing the noise intrusion.

General Motors Plaza - This is a bi-level plaza, street level and below grade plaza area. The source of noise is Fifth Avenue traffic.

Grand Army Plaza - The plaza is flat, with some benches and vegetation and a large fountain in the center which provides additional seating. Fifth Avenue traffic is the noise source.

Plaza 400 - This is a multilevel residential plaza affected by traffic noise along First Avenue. The traffic has a high percentage of trucks, more so than the other plazas selected.

KLM Plaza - This plaza was selected for its location on Madison Avenue which has a high volume of express buses during the afternoon rush hour.

Traffic counts were obtained concurrently with the noise measurement survey for each plaza and are presented in Figures 8 through 14.

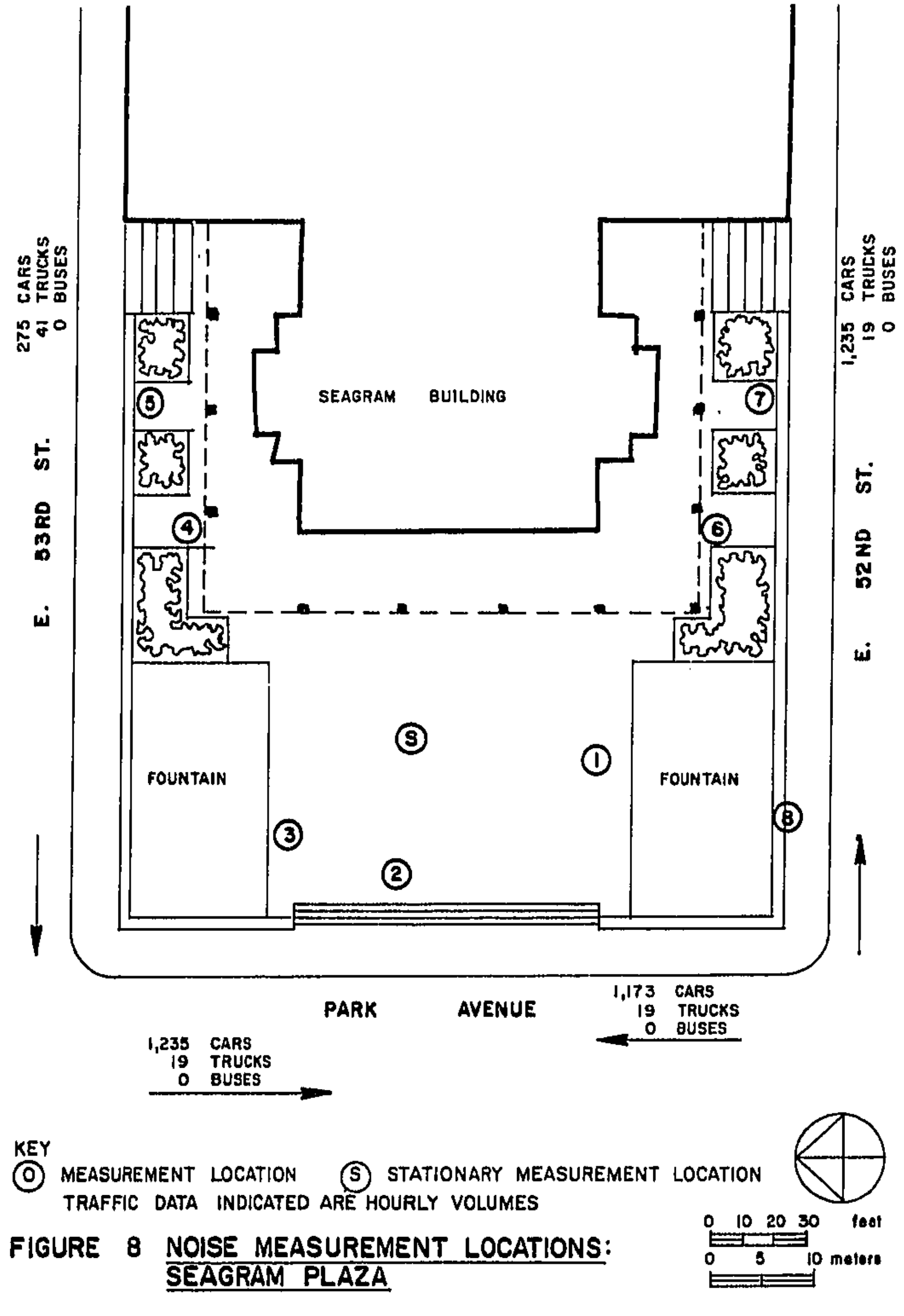
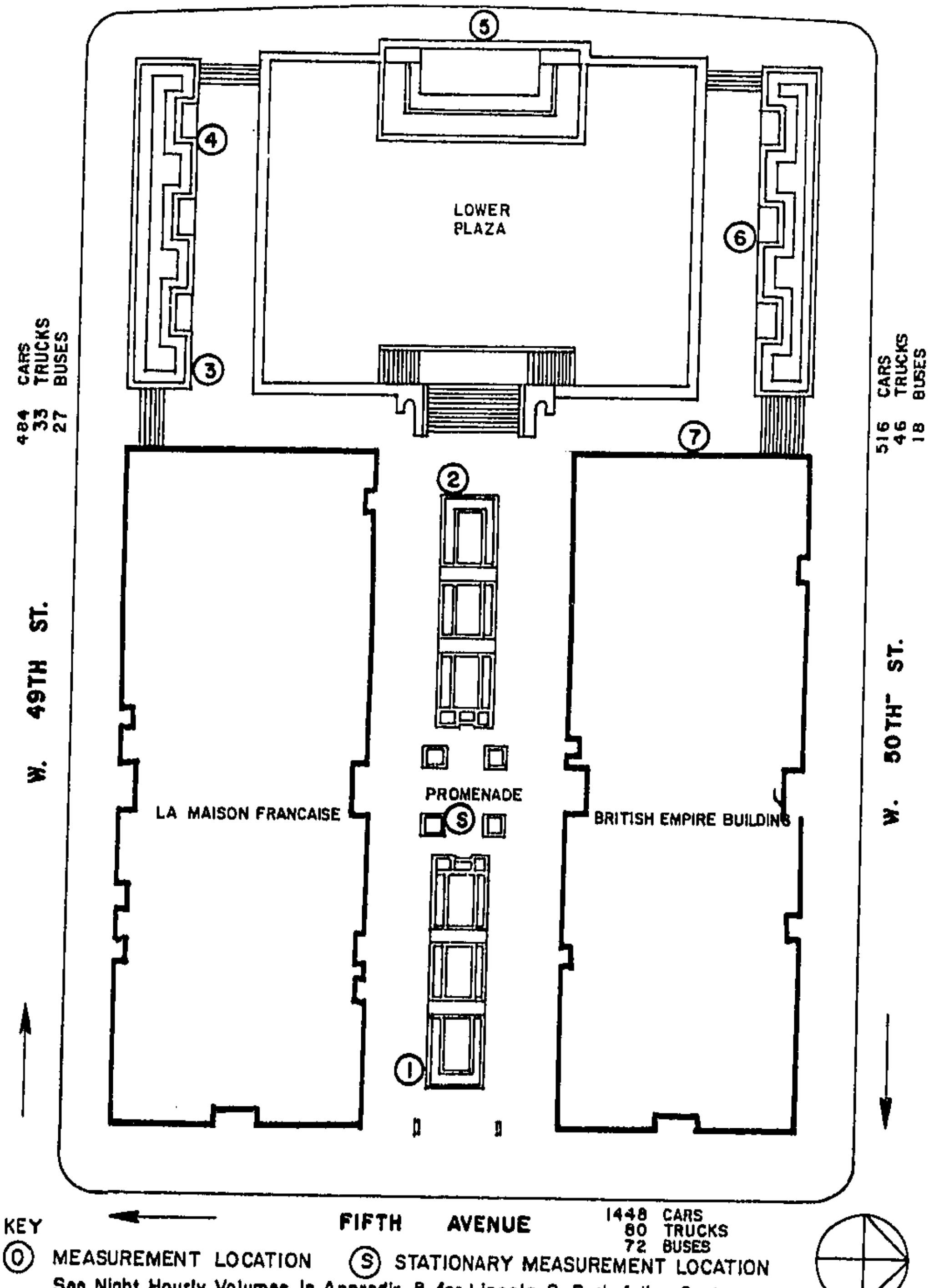



FIGURE 8 NOISE MEASUREMENT LOCATIONS: SEAGRAM PLAZA




KEY

(O) MEASUREMENT LOCATION (S) STATIONARY MEASUREMENT LOCATION

See Night Hourly Volumes in Appendix B for Lincoln & Rockefeller Center

FIGURE 9 NOISE MEASUREMENT LOCATIONS: ROCKEFELLER CENTER

0 10 20 30 feet

0 5 10 meters

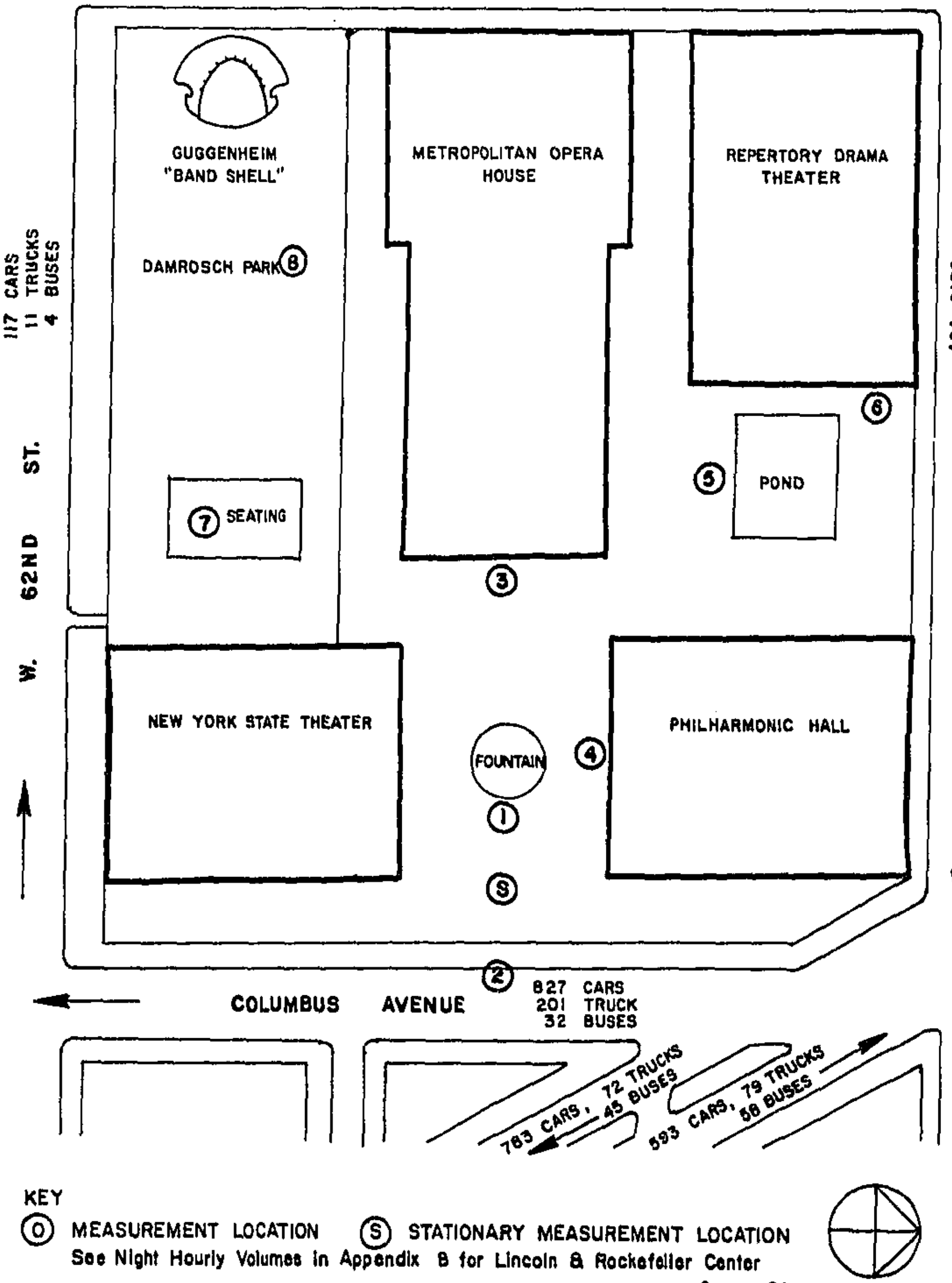
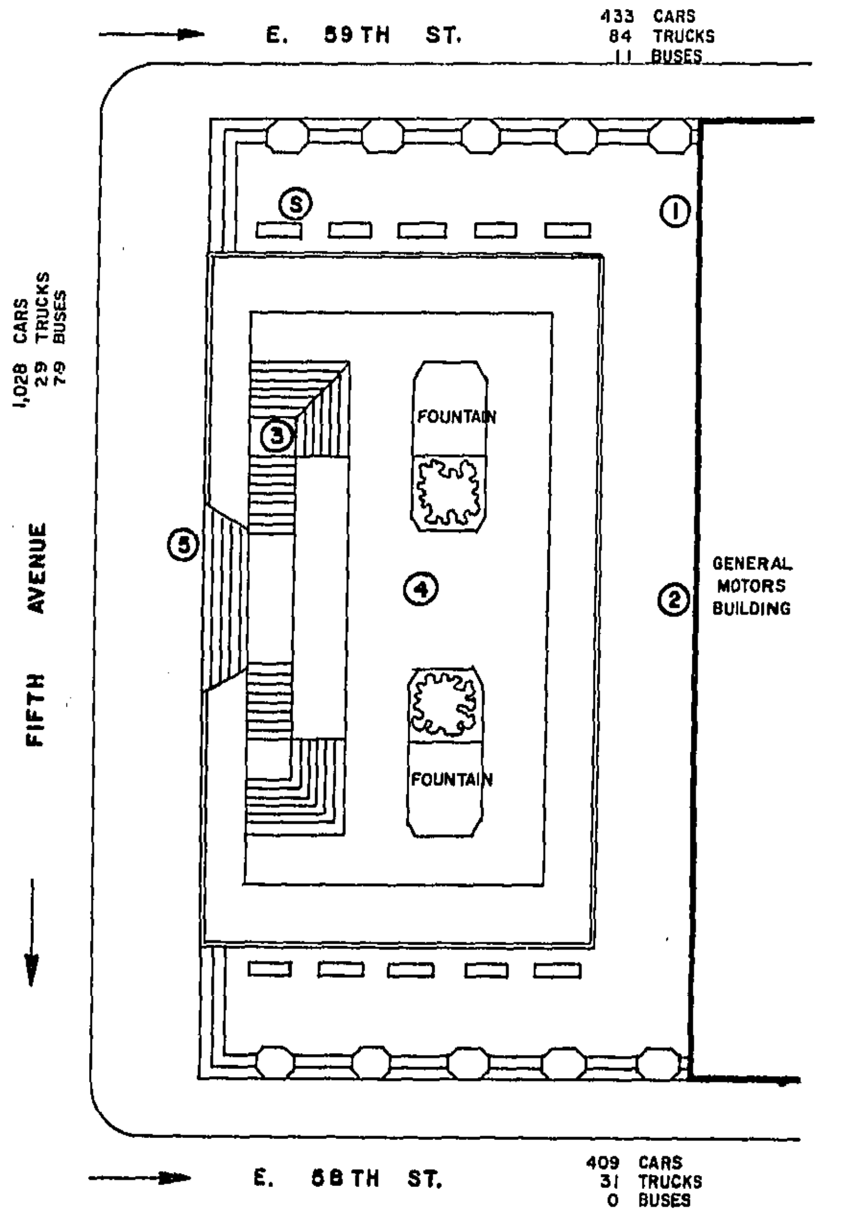



FIGURE 10 NOISE MEASUREMENT LOCATIONS: LINCOLN CENTER




KEY

(O) MEASUREMENT LOCATION (S) STATIONARY MEASUREMENT LOCATION

TRAFFIC DATA INDICATED ARE HOURLY VOLUMES

0 10 20 30 feet

0 5 10 meters

**FIGURE 11 NOISE MEASUREMENT LOCATIONS: GENERAL MOTORS PLAZA**

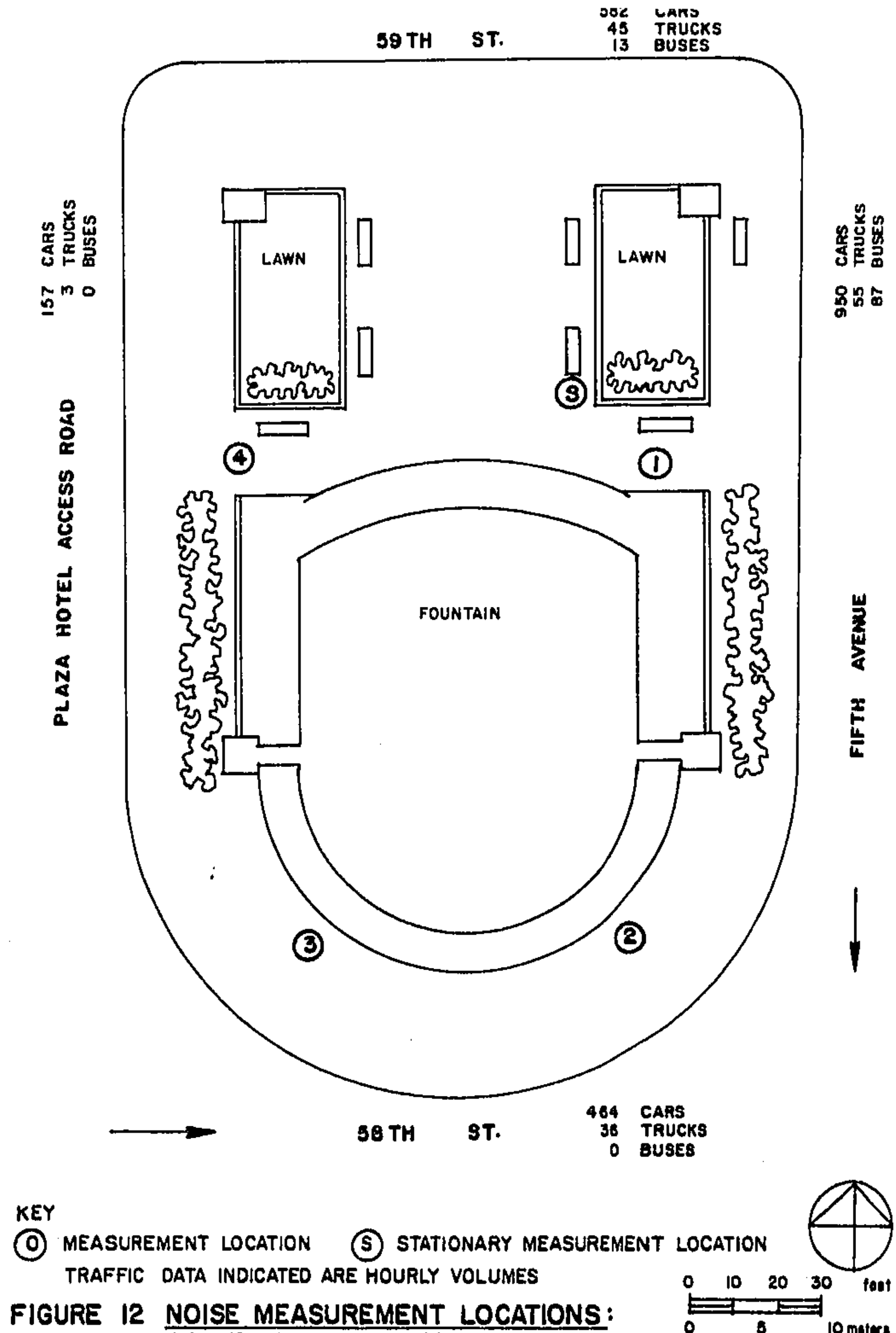
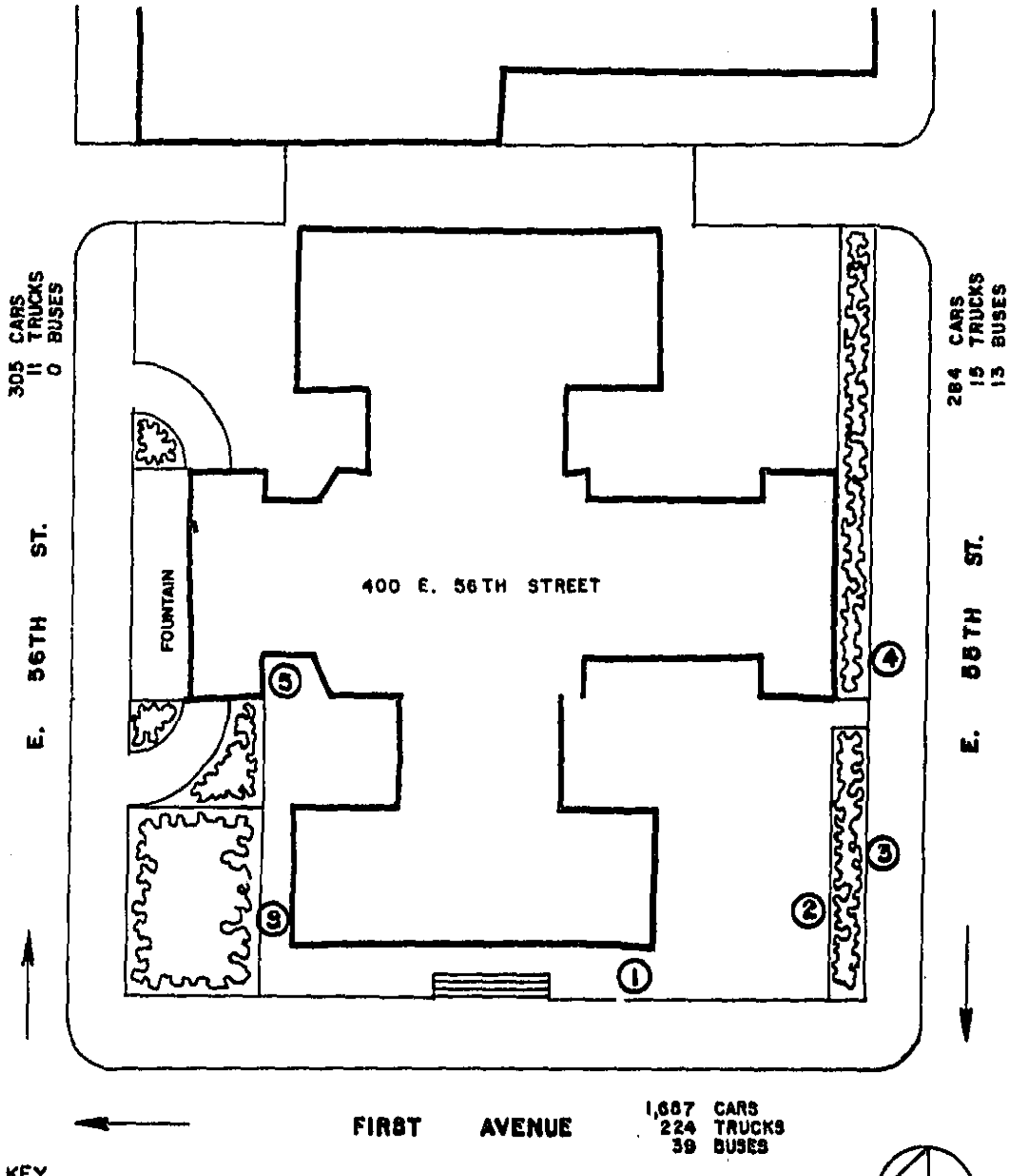



**FIGURE 12 NOISE MEASUREMENT LOCATIONS: GRAND ARMY PLAZA**




KEY

(0) MEASUREMENT LOCATION (S) STATIONARY MEASUREMENT LOCATION

TRAFFIC DATA INDICATED ARE HOURLY VOLUMES

0 10 20 30 feet

0 5 10 meters

FIGURE 13 NOISE MEASUREMENT LOCATIONS: PLAZA 400

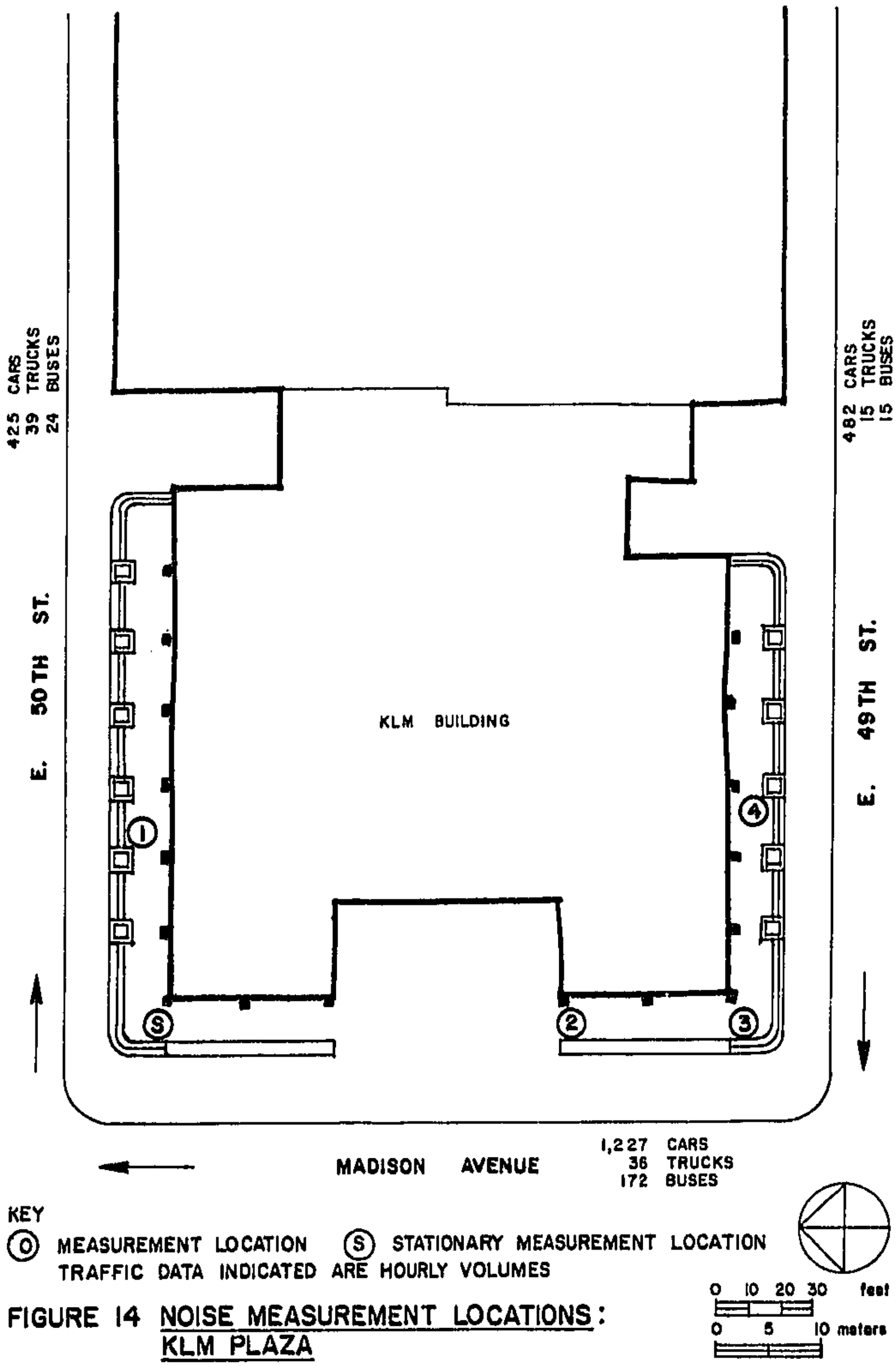



FIGURE 14 NOISE MEASUREMENT LOCATIONS: KLM PLAZA

## 3.3 Results of Noise Survey

The results of the noise measurement surveys (Table 4) indicate that some of the plaza design elements did result in a reduction in plaza noise level. The noise characteristics of the individual plazas are described as follows in terms of the measured equivalent sound levels ($L_{eq}$):

Seagram Plaza - This plaza is flanked on three sides by traffic. The major source of noise is along Park Avenue; however, as one walks away from Park Avenue, traffic along 52nd Street or 53rd Street becomes the predominate noise source. The flat plaza design along with the multiple sources of traffic noise result in a relatively uniform noise level ($\pm 2$ dB) at any location in the plaza.

Lincoln Center - The traffic along Broadway and Columbus Avenues and the large fountain at the center of the plaza are the predominate sources of noise. The noise level of the fountain at 3 m (10 ft) was 71 dBA during the day and 75 dBA at night when the fountain water column was higher. The noise levels at the rear of the plaza in Damrosch Park and the smaller plaza area in front of the Library and Museum of Performing Arts were in the range of 4 dB to 8 dB less than the stationary measurement location at the plaza entrance. The noise reduction is due to distance and partial blockage of the New York State Theater and Avery Fisher Hall.

Rockefeller Center - The predominate sources of noise within Rockefell Center are people and programmed events. As one enters the Channel Gardens, the sound of traffic is gradually masked by the other sources of noise. The buildings adjoining the Channel Gardens create a slight "canyon effect" which tends to reflect the noise many times and sustains the noise at a higher level (2 dB to 3 dB).

Table 4

Measured A-Weighted Sound Levels-Leq

| Measurement Location[1] | Seagram | Rockefeller Center day | Rockefeller Center evening | Lincoln Center day | Lincoln Center evening | GM | Grand Army Plaza | Plaza 400 | KLM |
|---|---|---|---|---|---|---|---|---|---|
| M1 | 68 | 79 | 71 | 71 | 75 | 67 | 69 | 74 | 77 |
| S1 | 69 | 66 | 66 | 69 | 68 | 69 | 71 | 71 | 75 |
| M2 | 71 | 78 | 73 | 72 | 75 | 67 | 72 | 70 | 77 |
| S2 | 70 | 68 | 65 | 69 | 69 | 71 | 73 | 71 | 75 |
| M3 | 70 | 78 | 72 | 68 | 72 | 65 | 72 | 74 | 75 |
| S3 | 71 | 66 | 68 | 70 | 69 | 70 | 68 | 72 | 74 |
| M4 | 69 | 69 | 73 | 69 | 76 | 65 | 69 | 75 | 73 |
| S4 | 69 | 66 | 67 | 70 | 70 | 70 | 68 | 72 | 74 |
| M5 | 71 | 71 | 70 | 62 | 64 | 70 | - | 75 | - |
| S5 | 69 | 67 | 66 | 69 | 70 | 69 | - | 72 | - |
| M6 | 70 | 69 | 71 | 61 | 63 | - | - | - | - |
| S6 | 69 | 67 | 65 | 68 | 69 | - | - | - | - |
| M7 | 69 | 71 | 72 | 61 | 60 | - | - | - | - |
| S7 | 68 | 67 | 65 | 69 | 68 | - | - | - | - |
| M8 | 69 | - | - | 64 | 62 | - | - | - | - |
| S8 | 72 | - | - | 68 | 66 | - | - | - | - |

Note: 1. M denotes mobile measurement locations and S denotes stationary measurement location corresponding to the mobile measurement time period.

General Motors Plaza - The noise measurements on the below grade level of the plaza indicated a 5 dB reduction in noise level. The at-grade plaza area is exposed to traffic noise on three sides which results in a uniform noise level ($\pm$2 dB) at any location in the plaza.

Grand Army Plaza - The variation in noise level within this plaza is a function of a user's distance from Fifth Avenue, the major source of traffic noise. The flat, stark design of this plaza provides little noise reduction to its users.

Plaza 400 - This is a multi-level plaza with areas below grade. The measured difference in noise level due to these below grade areas is 3 dB. This is less than the 5 dB difference in noise level measured at the General Motors Plaza due to a below grade plaza area. The predominant noise source affecting the plaza is heavy trucks (three axles or more) along First Avenue. The engine exhaust height of these trucks (3 m to 4 m) tends to minimize the noise reduction provided by the below grade plaza area.

KLM Plaza - This plaza had consistently high noise levels (73 dBA to 77 dBA) due to its flat design and its proximity to Madison Avenue. The survey was scheduled for 4 pm to 6 pm to measure the noise levels generated by regular and express bus service along Madison Avenue.

A more detailed description of the noise nomenclature is presented in Appendix B. The complete set of noise measurements are presented in Appendix C.

## 4.0 EFFECTS OF NOISE ON PLAZA USERS

### 4.1 Sensitivity to Noise

The attitudinal survey indicates 54 percent of the daytime users and 45 percent of the evening users were aware of noise prior to this interview. The opinion "thermometer" for questions 9 and 9a uses a scale of 1 to 5. When evaluating the response to these questions the following designations are used:

| | | |
|---|---|---|
| Question 9: | 5 | Extremely noisy |
| | 4, 3 | Moderately noisy |
| | 2 | Somewhat noisy |
| | 1 | Not noisy at all |
| Question 9a: | 5 | Extremely bothered |
| | 4, 3 | Moderately bothered |
| | 2 | Somewhat bothered |
| | 1 | Not bothered at all |

The majority of daytime users (69 percent) estimated the plaza noise level as moderately to extremely noisy. However, only a portion of those users (37 percent) were moderately to extremely bothered by the plaza noise. The majority of evening users (59 percent) also considered the plaza noise level as moderately to extremely noisy. Of these evening users only 39 percent were moderately to extremely bothered by the plaza noise.

The attitudinal survey indicated very clearly that the majority of plaza users are either not bothered or somewhat bothered by plaza noise (63 percent). As a subjective measure of noise, past studies have shown agreement between annoyance and verbal communications (Alexandre, 1975). Annoyance occurs when verbal communications are frequently disturbed. The fact that the majority of plaza users indicated minimal annoyance from noise may be due to the following:

o the majority of plaza users do not visit the plaza for the purpose of talking

o the measured plaza noise levels indicate that comfortable communication at a normal voice level (95 percent speech intelligibility) can be maintained at an average distance of 0.6 m (2 ft) (USEPA,1974) for normal hearing listencers.

The criteria used for determining the maximum distances outdoors for which conversation is considered to be satisfactorily intelligible is presented in Figure 15.

When asked which plaza design element would best alleviate noise annoyance (Q10) 34 percent of the daytime users and 44 percent of the evening users indicated trees. In reality, the most effective noise alleviant is a barrier wall but only 13 percent of daytime users and 8 percent of the nighttime users were aware of this.

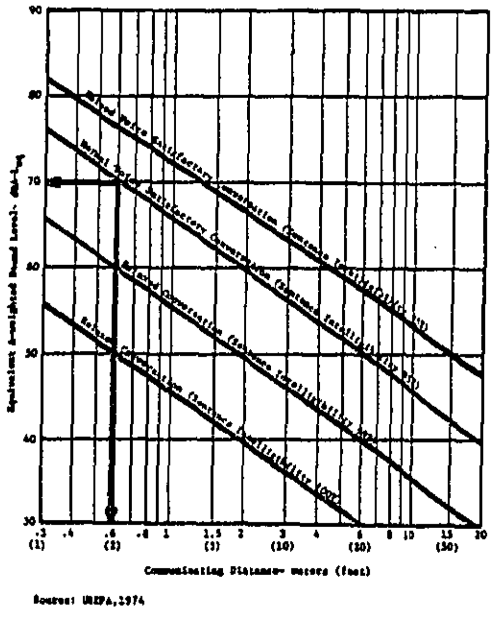


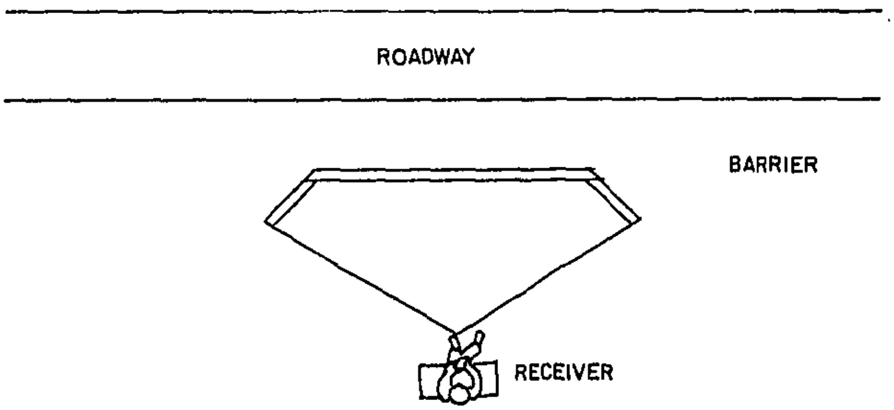
Figure 15 MAXIMUM DISTANCE OUTDOORS OVER WHICH CONVERSATION IS CONSIDERED TO BE SATISFACTORILY INTELLIGIBLE

## 5.0 NOISE ABATEMENT MEASURES FOR PLAZA DESIGN

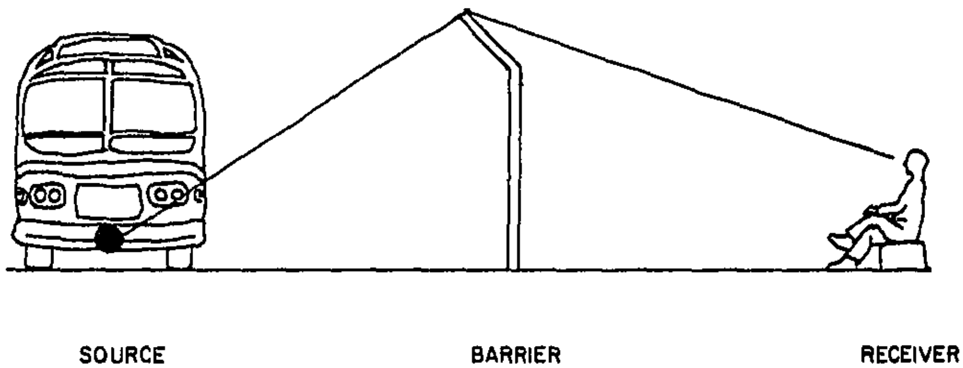
Plaza design elements which can reduce traffic noise propagation within a plaza have been evaluated. The design elements observed during this study have been combined with noise reduction techniques used for other types of architectural design. The noise attenuation values of the design elements discussed below can be determined by the calculation methods described in Chapter 6.0.

Sound Barriers - A sound barrier can be any obstruction which shields, or partially shields the traffic noise from the plaza. The effect of this shielding is dependent on the barrier height, distance from barrier to receiver and from barrier to noise source, and the height of the noise sources. Sound barriers can take the form of a taxi or bus shelter, a building structure, a wall, or any other obstruction which is located between the plaza and the roadway. The height of a barrier may become an aesthetic consideration that may interfere with the look and function of the plaza. A compromise between aesthetics and noise reduction could be achieved by using 1.0 to 1.5 m (3 to 5 ft) high barriers arranged around seating areas rather than the entire plaza. The barriers would provide noise reduction to a pedestrian user when sitting and when the user is standing he would have an unobstructed view of the entire plaza. This design approach would provide a reduction in noise level for users who read or talk while not interfering with other users who people watch or eat lunch. If a barrier is not straight but angled, either at the end or at the top (Figure 16) its noise reduction value can be increased without making the barrier excessively long or high.

Multilevel Design - A below grade plaza area was found to have a lower noise level than a street level plaza area. This could be used as a major design element with the entire plaza area below grade or it could be limited to smaller areas designed for seating. The depressed plaza should be a minimum



**(A) PLAN VIEW OF BARRIER TURNED AT ENDS**



**(B) ELEVATION OF BARRIER TURNED AT THE TOP**

## FIGURE 16 BARRIERS TURNED AT THE END OR THE TOP

of 1.5 to 3.0 m (5 to 10 ft) below grade.

Seating Placement - Seating areas should be segregated within the plaza at the maximum allowable distance from the traffic noise.

Vegetation - To provide some noise attenuation the vegetation should consist of trees or shrubs dense enough to visually block the noise source from the plaza user. To be effective year round, the vegetation should be a reasonable mix of both deciduous and evergreen trees, or all should be evergreen. Noise attenuation provided by vegetation is minimal; 30 m (100 ft) of vegetation are required to obtain a 5 dB reduction in noise level.

Fountains or Waterfalls - A fountain or a waterfall may be used to provide masking of the traffic noise.

Piped in Music - Music will not mask as well as a fountain or a waterfall because it would compete with the traffic noise for the attention of the listener.

These plaza design elements can be used alone or in combination to maximize traffic noise reduction and still be compatible with form, function, and aesthetics of the plaza design.

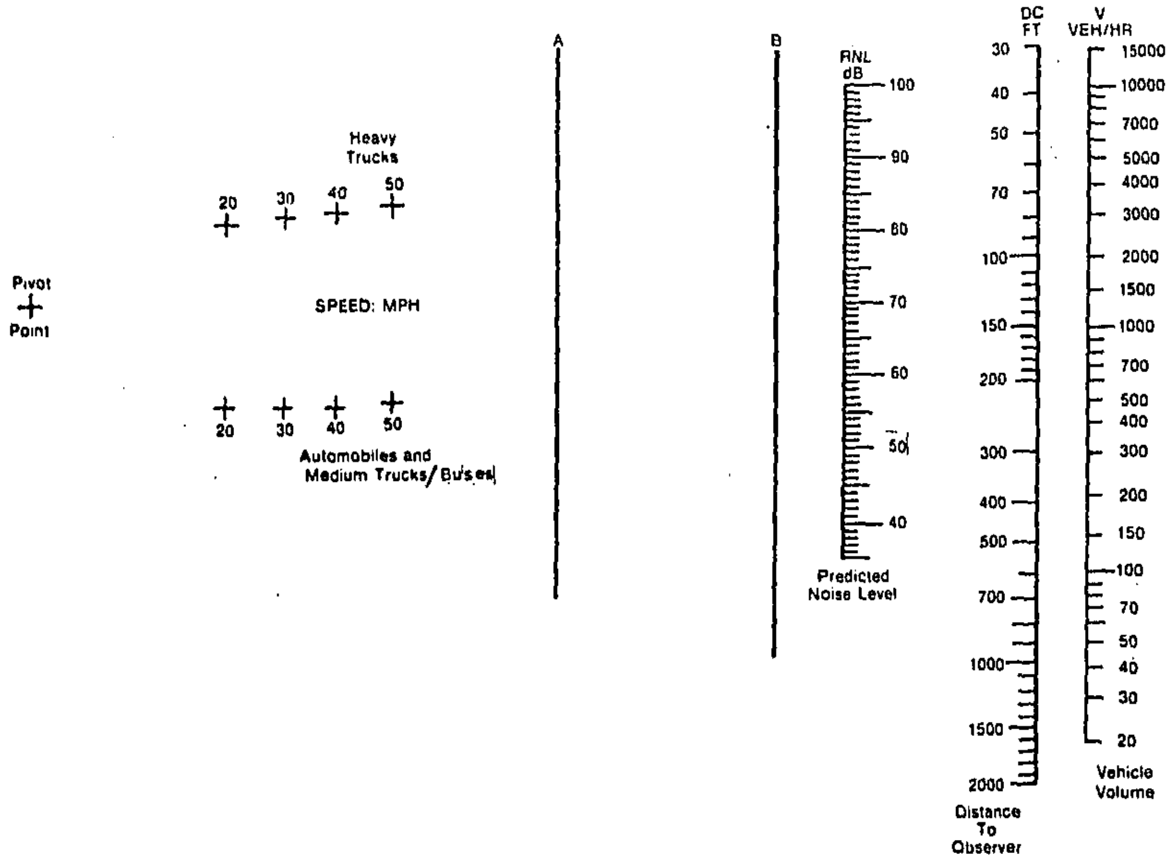
## 6.0 METHODOLOGY TO ESTIMATE PLAZA DESIGN LEVELS

Traffic is the major noise source affecting urban pedestrian plazas. As a result, to estimate plaza noise levels, it is necessary to calculate the traffic noise of each roadway which adjoins the plaza. To estimate roadway noise, simple assumptions must be made concerning how the traffic noise is generated and how it propagates from the roadway to the plaza. As part of this study, a simplified method of traffic noise prediction has been developed as a planning tool to be used by plaza designers. Once the plaza noise level has been estimated the impact on pedestrian users can then be determined subjectively by its effect on speech communications (USEPA, 1974).

One of the simplest methods for estimating traffic noise is a nomogram developed by Bolt, Beranek and Newman, Inc. (1973). The nomogram is valid for traffic moving at a constant speed. An average traffic speed should be calculated that considers acceleration and deceleration between traffic signals.

A nomogram is a graph containing three or more scales graduated for different variables so that when a straight line connects the values on any two scales, the related values may be read directly from the third scale at the point intersected by the line (Figure 17). The procedure for using this nomogram is discussed later in this section.

Three different vehicle categories based on the vehicles' noise generating characteristics are incorporated into the nomogram (automobiles, medium trucks/buses, and heavy trucks). Automobiles are vehicles with two axles and four wheels. This group includes passenger cars, light pick-up and panel trucks. Under normal conditions, automobile noise is composed primarily of engine exhaust noise and tire-roadway interaction noise, which are both concentrated near the pavement surface. Hence, the effective source height




Metric Conversion: 1 foot equals 0.3048 meters

Source: National Bureau of Standards, 1978.

Figure 17 TRAFFIC NOISE PREDICTION NOMOGRAM for automobiles is taken at the pavement surface.

Medium trucks/buses refer to gasoline-powered two-axle, six wheel vehicles. Medium trucks and buses are grouped as one category because of their similar noise emission levels. One distinction between this group and heavy trucks, other than just physical size, is that medium trucks/buses do not have a vertical exhaust stack. Like automobiles, medium truck/bus noise is primarily engine-exhaust and tire noise, which again are concentrated near the pavement surface. Although the exhaust outlet may be slightly higher for medium trucks/buses than for automobiles, the effective source location is still assumed to be at the pavement surface. In general, the sound levels generated by medium trucks/buses are similar, but are higher than automobiles for the same operating conditions.

Approximately 80 percent of heavy trucks are diesel-powered vehicles with three or more axles. Long-haul tractor-trailer vehicles constitute the majority of this group, which also includes dump trucks, cement mixers, etc. Heavy truck noise is a combination of engine, fan, intake, exhaust, and tire noises. However, extensive measurements of actual traffic conditions have shown that heavy truck noise can be adequately simulated by using the exhaust noise source only and neglecting other sources. Based on this, the effective source location is assumed to be 2.5 m (8 ft) above the pavement surface. Thus, the major differences between the sound generated by automobiles and medium trucks/buses and the sound generated by heavy trucks are the magnitude and spatial location of the sound source.

The method assumes that the real roadway configuration can be approximated by a single "equivalent" lane that is straight and infinitely long. It also assumes that this equivalent lane lies at-grade on a level terrain, which means that there is no shielding. The model further assumes that the noise generated by each of the vehicle groups can be characterized by the traffic volume flow (vehicles/hour) and the average speed (miles/hour) for that group. Analysis of this idealized model shows that the noise of automobiles and medium trucks/buses increases with traffic volume and average speed; and that the noise of heavy trucks under the same conditions increases with traffic volume, but decreases slightly with an increase in average speed.

The equivalent level of the noise propagated from the roadway decreases by an A-weighted sound level of 4.5 dB for every doubling of distance from the roadway (Kugler, 1974). This value of attenuation has been determined empirically, and includes losses due to air absorption and excess ground attenuation.

The predicted sound levels are conservatively high except when the ground plane is very reflective and no shielding is present. A highly sound reflective ground plane is typical for most urban pedestrian plazas which tends to maximize the accuracy of this method.

The steps necessary to estimate plaza noise levels are outlined in Figure 18. A sample problem is included in Section III - 7.0. All step results should be recorded on the Roadway Worksheet shown in Figure 19.

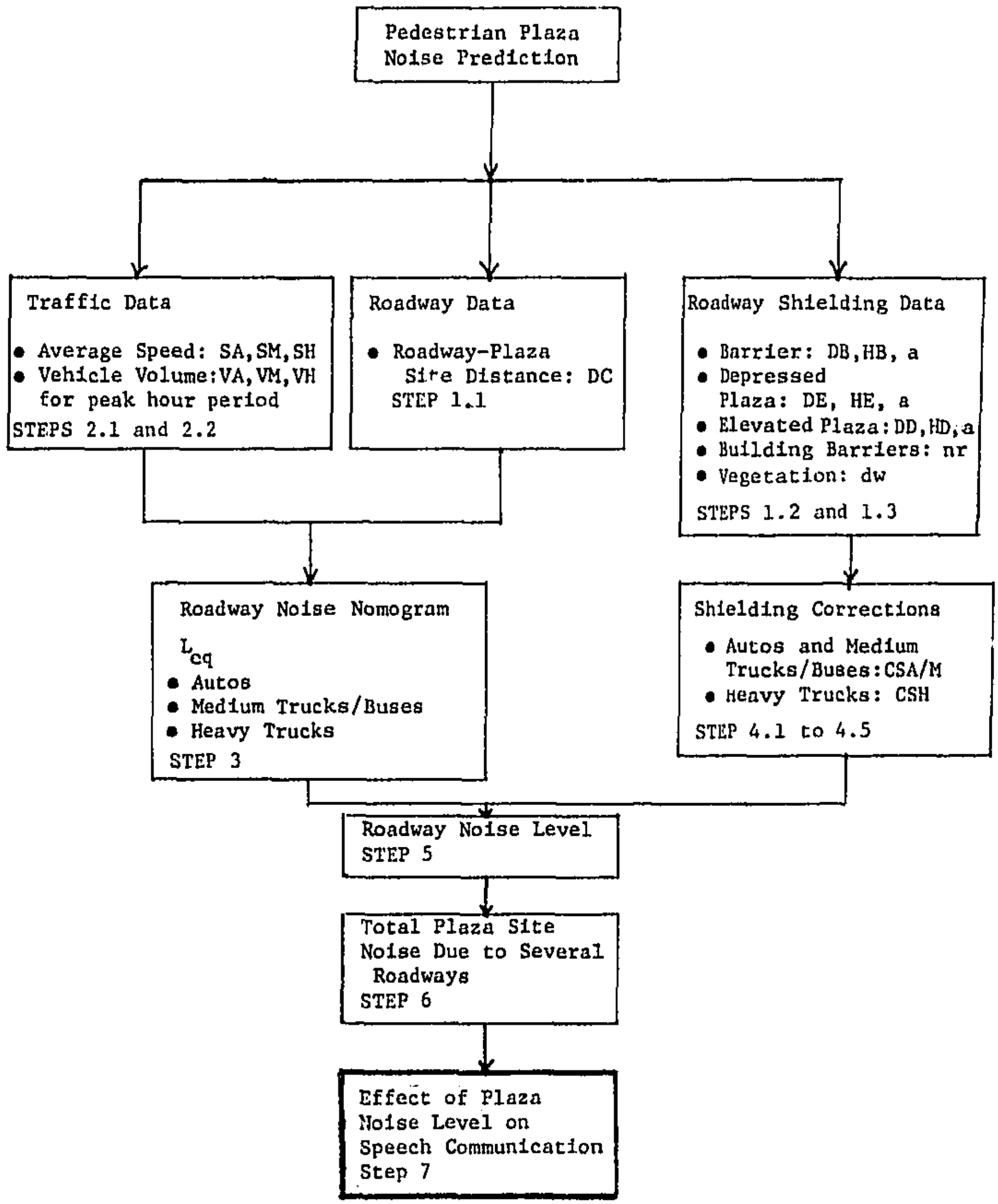



Figure 18. PLAZA NOISE PREDICTION FLOW DIAGRAM

## Roadway Worksheet

Plaza Project ______________________ Roadway ______________________

Location ______________________ Site point within plaza for which noise levels are being estimated ______________________

Owner ______________ Designer ______________ Date __________ Revised __________

Roadway-Plaza Site Distance: DC meters (feet)

| | | Autos | | Medium Trucks/ Buses | | Heavy Trucks | |
|---|---|---|---|---|---|---|---|
| Average Vehicle Speed, mph | | SA | | SM | | SH | |
| Average Vehicle Volume (veh/hr) | | VA | | VM | VMB | VH | |
| Predicted Noise Levels No Shielding ($L_{eq}$) | | | | | | | |
| Path Length Difference | Autos and Medium Trucks | $A_{a/m}$ | | $B_{a/m}$ | | $C_{a/m}$ | $L_{a/m}$ |
| | Heavy Trucks | $A_h$ | | $B_h$ | | $C_h$ | $L_h$ |
| Correction For "Infinite" Shielding Element | | Auto | | Medium Trucks/Bus | | Heavy Truck | |
| | | CSA/M | | CSA/M | | CSH | |
| Correction For "Finite" Shielding Element | | Included Angle Ratio, RA | | | | | |
| | | Auto | | Medium Truck | | Heavy Truck | |
| | | CSA/M | | CSA/M | | CSH | |
| Building Barrier | | nr | | CSB | | | |
| Vegetation | | dw | | CSV | | | |
| Total Shielding Correction | | Auto | | Medium Truck | | Heavy Truck | |
| | | CSA/M + CSB + CSV | | CSA/M + CSB + CSV | | CSH + CSB + CSV | |
| Plaza Site Noise Due to Roadway | | | | | | | |
| Plaza Site Noise Due To Several Roadways | | | | | | | |

FIGURE 19. ROADWAY WORKSHEET

Plaza Noise Prediction Method

STEP 1. Physical Site Data

The roadway geometry and the plaza site location should be determined for each roadway adjoining the plaza. The required data are:

1.1. Nearest perpendicular distance between the center of the roadway and the selected location on the plaza site (DC) in meters (feet).

1.2. Location and geometry of obstructions (if any) that visually shield the roadway from the plaza in meters (feet). Determine if any barriers are present and if the plaza is depressed or elevated, and then obtain the appropriate distances as shown in Figures 20, 21, and 22 and listed below:

| | |
|---|---|
| Barrier: | DC, DB, HB, a |
| Depressed Plaza: | DC, DE, HE, a |
| Elevated Plaza: | DC, DD, HD, a |

1.3. Presence of any rows of buildings or belts of vegetation that shield the plaza from the roadway.

| | |
|---|---|
| a) Buildings as Barriers: | nr=number of rows of buildings |
| b) Vegetation: | dw=depth of vegetation |

Record the value on the Roadway Worksheet.

STEP 2. Roadway Traffic Data

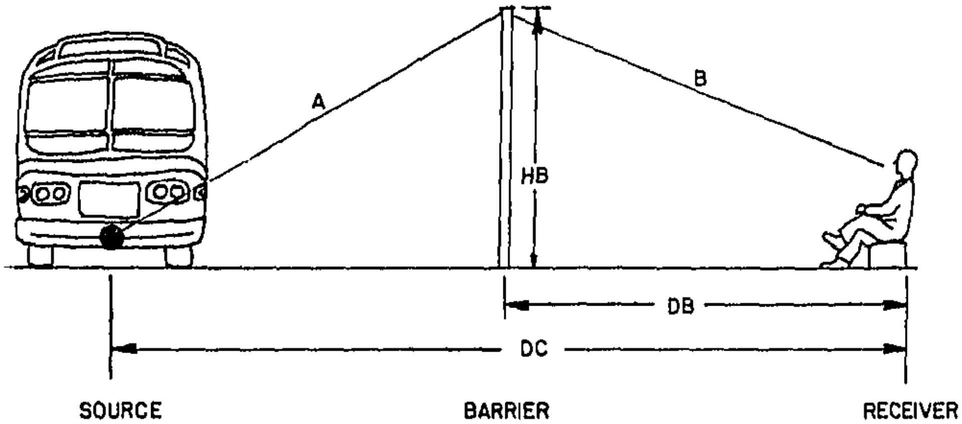
The information that is required on roadway vehicle traffic should be the total for all lanes of the roadway and should be based on typical operating conditions. Calculations are based upon existing traffic volumes; but, if available, use future traffic volumes. If truck volume data does not differentiate medium and heavy trucks, consider these volumes as heavy trucks (VH); bus volumes, if available, are considered medium trucks (VM).

The required data to be recorded on the Roadway Worksheet are:

2.1. Average vehicle speed in miles per hour: SA-auto; SM-medium truck/bus; SH-heavy truck.

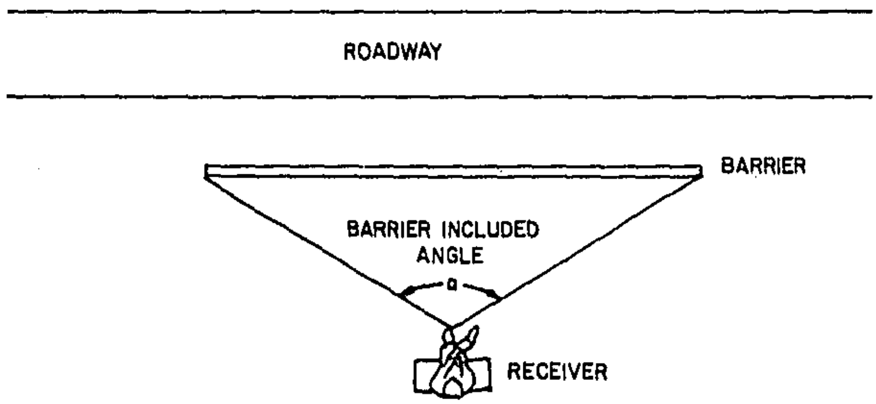
2.2. Average vehicle traffic volume in vehicles per hour: VA-auto; VM-medium truck/bus; VH-heavy truck. Determine the total number of vehicles in each group that pass by during the one selected hour of critical plaza use.

The necessary input data for the prediction of roadway noise is now completed.




**(A) BARRIER LINEAR DIMENSIONS**

NOTE : SOURCE HEIGHT FOR AUTO, MEDIUM TRUCK/BUS IS 0 METERS, HEAVY TRUCK IS 2.5 m ( 8 ft )
RECEIVER HEIGHT FOR AN ADULT SITING IS 1 m (3 ft)




**(B) BARRIER INCLUDED ANGLE**

**FIGURE 20 <u>ROADWAY BARRIER DIMENSIONS</u>**

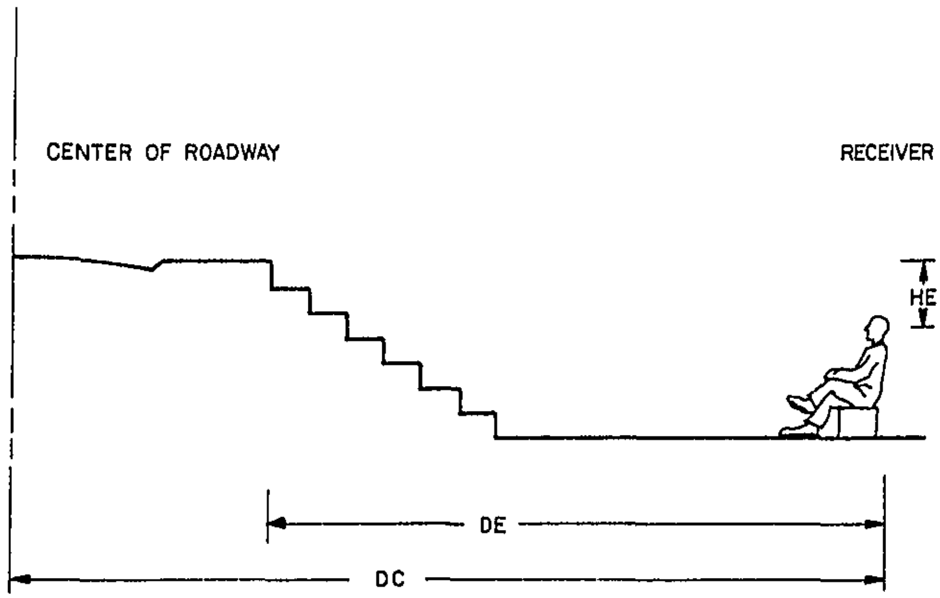



FIGURE 21 DEPRESSED PLAZA DIMENSIONS

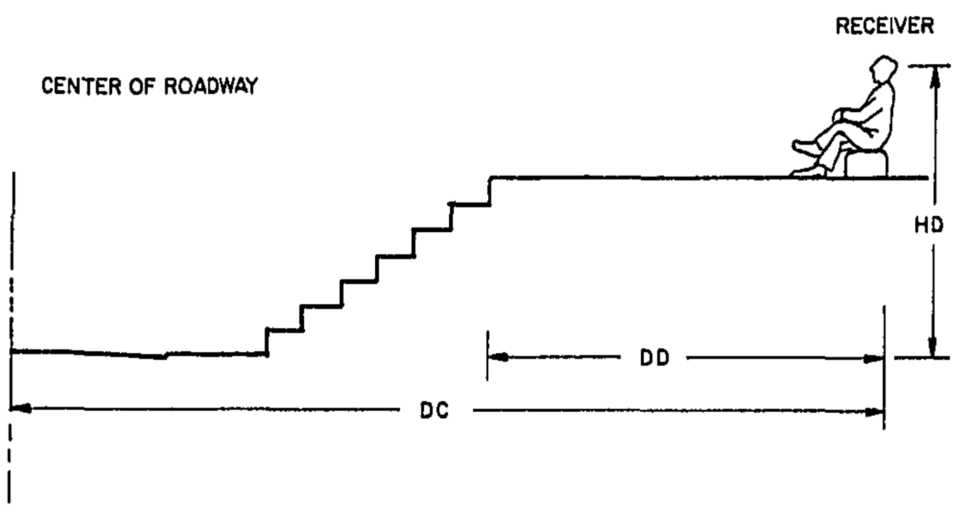



FIGURE 22 ELEVATED PLAZA DIMENSIONS

STEP 3. Nomogram Procedure

The nomogram procedure described below must be repeated for each of the classes of vehicles. To account for the difference in noise level between autos and medium trucks/buses, a corrected medium truck/bus value is used. This corrected volume (VMC) is equal to the actual volume (VM) multiplied by ten (VMC = 10VM).

3.1. Draw a straight line from the left pivot point through the point corresponding to the vehicle speed (the bottom scale for autos and medium trucks/buses and the upper scale for heavy trucks). Extend this line until it intersects with line A.

3.2. Draw another straight line from this point of intersection on line A to the point on the far right scale corresponding to the vehicle traffic volume. This line intersects line B.

3.3. Draw a third straight line from the intersection on line B to the point on the DC scale corresponding to the distance from the selected location on the building site to the center of the roadway. This line intersects the scale marked RNL. The value of RNL at this point of intersection is the predicted noise level. Record this value on the Roadway Worksheet and continue the prediction procedures.

STEP 4. Shielding Corrections

No obstruction or shielding between the roadway and the plaza site was assumed in STEPS 1-3. If there is any shielding due to a barrier, elevated or depressed plaza, rows of buildings or a belt of vegetation, it should be taken into account. This is done in STEPS 4.1 to 4.5.

The corrections for shielding due to barriers and elevated or depressed plazas are related to the effective sound source heights for the three vehicle groups. The effective sources are assumed to be near the roadway surface for autos and medium trucks/buses (0.0 m) and 2.5 m (8 ft) above the roadway surface for heavy trucks. Therefore, there are two corrections: one for autos and medium trucks/buses (CSA/M), and one for heavy trucks (CSH). These corrections are determined by calculating the path length differences from the equations listed in STEP 4.1 for the type of shielding that is present. Using these values of L, CSA/M and CSH are determined in STEPS 4.2 and 4.3 for an "infinite" and "finite" shielding elements.

The shielding corrections for rows of buildings which act as barriers and for vegetation are related to the physical layout of the roadway, the site, and plaza. The correction for the shielding due to rows of buildings which act as barriers (CSB) is computed in STEP 4.4. The correction for the shielding due to vegetation, (CSV), is computed in STEP 4.5. Note that the attenuation due to rows of buildings which act as barriers, and to vegetation, is added to any attenuation due to barriers and elevated or depressed plazas. For example, if the A-weighted sound level attenuation of a barrier, two rows of buildings, and a depressed plaza are 5 dB, 6 dB, and 5 dB, respectively, the total A-weighted sound level attenuation is 16 dB.

After shielding corrections are applied (if any), the individual component sound levels are calculated. These are then combined to get the total roadway noise in STEP 5.

4.1. Path Length Difference - Compute the path length difference for autos and medium trucks/buses (La/m) and for heavy trucks (Lh) for the type of shielding present. Be sure the obstruction blocks the line-of-sight between the source and receiver, in particular for heavy trucks which have the source located 2.5 m (8 ft) above the road surface. If the line-of-sight is not blocked, the correction is zero.

1. Barrier:

$$Aa/m = \sqrt{HB^2 + (DC-DB)^2}$$
$$Ah = \sqrt{(HB-2.5)^2 + (DC-DB)^2}$$
$$Ba/m = Bh = \sqrt{(HB + 3)^2 + DB^2}$$
$$Ca/M = \sqrt{1 + DC^2}$$
$$Ch = \sqrt{(1 + 2.5)^2 + DC^2}$$

2. Depressed Plaza:

$$Aa/m = (DC-DE)$$
$$Ah = \sqrt{6.25 + (DC - DE)^2}$$
$$Ba/m = Bh = \sqrt{HE^2 + DC^2}$$
$$Ca/m = \sqrt{HE^2 + DC^2}$$
$$Ch = \sqrt{(HE + 2.5)^2 + DC^2}$$

3. Elevated Plazas:

$$Aa/m = \sqrt{HD^2 + (DC - DD)^2}$$

$$Ah = \sqrt{(HD - 2.5)^2 + (DC - DD)^2}$$

$$Ba/m = Bh = DD$$

$$Ca/m = \sqrt{(HD + 1)^2 + DC^2}$$

$$Ch = \sqrt{(HD - 1.5)^2 + DC^2}$$

From these values the path length differences are calculated from the following equations.

$$La/m = Aa/m + Ba/m - Ca/m$$

$$Lh = Ah + Bh - Ch$$

Record these values on the Roadway Worksheet and proceed to the next step.

4.2. "Infinitely" Long Barrier - Compute the shielding corrections CSA/M and CSH. These values are determined from the path length differences calculated in the previous step. If the path length difference is less than 0.03 m (0.1 ft), or is negative, there is no significant shielding and the correction is zero. If the path length difference is positive and greater than 0.03 m (0.1 ft), the shielding correction is determined by locating the value of the path length difference on the horizontal axis of Figure 23. Read up until intersecting the curve. The value of the shielding correction can be read off the vertical axis directly left of the intersection. This procedure is followed using La/m to determine CSA/M and Lh to determine CSH. Record these values on the Roadway Worksheet. If the included angle, a, is less than $170^{\circ}$ the shielding element is of "finite" length, and you must proceed to STEP 4.3. If this included angle (a) is greater than $170^{\circ}$, no adjustment to the shielding corrections is needed. Omit STEP 4.3 and continue the design guide analysis.

4.3. "Finite" Barrier - Compute the adjusted values of CSA/M and CSH to account for shielding elements of "finite" length. These adjusted shielding corrections are determined from the factor RA, which is calculated from the included angle, a (in degrees), using the following equation:

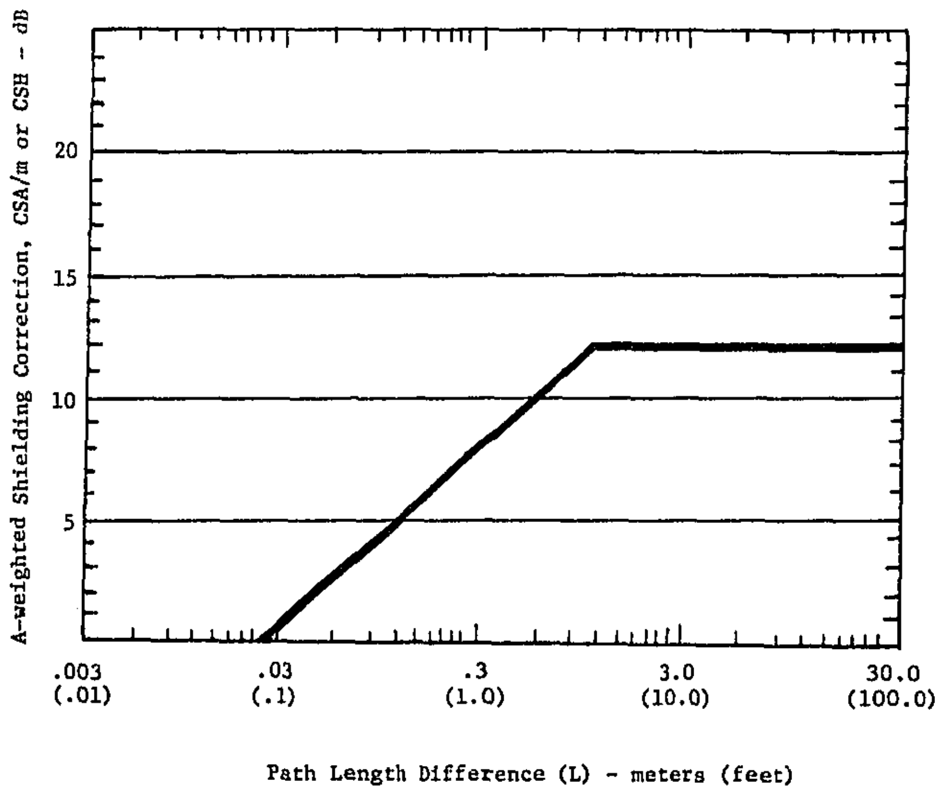
$$RA = \frac{a}{180^{\circ}}$$

Now go to Table 5 and enter the first column at the value of CSA/M and read across that row to the column corresponding to the value of RA. This is the adjusted value of CSA/M. Repeat this procedure using the value of CSH to get the finite shielding correction for heavy trucks. Record these adjusted shielding corrections on the Roadway Worksheet and continue the design guide analysis.

Table 5. Shielding Corrections for a Finite Barrier

| "Infinite" Barrier Shielding Correction | RA = $a/180^{o}$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CSA/M or CSH | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 | .10 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 3 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |
| 4 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 |
| 5 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 |
| 6 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 6 |
| 7 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 6 | 7 |
| 8 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 |
| 9 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 7 | 9 |
| 10 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 7 | 9 |
| 11 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 6 | 8 | 11 |
| 12 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 12 |

Source: National Bureau of Standards, 1978.




Source: National Bureau of Standards, 1978.

Figure 23 A-WEIGHTED SHIELDING CORRECTIONS FOR BARRIERS

4.4. Shielding Correction - for Buildings Acting as Barriers - Calculate the correction, CSB, for rows of buildings which shield the roadway from your plaza site. This correction depends on the number of rows of intervening buildings, nr, and is determined from Table 6. Record this correction on The Roadway Worksheet and continue the design guide analysis.

4.5. Shielding Correction - for Vegetation - The shielding correction, CSV, for a belt of vegetation of depth dw, which shields the roadway from the plaza. This correction is simply an A-weighted sound level attenuation of 5 dB for 30 m (100 ft) of vegetation. Interpolation for depths less than 30 m (100 ft) can be approximated at 1 dB per 6 m (20 ft) of vegetation. Record the correction on the Roadway Worksheet and continue the design guide analysis.

STEP 5 Total Roadway Noise

Compute the total noise at the plaza site due to the roadway. First, sum the shielding corrections on the Roadway Worksheet for each vehicle group. Subtract these total shielding corrections from the unshielded noise levels to get the individual components at the plaza site.

Since these levels are logarithmic in nature, they cannot be simply added together or averaged to get the total noise level. Instead, they are combined, two values at a time, with the use of Table 7. Starting with the auto and medium truck/bus noise levels, subtract one from the other to get the difference. With this value go to Table 7 and determine the level admustment which is added to the larger of the two original noise levels.

Now repeat this procedure with this adjusted level and the noise level for heavy trucks. The result of this combination is the total noise at the plaza site due to this (one) roadway. For example, if the A-weighted sound levels for autos, medium trucks/buses and heavy trucks are 55, 55, and 60 dB respectively, the total noise due to this highway is:

$$\left.\begin{array}{l} \left.\begin{array}{l} 55 \\ 55 \end{array}\right\} \dfrac{\text{difference} = 0}{\text{add } 3} \; 58 \\ 60 \end{array}\right\} \dfrac{\text{difference} = 0}{\text{add } 2} \; 62 \text{ dB}$$

Record the total noise level on the Roadway Worksheet.

Table 6. Shielding Corrections for Buildings Acting as Barriers

| Number of Rows | Shielding Correction, CSB |
| --- | --- |
| 1 | 4.5 |
| 2 | 6.0 |
| 3 | 7.5 |
| 4 | 9.0 |
| 5 or more | 10.0 |

Source: National Bureau of Standards, 1978.

Table 7. Level Adjustment for Summing Noise Levels.

| Difference Between Two Noise Levels, dB | Level Adjustment (To Be Added To The Larger of the Two Values) |
| --- | --- |
| 10 or more | 0 |
| 4-9 | 1 |
| 2-3 | 2 |
| 0-1 | 3 |

Source: National Bureau of Standards, 1978.

This completes the prediction of roadway noise. These procedures should be repeated for each roadway that adjoins the plaza. The total noise at the plaza site due to all roadways is the logarithmic summation of the noise contributions from each roadway. This computation is performed in STEP 6.

STEP 6. Total Noise Level at Plaza

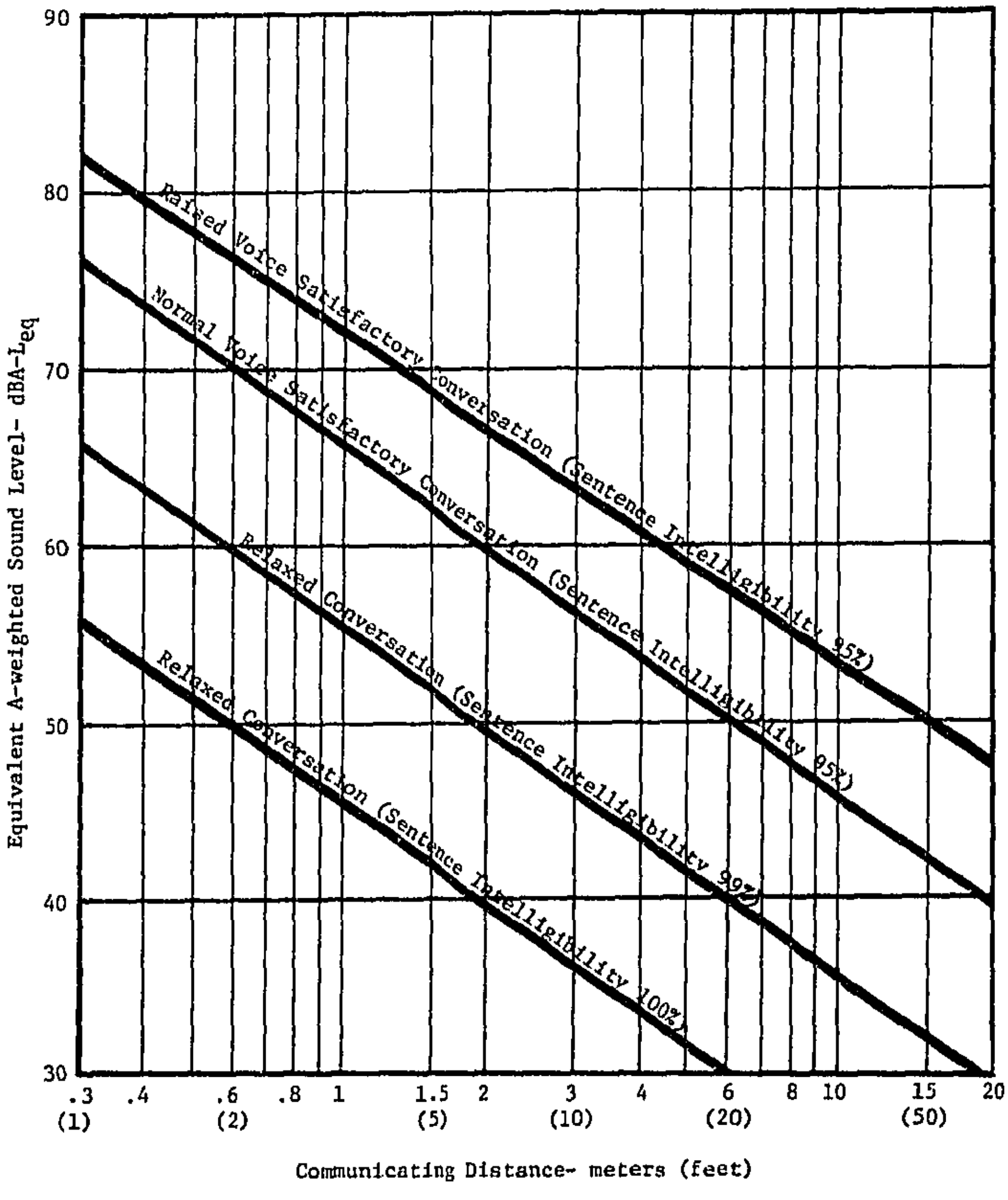
The total noise level at the plaza is determined by summing the components from all roadways affecting the site. Summing is done two values at a time by the same method as used in STEP 5. Record this value on the Roadway Worksheet.

STEP 7. Effect of Plaza Noise on Speech Communication

The maximum distances outdoors over which conversation is considered to be satisfactorily intelligible (Figure 24) can be used to develop criteria for plaza design or as a criteria for specific areas within a plaza.

For example, if the plaza designer would like relaxed normal voice satisfactory conversation with 95 percent sentence intelligibility possible at four feet, then the plaza equivalent noise level should not exceed 64 dBA.

For this step the minimum communicating distance is determined by Figure 24 with the voice effort selected to be satisfactory (raised, normal or relaxed).




Source: USEPA,1974

Figure 24 MAXIMUM DISTANCE OUTDOORS OVER WHICH CONVERSATION IS CONSIDERED TO BE SATISFACTORILY INTELLIGIBLE

## 6.1 Example of How to Estimate Plaza Site Noise

The example shown in Figure 25 is a plaza that is affected by two roadways. The plaza is depressed 6 m (19 ft) below street level as shown in Figure 26. The location within the plaza at which the noise level will be calculated is designated as the receiver.

STEP 1 Roadways to Plaza Distances

1.1. The roadway plaza site distances for evaluating a depressed plaza are 40 m (135 ft) for Roadway #1 and 20 m (70 ft) for Roadway #2. These dimensions are recorded on separate copies of the Roadway Worksheet (Figures 27 and 28).

1.2. The distances associated with a depressed plaza are as follows:

| Roadway #1 | Roadway #2 |
|---|---|
| HE = 5 m (15 ft) | HE = 5 m (15 ft) |
| DE = 30 m (100 ft) | DE = 10 m (35 ft) |
| DC = 40 m (135 ft) | DC = 20 m (70 ft) |
| $a = 180^{\circ}$ | $a = 180^{\circ}$ |

1.3. There are no intervening rows of buildings and no vegetation which would shield the plaza from the roadways. Therefore, for this example these types of shielding are neglected.

STEP 2 Traffic Data

2.1. For both Roadway #1 and #2 the average vehicle speed is 30 mph during the expected peak hours of plaza use.

2.2. The projected hourly traffic volumes for both roadways, for the year when the plaza will be completed are as follows:

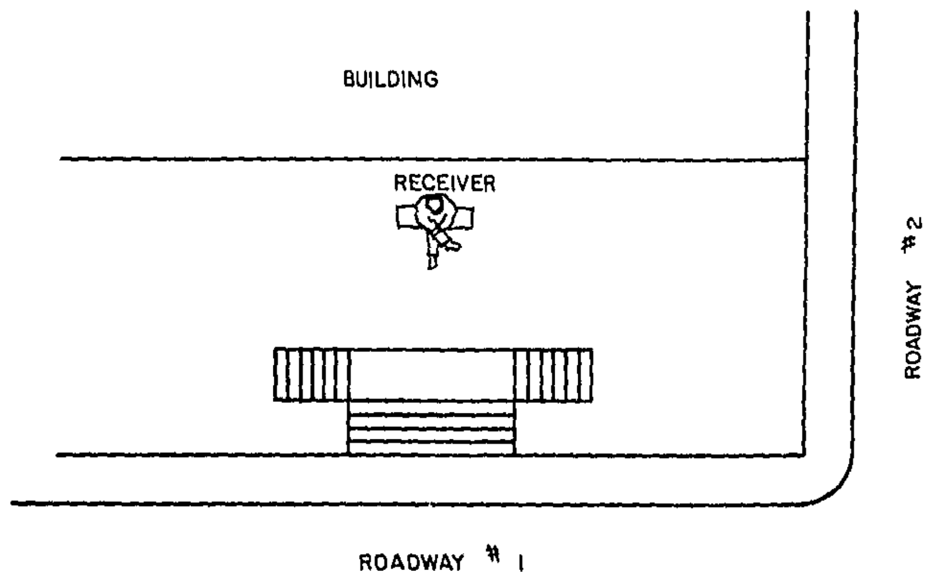



FIGURE 25 PLAN OF PLAZA

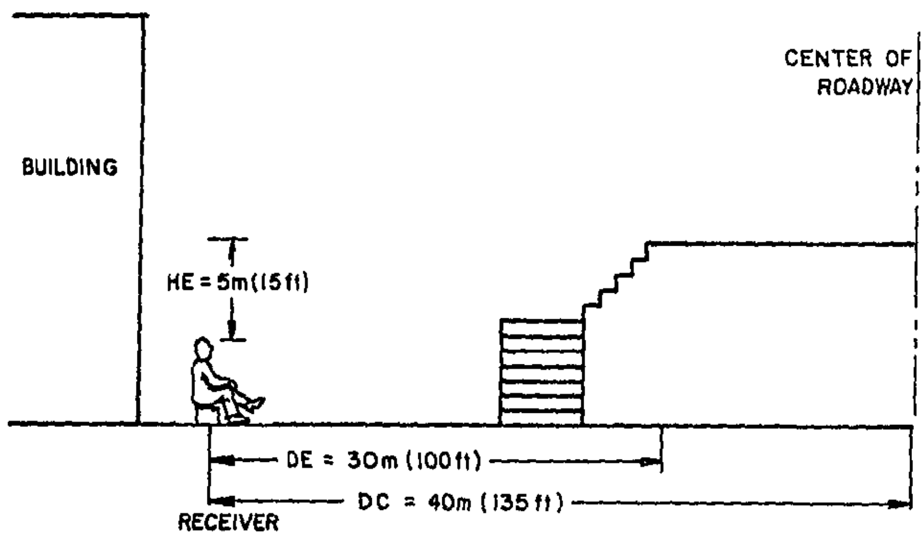



FIGURE 26 CROSS-SECTION OF PLAZA SHOWING ROADWAY #1

Roadway Worksheet #1

Plaza Project Carter Center    Roadway #1

Location Gorham, USA    Site point within plaza for which noise levels are being estimated: Sitting Area

Owner P. Nutz Inc.    Designer K. Shew    Date 2/79    Revised 3/79

Roadway-Plaza Site Distance: DC meters (feet)
40 m (135 ft)

| | | Autos | | Medium Trucks/ Buses | | Heavy Trucks | |
|---|---|---|---|---|---|---|---|
| Average Vehicle Speed, mph | | SA | 30 | SM 30 | | SH | 30 |
| Average Vehicle Volume (veh/hr) | | VA | 1500 | VM 20 | VMB 30 | VH | 30 |
| Predicted Noise Levels No Shielding ($L_{eq}$) | | 58 dB | | 53 dB | | 64dB | |
| Path Length Difference | Autos and Medium Trucks | $A_{a/m}$ 10 m | $B_{a/m}$ 30.41 m | $C_{a/m}$ 40.31 m | | $L_{a/m}$ 0.10 m | |
| | Heavy Trucks | $A_h$ 10.31 m | $B_h$ 30.41 m | $C_h$ 40.71 m | | $L_h$ 0.01 m | |
| Correction For "Infinite" Shielding Element | | Auto CSA/M 4 dB | Medium Trucks/Bus CSA/M 4 dB | | | Heavy Truck CSH 0 dB | |
| Correction For "Finite" Shielding Element | | Included Angle Ratio, RA -- | | | | | |
| | | Auto CSA/M -- | Medium Truck CSA/M -- | | | Heavy Truck CSH -- | |
| Building Barrier | | nr -- | CSB -- | | | -- | |
| Vegetation | | dw -- | CSV -- | | | -- | |
| Total Shielding Correction | | Auto CSA/M + CSB + CSV 4 dB | Medium Truck CSA/M + CSB + CSV 4 dB | | | Heavy Truck CSH + CSB + CSV 0 dB | |
| Plaza Site Noise Due To Roadway | | 65 dB | | | | | |
| Plaza Site Noise Due To Several Roadways | | 67 dB | | | | | |

FIGURE 27. WORKSHEET FOR ROADWAY #1

Roadway Worksheet #2

| | |
|---|---|
| Plaza Project Carter Center | Roadway #2 |
| Location Gotham, USA | Site point within plaza for which noise levels are being estimated<br>Sitting Area |

Owner P. Nutz Inc. Designer K. Shew Date 2/69 Revised 3/79

Roadway-Plaza Site Distance: DC meters (feet)

20 m (70 ft)

| | | | | | |
|---|---|---|---|---|---|
| | | Autos | Medium Trucks/ Buses | | Heavy Trucks |
| Average Vehicle Speed, mph | | SA 30 | SM 30 | | SH 30 |
| Average Vehicle Volume (veh/hr) | | VA 350 | VM 10 | VMB 20 | VH 20 |
| Predicted Noise Levels No Shielding ($L_{eq}$) | | 56 dB | 55 dB | | 66 db |
| Path Length Difference | Autos and Medium Trucks | $A_{a/m}$<br>10 m | $B_{a/m}$<br>11.18 m | $C_{a/m}$<br>20.61 m | $L_{a/m}$<br>0.57 m |
| | Heavy Trucks | $A_h$<br>10.3 m | $B_h$<br>11.18 m | $C_h$<br>21.35 m | $L_h$<br>0.13 m |
| Correction For "Infinite" Shielding Element | | Auto<br>CSA/M<br>9 dB | Medium Trucks/Bus<br>CSA/M<br>9 dB | | Heavy Truck<br>CSH<br>4 dB |
| Correction For "Finite" Shielding Element | | Included Angle Ratio, RA -- | | | |
| | | Auto<br>CSA/M<br>-- | Medium Truck<br>CSA/M<br>-- | | Heavy Truck<br>CSH<br>-- |
| Building Barrier | | nr -- | CSB -- | | -- |
| Vegetation | | dw -- | CSV -- | | -- |
| Total Shielding Correction | | Auto<br>CSA/M + CSB + CSV<br>9 dB | Medium Truck<br>CSA/M + CSB + CSV<br>9 dB | | Heavy Truck<br>CSH + CSB + CSV<br>4 dB |
| Plaza Site Noise Due To Roadway | | 62 | | | |
| Plaza Site Noise Due To Several Roadways | | 67 dB | | | |

FIGURE 28. WORKSHEET FOR ROADWAY #2

| | Roadway #1 | Roadway #2 |
|---|---|---|
| automobiles | VA = 1500 vehicles | VA = 350 vehicles |
| medium trucks/ buses | VM = 50 vehicles | VM = 30 vehicles |
| heavy trucks | VH = 30 vehicles | VH = 20 vehicles |

Step 3 Nomogram Procedure - Roadway #1

Predict the noise generated by each of the three vehicle classifications as follows:

3.1. Automobile Noise - Using the values SA = 30 mph, VA = 1500 veh/hr and DC = 40 m (135 ft) the nomogram procedures are performed to predict the noise level of automobiles (Figure 29). The value of RNL is determined to be an A-weighted equivalent sound level of 58 dB.

3.2. Medium Truck/Bus Noise - The general nomogram procedure is repeated for medium trucks/buses using a corrected vehicle volume (VMC) calculated as:

$$VMC = 10\ VM = 10 \times 50 = 500\ \text{Veh/hr}$$

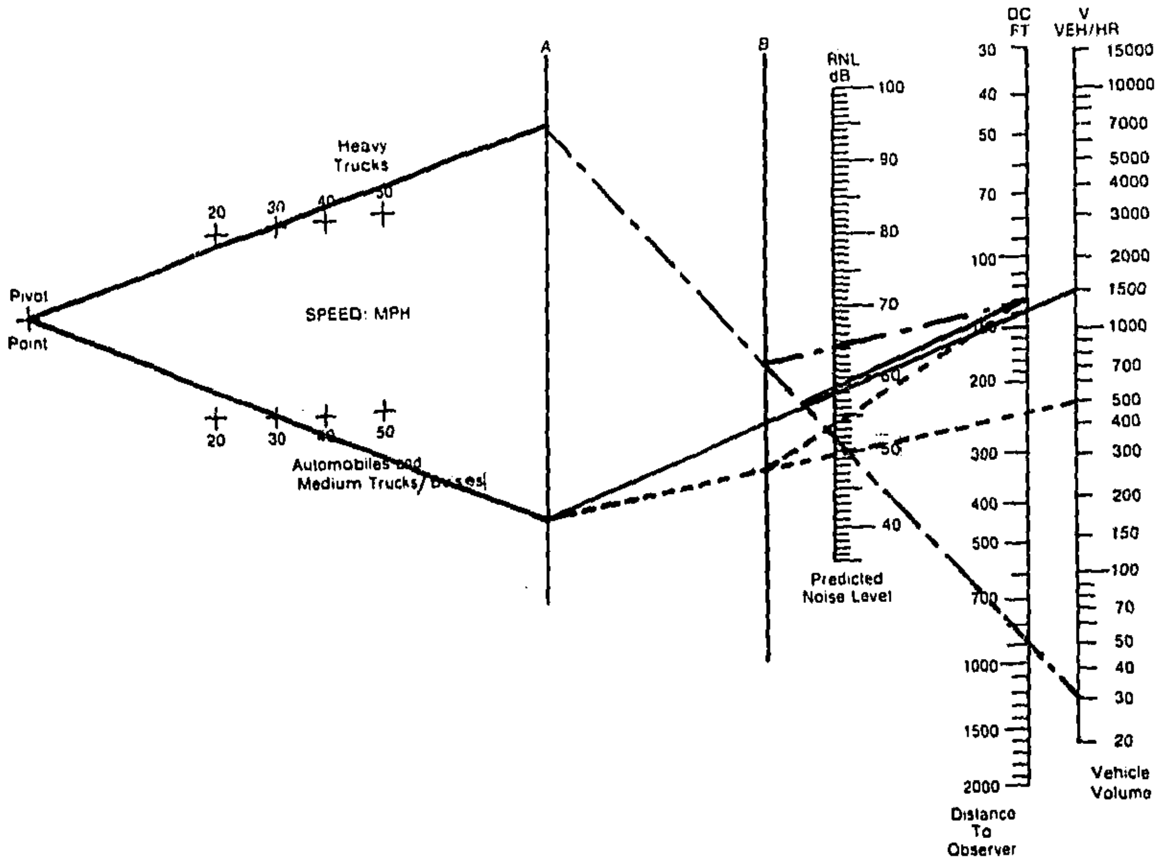
Using the values SM = 30 mph and DC = 40 m (135 ft) the RNL is 53 dB.

3.3. Heavy Truck Noise - For heavy trucks, the nomogram procedure is again repeated (using the top scale of vehicle speeds) with the values SH = 30 mph, VH = 30 veh/hr and DC = 40 m (135 ft). The predicted value of RNL is 64 dB.

These steps are repeated for Roadway #2 and are recorded on Roadway Worksheet #2 (Figure 28).

STEP 4 Shielding Corrections

4.1. Path Length Difference - The path length difference for automobiles and medium trucks/buses is:




Key: ________________ Automobiles RNL = 58 dB

-------------------- Medium Trucks/Buses RNL = 53 dB

______ __ ______ Heavy Trucks RNL = 64 dB

Metric Conversion: 1 foot equals 0.3048 meters

Figure 29 TRAFFIC NOISE PREDICTION NOMOGRAM FOR ROADWAY #1 OF EXAMPLE

$$Aa/m = (DC - DE)$$

$$(40 - 30) = 10 \text{ m } (35 \text{ ft})$$

$$Ba/m = \sqrt{HE^2 + DE^2}$$

$$\sqrt{5^2 + 30^2} = 30.41 \text{ m } (101 \text{ ft})$$

$$Ca/m = \sqrt{HE^2 + DC^2}$$

$$\sqrt{5^2 + 40^2} = 40.31 \text{ m } (136 \text{ ft})$$

$$La/m = Aa/m = Ba/m - Ca/m = 0.10 \text{ m } (0.33 \text{ ft})$$

The path length difference for heavy trucks is:

$$Ah = \sqrt{6.25 + (DC - DE)^2}$$

$$\sqrt{6.25 + (40 - 30)^2} = 10.31 \text{ m } (36 \text{ ft})$$

$$Bh = \sqrt{HE^2 + DE^2}$$

$$\sqrt{5^2 + 30^2} = 30.41 \text{ m } (101 \text{ ft})$$

$$Ch = \sqrt{(HE + 2.5)^2 + DC^2}$$

$$\sqrt{(5 + 2.5)^2 + 40^2} = 40.70 \text{ m } (137 \text{ ft})$$

$$Lh = Ah + Bh - Ch = 0.01 \text{ m } (0.03 \text{ ft})$$

4.4. "Infinite Barrier" - The A-weighted shielding correction (CSA/M) is determined from Figure 23 to be approximately 4 dB for automobiles and medium trucks/buses and 0.0 dB for heavy trucks. This value is recorded on Roadway Worksheet #1 (Figure 27). Since the included angle of the depressed plane is 180° the shielding effect can be considered infinite and no further adjustment is required.

STEP 5 Total Noise Level for Roadway #1

The total noise level for Roadway #1 is computed by logarithm addition of the levels of the three types of vehicles after the shielding corrections have been subtracted (STEP 4) from the unshielded levels (STEP 3). The levels (automobiles - 54 dB; medium trucks/buses - 49 dB; and heavy trucks - 64 dB) are added as follows:

54 } difference = 5 / add 1 — 55
49 }

55 } difference = 9 / add 1 — 65 dB
64 }

Similar results are obtained for Roadway #2 by using these same calculations. The noise levels are 45 dB, 44 dB and 62 dB for automobiles, medium trucks/buses and heavy trucks respectively. The total noise level due to Roadway #2 at the plaza is 62 dB.

STEP 6 <u>Total Plaza Noise Level From Roadways #1 and #2</u>

The levels from the two roadways are combined to obtain the total noise level at the plaza. This combination yields a total A-weighted equivalent sound level of 67 dB.

STEP 7 <u>Effect of Plaza Noise Level on Speech Communication</u>

The affect of the calculated noise level on speech communication within the plaza can be determined from Figure 24. The voice effort (raised, normal, or relaxed) is selected as the criteria for communication, and a communicating distance is determined based on the plaza noise level. Assuming a normal voice level for satisfactory conversation (95 percent sentence intelligibility) a minimum communicative distance of 0.8 m (2.6 ft) is required for this plaza.

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# APPENDIX A: SURVEY QUESTIONNAIRE WITH RESPONSE FREQUENCIES

## Attitudinal Survey: Daytime Aggregate

Response

| Response | | |
|---|---|---|
| | 1. | How often do you visit the plaza weather permitting? |
| 36% | a. | 3-5 times per week |
| 30% | b. | 1-2 times per week |
| 9% | c. | every other week |
| 9% | d. | once a month |
| 16% | e. | less than once a month |
| | 2. | What time do you usually visit the plaza? |
| 8% | a. | morning |
| 11% | b. | during work breaks |
| 70% | c. | lunch |
| 5% | d. | after work |
| 4% | e. | evening |
| 2% | f. | other |
| | 3. | What influences what time of day you visit the plaza? |
| 9% | a. | crowds at the plaza |
| 58% | b. | climate/sunshine |
| 8% | c. | special scheduled events |
| 25% | d. | other |
| | 4. | What do you mainly do when you visit the plaza? |
| 21% | a. | eat |
| 22% | b. | talk with friends |
| 9% | c. | read |
| 33% | d. | people watch |
| 15% | e. | other |
| | 5. | How long do you stay? |
| 11% | a. | less than 15 minutes |
| 46% | b. | 15-30 minutes |
| 23% | c. | 30-45 minutes |
| 15% | d. | 45 mins. - 1 hour |
| 5% | e. | over 1 hour |
| | 6. | What conditions would you like to see changed to make your visits more pleasant? |
| 25% | a. | more seating |
| 18% | b. | shielding from sun, rain, wind |
| 4% | c. | better maintenance |
| 28% | d. | aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 20% | e. | program events |
| 5% | f. | other |

| Response | | |
|---|---|---|
| | 7. | Which of the following affect you most when you're in the plaza? |
| 14% | | a. air quality |
| 19% | | b. noise |
| 21% | | c. uncleanliness |
| 20% | | d. crowding |
| 20% | | e. surrounding traffic |
| 6% | | f. other |
| | 8. | Were you aware of noise in this plaza prior to this interview? |
| 54% | | a. yes |
| 46% | | b. no |
| | 8a. | Can you identify the source of this noise? |
| 90% | | a. traffic |
| 2% | | b. construction |
| 6% | | c. aircraft |
| 1% | | d. internal activities |
| 1% | | e. building equipment |
| 0% | | f. other |
| | 9. | Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy. |
| | | not noisy at all |
| 10% | | a. 1 |
| 21% | | b. 2 |
| 44% | | c. 3 |
| 21% | | d. 4 |
| 4% | | e. 5 |
| | | extremely noisy |
| | 9a. | Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered. |
| | | not bothered at all |
| 33% | | a. 1 |
| 30% | | b. 2 |
| 23% | | c. 3 |
| 9% | | d. 4 |
| 5% | | e. 5 |
| | | extremely bothered |
| | 10. | Which of the following do you feel could best alleviate noise annoyance? |
| 34% | | a. trees |
| 4% | | b. plaza furniture |
| 23% | | c. waterfall |
| 19% | | d. piped in music |
| 13% | | e. barrier wall |
| 7% | | f. other |

Attitudinal Survey: Evening Aggregate

Response

1. How often do you visit the plaza weather permitting?

| | | |
|---|---|---|
| 13% | a. | 3-5 times per week |
| 21% | b. | 1-2 times per week |
| 9% | c. | every other week |
| 20% | d. | once a month |
| 37% | e. | less than once a month |

2. What time do you usually visit the plaza?

| | | |
|---|---|---|
| 7% | a. | morning |
| 7% | b. | during work breaks |
| 13% | c. | lunch |
| 32% | d. | after work |
| 40% | e. | evening |
| 1% | f. | other |

3. What influences what time of day you visit the plaza?

| | | |
|---|---|---|
| 9% | a. | crowds at the plaza |
| 38% | b. | climate/sunshine |
| 31% | c. | special scheduled events |
| 22% | d. | other |

4. What do you mainly do when you visit the plaza?

| | | |
|---|---|---|
| 4% | a. | eat |
| 24% | b. | talk with friends |
| 7% | c. | read |
| 39% | d. | people watch |
| 26% | e. | other |

5. How long do you stay?

| | | |
|---|---|---|
| 16% | a. | less than 15 minutes |
| 48% | b. | 15-30 minutes |
| 13% | c. | 30-45 minutes |
| 8% | d. | 45 mins. - 1 hour |
| 15% | e. | over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| | | |
|---|---|---|
| 35% | a. | more seating |
| 15% | b. | shielding from sun, rain, wind |
| 5% | c. | better maintenance |
| 25% | d. | aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 19% | e. | program events |
| 1% | f. | other |

| Response | |
|---|---|
| | 7. Which of the following affect you most when you're in the plaza? |
| 13% | a. air quality |
| 20% | b. noise |
| 20% | c. uncleanliness |
| 27% | d. crowding |
| 20% | e. surrounding traffic |
| | 8. Were you aware of noise in this plaza prior to this interview? |
| 45% | a. yes |
| 55% | b. no |
| | 8a. Can you identify the source of this noise? |
| 88% | a. traffic |
| 1% | b. construction |
| 3% | c. aircraft |
| 4% | d. internal activities |
| 4% | e. building equipment |
| 0% | f. other |
| | 9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy. |
| | not noisy at all |
| 20% | a. 1 |
| 22% | b. 2 |
| 41% | c. 3 |
| 13% | d. 4 |
| 4% | e. 5 |
| | extremely noisy |
| | 9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered. |
| | not bothered at all |
| 40% | a. 1 |
| 23% | b. 2 |
| 23% | c. 3 |
| 9% | d. 4 |
| 5% | e. 5 |
| | extremely bothered |
| | 10. Which of the following do you feel could best alleviate noise annoyance? |
| 44% | a. trees |
| 4% | b. plaza furniture |
| 25% | c. waterfall |
| 16% | d. piped in music |
| 8% | e. barrier wall |
| 3% | f. other |

## Attitudinal Survey: Seagrams Plaza

Response

1. How often do you visit the plaza weather permitting?

| | |
|---|---|
| 45% | a. 3-5 times per week |
| 26% | b. 1-2 times per week |
| 7% | c. every other week |
| 8% | d. once a month |
| 14% | e. less than once a month |

2. What time do you usually visit the plaza?

| | |
|---|---|
| 2% | a. morning |
| 2% | b. during work breaks |
| 92% | c. lunch |
| 2% | d. after work |
| 2% | e. evening |

3. What influences what time of day you visit the plaza?

| | |
|---|---|
| 16% | a. crowds at the plaza |
| 49% | b. climate/sunshine |
| 2% | c. special scheduled events |
| 33% | d. other |

4. What do you mainly do when you visit the plaza?

| | |
|---|---|
| 26% | a. eat |
| 27% | b. talk with friends |
| 4% | c. read |
| 26% | d. people watch |
| 17% | e. other |

5. How long do you stay?

| | |
|---|---|
| 7% | a. less than 15 minutes |
| 44% | b. 15-30 minutes |
| 27% | c. 30-45 minutes |
| 18% | d. 45 mins. - 1 hour |
| 4% | e. over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| | |
|---|---|
| 22% | a. more seating |
| 17% | b. shielding from sun, rain, wind |
| 0% | c. better maintenance |
| 28% | d. aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 24% | e. program events |
| 9% | f. other |

| Response | | |
|---|---|---|
| | 7. | Which of the following affect you most when you're in the plaza? |
| 7% | a. | air quality |
| 23% | b. | noise |
| 15% | c. | uncleanliness |
| 16% | d. | crowding |
| 38% | e. | surrounding traffic |
| 1% | f. | other |
| | 8. | Were you aware of noise in this plaza prior to this interview? |
| 61% | a. | yes |
| 39% | b. | no |
| | 8a. | Can you identify the source of this noise? |
| 100% | a. | traffic |
| 0% | b. | construction |
| 0% | c. | aircraft |
| 0% | d. | internal activities |
| 0% | e. | building equipment |
| 0% | f. | other |
| | 9. | Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy. |
| | | not noisy at all |
| 6% | a. | 1 |
| 10% | b. | 2 |
| 51% | c. | 3 |
| 27% | d. | 4 |
| 6% | e. | 5 |
| | | extremely noisy |
| | 9a. | Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered. |
| | | not bothered at all |
| 31% | a. | 1 |
| 26% | b. | 2 |
| 26% | c. | 3 |
| 8% | d. | 4 |
| 9% | e. | 5 |
| | | extremely bothered |
| | 10. | Which of the following do you feel could best alleviate noise annoyance? |
| 29% | a. | trees |
| 6% | b. | plaza furniture |
| 20% | c. | waterfall |
| 21% | d. | piped in music |
| 16% | e. | barrier wall |
| 8% | f. | other |

## Attitudinal Survey: Rockefeller Center (Day)

Response

1. How often do you visit the plaza weather permitting?

| Response | | |
|---|---|---|
| 31% | a. | 3-5 times per week |
| 36% | b. | 1-2 times per week |
| 10% | c. | every other week |
| 6% | d. | once a month |
| 17% | e. | less than once a month |

2. What time do you usually visit the plaza?

| Response | | |
|---|---|---|
| 15% | a. | morning |
| 10% | b. | during work breaks |
| 68% | c. | lunch |
| 4% | d. | after work |
| 1% | e. | evening |
| 2% | f. | other |

3. What influences what time of day you visit the plaza?

| Response | | |
|---|---|---|
| 7% | a. | crowds at the plaza |
| 54% | b. | climate/sunshine |
| 12% | c. | special scheduled events |
| 27% | d. | other |

4. What do you mainly do when you visit the plaza?

| Response | | |
|---|---|---|
| 13% | a. | eat |
| 26% | b. | talk with friends |
| 7% | c. | read |
| 48% | d. | people watch |
| 6% | e. | other |

5. How long do you stay?

| Response | | |
|---|---|---|
| 11% | a. | less than 15 minutes |
| 50% | b. | 15-30 minutes |
| 26% | c. | 30-45 minutes |
| 12% | d. | 45 mins. - 1 hour |
| 1% | e. | over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| Response | | |
|---|---|---|
| 29% | a. | more seating |
| 18% | b. | shielding from sun, rain, wind |
| 4% | c. | better maintenance |
| 28% | d. | aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 19% | e. | program events |
| 2% | f. | other |

Response

7. Which of the following affect you most when you're in the plaza?

13% a. air quality
16% b. noise
19% c. uncleanliness
42% d. crowding
10% e. surrounding traffic

8. Were you aware of noise in this plaza prior to this interview?

55% a. yes
45% b. no

8a. Can you identify the source of this noise?

72% a. traffic
2% b. construction
0% c. aircraft
26% d. internal activities
0% e. building equipment
0% f. other

9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy.

not noisy at all
10 % a. 1
20 % b. 2
50 % c. 3
18 % d. 4
2 % e. 5
extremely noisy

9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered.

not bothered at all
27 % a. 1
37 % b. 2
24 % c. 3
6 % d. 4
6 % e. 5
extremely bothered

10. Which of the following do you feel could best alleviate noise annoyance?

30% a. trees
1% b. plaza furniture
25% c. waterfall
26% d. piped in music
17% e. barrier wall
1% f. other

## Attitudinal Survey: Rockefeller Center - Evening

| Response | | |
|---|---|---|
| | 1. | How often do you visit the plaza weather permitting? |
| 17% | a. | 3-5 times per week |
| 21% | b. | 1-2 times per week |
| 7% | c. | every other week |
| 15% | d. | once a month |
| 40% | e. | less than once a month |
| | 2. | What time do you usually visit the plaza? |
| 9% | a. | morning |
| 9% | b. | during work breaks |
| 17% | c. | lunch |
| 30% | d. | after work |
| 33% | e. | evening |
| 2% | f. | other |
| | 3. | What influences what time of day you visit the plaza? |
| 15% | a. | crowds at the plaza |
| 51% | b. | climate/sunshine |
| 17% | c. | special scheduled events |
| 17% | d. | other |
| | 4. | What do you mainly do when you visit the plaza? |
| 6% | a. | eat |
| 20% | b. | talk with friends |
| 9% | c. | read |
| 46% | d. | people watch |
| 19% | e. | other |
| | 5. | How long do you stay? |
| 12% | a. | less than 15 minutes |
| 48% | b. | 15-30 minutes |
| 15% | c. | 30-45 minutes |
| 10% | d. | 45 mins. - 1 hour |
| 15% | e. | over 1 hour |
| | 6. | What conditions would you like to see changed to make your visits more pleasant? |
| 29% | a. | more seating |
| 22% | b. | shielding from sun, rain, wind |
| 7% | c. | better maintenance |
| 16% | d. | aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 23% | e. | program events |
| 3% | f. | other |

Response

7. Which of the following affect you most when you're in the plaza?

| | |
|---|---|
| 12% | a. air quality |
| 20% | b. noise |
| 24% | c. uncleanliness |
| 32% | d. crowding |
| 12% | e. surrounding traffic |

8. Were you aware of noise in this plaza prior to this interview?

| | |
|---|---|
| 50% | a. yes |
| 50% | b. no |

8a. Can you identify the source of this noise?

| | |
|---|---|
| 78% | a. traffic |
| 2% | b. construction |
| 5% | c. aircraft |
| 8% | d. internal activities |
| 5% | e. building equipment |
| 2% | f. other |

9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy.

| | |
|---|---|
| | not noisy at all |
| 21% | a. 1 |
| 20% | b. 2 |
| 41% | c. 3 |
| 14% | d. 4 |
| 4% | e. 5 |
| | extremely noisy |

9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered.

| | |
|---|---|
| | not bothered at all |
| 42% | a. 1 |
| 20% | b. 2 |
| 22% | c. 3 |
| 8% | d. 4 |
| 8% | e. 5 |
| | extremely bothered |

10. Which of the following do you feel could best alleviate noise annoyance?

| | |
|---|---|
| 40% | a. trees |
| 3% | b. plaza furniture |
| 26% | c. waterfall |
| 19% | d. piped in music |
| 7% | e. barrier wall |
| 5% | f. other |

Attitudinal Survey: Lincoln Center (Day)

Response

1. How often do you visit the plaza weather permitting?

| | | |
|---|---|---|
| 34% | a. | 3-5 times per week |
| 26% | b. | 1-2 times per week |
| 12% | c. | every other week |
| 17% | d. | once a month |
| 11% | e. | less than once a month |

2. What time do you usually visit the plaza?

| | | |
|---|---|---|
| 5% | a. | morning |
| 21% | b. | during work breaks |
| 56% | c. | lunch |
| 1% | d. | after work |
| 10% | e. | evening |
| 6% | f. | other |

3. What influences what time of day you visit the plaza?

| | | |
|---|---|---|
| 2% | a. | crowds at the plaza |
| 70% | b. | climate/sunshine |
| 13% | c. | special scheduled events |
| 13% | d. | other |

4. What do you mainly do when you visit the plaza?

| | | |
|---|---|---|
| 20% | a. | eat |
| 21% | b. | talk with friends |
| 20% | c. | read |
| 22% | d. | people watch |
| 17% | e. | other |

5. How long do you stay?

| | | |
|---|---|---|
| 9% | a. | less than 15 minutes |
| 33% | b. | 15-30 minutes |
| 25% | c. | 30-45 minutes |
| 23% | d. | 45 mins. - 1 hour |
| 10% | e. | over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| | | |
|---|---|---|
| 26% | a. | more seating |
| 20% | b. | shielding from sun, rain, wind |
| 1% | c. | better maintenance |
| 24% | d. | aesthetic improvements, such as trees, waterfalls, plaza furnitur |
| 20% | e. | program events |
| 9% | f. | other |

Response

7. Which of the following affect you most when you're in the plaza?

| | |
|---|---|
| 16% | a. air quality |
| 16% | b. noise |
| 10% | c. uncleanliness |
| 20% | d. crowding |
| 16% | e. surrounding traffic |
| 21% | f. other |

8. Were you aware of noise in this plaza prior to this interview?

| | |
|---|---|
| 35% | a. yes |
| 65% | b. no |

8a. Can you identify the source of this noise?

| | |
|---|---|
| 82% | a. traffic |
| 4% | b. construction |
| 0% | c. aircraft |
| 7% | d. internal activities |
| 7% | e. building equipment |
| 0% | f. other |

9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy.

| | |
|---|---|
| | not noisy at all |
| 24% | a. 1 |
| 38% | b. 2 |
| 34% | c. 3 |
| 4 % | d. 4 |
| 0 % | e. 5 |
| | extremely noisy |

9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered.

| | |
|---|---|
| | not bothered at all |
| 44% | a. 1 |
| 31% | b. 2 |
| 15% | c. 3 |
| 6% | d. 4 |
| 4% | e. 5 |
| | extremely bothered |

10. Which of the following do you feel could best alleviate noise annoyance?

| | |
|---|---|
| 26% | a. trees |
| 4% | b. plaza furniture |
| 35% | c. waterfall |
| 15% | d. piped in music |
| 8% | e. barrier wall |
| 12% | f. other |

## Attitudinal Survey: Lincoln Center - Evening

Response

1. How often do you visit the plaza weather permitting?

| | |
|---|---|
| 8% | a. 3-5 times per week |
| 22% | b. 1-2 times per week |
| 10% | c. every other week |
| 26% | d. once a month |
| 34% | e. less than once a month |

2. What time do you usually visit the plaza?

| | |
|---|---|
| 5% | a. morning |
| 5% | b. during work breaks |
| 11% | c. lunch |
| 33% | d. after work |
| 46% | e. evening |

3. What influences what time of day you visit the plaza?

| | |
|---|---|
| 4% | a. crowds at the plaza |
| 25% | b. climate/sunshine |
| 43% | c. special scheduled events |
| 28% | d. other |

4. What do you mainly do when you visit the plaza?

| | |
|---|---|
| 2% | a. eat |
| 27% | b. talk with friends |
| 6% | c. read |
| 31% | d. people watch |
| 34% | e. other |

5. How long do you stay?

| | |
|---|---|
| 19% | a. less than 15 minutes |
| 49% | b. 15-30 minutes |
| 12% | c. 30-45 minutes |
| 6% | d. 45 mins. - 1 hour |
| 14% | e. over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| | |
|---|---|
| 41% | a. more seating |
| 6% | b. shielding from sun, rain, wind |
| 4% | c. better maintenance |
| 34% | d. aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 15% | e. program events |

Response

| Response | |
|---|---|
| | 7. Which of the following affect you most when you're in the plaza? |
| 12% | a. air quality |
| 21% | b. noise |
| 18% | c. uncleanliness |
| 22% | d. crowding |
| 27% | e. surrounding traffic |
| | 8. Were you aware of noise in this plaza prior to this interview? |
| 40% | a. yes |
| 60% | b. no |
| | 8a. Can you identify the source of this noise? |
| 100% | a. traffic |
| 0% | b. construction |
| 0% | c. aircraft |
| 0% | d. internal activities |
| 0% | e. building equipment |
| 0% | f. other |
| | 9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy. |
| | not noisy at all |
| 19% | a. 1 |
| 24% | b. 2 |
| 41% | c. 3 |
| 12% | d. 4 |
| 4% | e. 5 |
| | extremely noisy |
| | 9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered. |
| | not bothered at all |
| 37% | a. 1 |
| 25% | b. 2 |
| 24% | c. 3 |
| 10% | d. 4 |
| 4% | e. 5 |
| | extremely bothered |
| | 10. Which of the following do you feel could best alleviate noise annoyance? |
| 47% | a. trees |
| 5% | b. plaza furniture |
| 25% | c. waterfall |
| 13% | d. piped in music |
| 9% | e. barrier wall |
| 1% | f. other |

## Attitudinal Survey: General Motors Plaza

Response

1. How often do you visit the plaza weather permitting?

| Response | Answer |
|---|---|
| 34% | a. 3-5 times per week |
| 25% | b. 1-2 times per week |
| 10% | c. every other week |
| 9% | d. once a month |
| 22% | e. less than once a month |

2. What time do you usually visit the plaza?

| Response | Answer |
|---|---|
| 8% | a. morning |
| 10% | b. during work breaks |
| 62% | c. lunch |
| 14% | d. after work |
| 6% | e. evening |

3. What influences what time of day you visit the plaza?

| Response | Answer |
|---|---|
| 17% | a. crowds at the plaza |
| 53% | b. climate/sunshine |
| 9% | c. special scheduled events |
| 21% | d. other |

4. What do you mainly do when you visit the plaza?

| Response | Answer |
|---|---|
| 15% | a. eat |
| 20% | b. talk with friends |
| 8% | c. read |
| 38% | d. people watch |
| 19% | e. other |

5. How long do you stay?

| Response | Answer |
|---|---|
| 19% | a. less than 15 minutes |
| 49% | b. 15-30 minutes |
| 20% | c. 30-45 minutes |
| 8% | d. 45 mins. - 1 hour |
| 4% | e. over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| Response | Answer |
|---|---|
| 29% | a. more seating |
| 20% | b. shielding from sun, rain, wind |
| 3% | c. better maintenance |
| 26% | d. aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 22% | e. program events |

Response

| Response | |
|---|---|
| | 7. Which of the following affect you most when you're in the plaza? |
| 16% | a. air quality |
| 30% | b. noise |
| 18% | c. uncleanliness |
| 15% | d. crowding |
| 21% | e. surrounding traffic |
| | 8. Were you aware of noise in this plaza prior to this interview? |
| 62% | a. yes |
| 38% | b. no |
| | 8a. Can you identify the source of this noise? |
| 96% | a. traffic |
| 2% | b. construction |
| 0% | c. aircraft |
| 0% | d. internal activities |
| 0% | e. building equipment |
| 2% | f. other |
| | 9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy. |
| | not noisy at all |
| 9% | a. 1 |
| 19% | b. 2 |
| 38% | c. 3 |
| 29% | d. 4 |
| 5% | e. 5 |
| | extremely noisy |
| | 9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered. |
| | not bothered at all |
| 36 % | a. 1 |
| 19 % | b. 2 |
| 27 % | c. 3 |
| 15 % | d. 4 |
| 3 % | e. 5 |
| | extremely bothered |
| | 10. Which of the following do you feel could best alleviate noise annoyance? |
| 52% | a. trees |
| 8% | b. plaza furniture |
| 15% | c. waterfall |
| 10% | d. piped in music |
| 15% | e. barrier wall |
| 0% | f. other |

Attitudinal Survey: Grand Army Plaza

Response

1. How often do you visit the plaza weather permitting?

| | |
|---|---|
| 34% | a. 3-5 times per week |
| 36% | b. 1-2 times per week |
| 6% | c. every other week |
| 6% | d. once a month |
| 18% | e. less than once a month |

2. What time do you usually visit the plaza?

| | |
|---|---|
| 11% | a. morning |
| 14% | b. during work breaks |
| 72% | c. lunch |
| 2% | d. after work |
| 1% | e. evening |

3. What influences what time of day you visit the plaza?

| | |
|---|---|
| 4% | a. crowds at the plaza |
| 61% | b. climate/sunshine |
| 4% | c. special scheduled events |
| 31% | d. other |

4. What do you mainly do when you visit the plaza?

| | |
|---|---|
| 29% | a. eat |
| 14% | b. talk with friends |
| 6% | c. read |
| 32% | d. people watch |
| 19% | e. other |

5. How long do you stay?

| | |
|---|---|
| 10% | a. less than 15 minutes |
| 51% | b. 15-30 minutes |
| 18% | c. 30-45 minutes |
| 18% | d. 45 mins. - 1 hour |
| 3% | e. over 1 hour |

6. What conditions would you like to see changed to make your visits more pleasant?

| | |
|---|---|
| 21% | a. more seating |
| 16% | b. shielding from sun, rain, wind |
| 14% | c. better maintenance |
| 31% | d. aesthetic improvements, such as trees, waterfalls, plaza furniture |
| 14% | e. program events |
| 4% | f. other |

Response:

7. Which of the following affect you most when you're in the plaza?

14% a. air quality
13% b. noise
42% c. uncleanliness
11% d. crowding
14% e. surrounding traffic
6% f. other

8. Were you aware of noise in this plaza prior to this interview?

56% a. yes
44% b. no

8a. Can you identify the source of this noise?

95% a. traffic
5% b. construction
0% c. aircraft
0% d. internal activities
0% e. building equipment
0% f. other

9. Please estimate the noise level in the plaza when you generally visit on a scale of one to five, five being extremely noisy.

not noisy at all
3% a. 1
17% b. 2
49% c. 3
25% d. 4
6% e. 5
extremely noisy

9a. Please indicate the extent to which you are bothered by this noise again on a scale of one to five, five being extremely bothered.

not bothered at all
29% a. 1
34% b. 2
23% c. 3
10% d. 4
4% e. 5
14% extremely bothered

10. Which of the following do you feel could best alleviate noise annoyance?

36% a. trees
3% b. plaza furniture
21% c. waterfall
19% d. piped in music
9% e. barrier wall
12% f. other

# APPENDIX B: NOISE NOMENCLATURE

NOISE NOMENCLATURE

The decibel as used herein is defined as:

Sound pressure level in decibels (dB) = $20 \log_{10} \left(\frac{P}{P_0}\right)$ where P is the measured sound pressure and $P_0$ is the reference sound pressure required for a minimum sensation of hearing. This reference sound pressure is 0.002 microbar and is equivalent to zero decibels. Essentially, decibel notation is used because it compresses the very large range of sound pressures that can be detected by humans to a workable range using logarithms.

Since the human ear perceives sounds at different frequencies in different manners, weighting networks are used to simulate the human ear. Sounds of equal intensity at low frequencies are not perceived as loud as those most commonly used in sound analysis to simulate the human ear. A-weighted values are used in Federal, State, and local noise guidelines and ordinances. Sound levels measured in decibels, on the A-weighting network are expressed in dBA.

Statistical analysis is used to describe the time-varying property of sound. Single number descriptors are used to report sound levels. This report contains the statistical A-weighted sound levels:

$L_x$- This is the sound level exceeded X% of the time. For example:

$L_{90}$ is the sound level exceeded 90 percent of the time during the measurement period and is often used to represent the "residual" sound level.

$L_{50}$ is the sound level exceeded 50 percent of the time during the measurement period and is used to represent the "median" sound level.

$L_{10}$ is the sound level exceeded 10 percent of the time during the measurement period and is often used to represent the "intrusive" sound level.

$L_{eq}$- This is the equivalent steady sound level which provides an equal amount of accoustic energy as the time varying sound.

APPENDIX C: NOISE MEASUREMENT DATA

Table C-1

Noise Measurement: Seagrams Plaza

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 71 | 69 | 68 | 68 | 66 | 64 | 68 |
| S1 | 75 | 72 | 69 | 69 | 68 | 67 | 69 |
| M2 | 76 | 71 | 70 | 69 | 68 | 66 | 71 |
| S2 | 77 | 73 | 71 | 70 | 67 | 65 | 70 |
| M3 | 74 | 72 | 70 | 70 | 68 | 67 | 70 |
| S3 | 79 | 73 | 71 | 70 | 68 | 67 | 71 |
| M4 | 74 | 73 | 70 | 66 | 64 | 62 | 69 |
| S4 | 76 | 71 | 69 | 69 | 68 | 67 | 69 |
| M5 | 81 | 72 | 71 | 69 | 68 | 67 | 71 |
| S5 | 79 | 72 | 69 | 68 | 66 | 65 | 69 |
| M6 | 79 | 72 | 71 | 69 | 68 | 67 | 70 |
| S6 | 77 | 70 | 67 | 68 | 66 | 65 | 69 |
| M7 | 73 | 71 | 71 | 69 | 67 | 67 | 69 |
| S7 | 74 | 71 | 69 | 68 | 66 | 65 | 68 |
| M8 | 74 | 72 | 71 | 69 | 68 | 67 | 69 |
| S8 | 79 | 74 | 72 | 71 | 70 | 68 | 72 |

Notes: In all of the following Tables the mobile noise measurement location is designated as M followed by the location number; stationary measurement location is designated as S.

Table C-2

Noise Measurements: Rockefeller Center Daytime

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 82 | 80 | 79 | 79 | 78 | 75 | 79 |
| S1 | 74 | 68 | 65 | 65 | 64 | 63 | 66 |
| M2 | 83 | 80 | 79 | 78 | 73 | 51 | 78 |
| S2 | 78 | 79 | 65 | 65 | 64 | 63 | 68 |
| M3 | 81 | 80 | 79 | 79 | 78 | 75 | 78 |
| S3 | 72 | 67 | 65 | 65 | 64 | 63 | 66 |
| M4 | 74 | 71 | 69 | 68 | 67 | 65 | 69 |
| S4 | 75 | 67 | 65 | 65 | 64 | 62 | 66 |
| M5 | 78 | 73 | 69 | 68 | 67 | 65 | 71 |
| S5 | 72 | 69 | 67 | 67 | 65 | 63 | 67 |
| M6 | 72 | 71 | 69 | 68 | 66 | 55 | 69 |
| S6 | 73 | 69 | 67 | 66 | 64 | 63 | 67 |
| M7 | 73 | 73 | 71 | 72 | 71 | 65 | 71 |
| S7 | 71 | 68 | 67 | 65 | 63 | 62 | 67 |

Table C-3

Noise Measurements: Rockefeller Center Evening

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 79 | 73 | 71 | 71 | 69 | 67 | 71 |
| S2 | 72 | 69 | 69 | 66 | 64 | 64 | 66 |
| M2 | 79 | 76 | 73 | 73 | 71 | 69 | 73 |
| S2 | 70 | 67 | 65 | 65 | 64 | 64 | 65 |
| M3 | 75 | 73 | 71 | 72 | 71 | 69 | 72 |
| S3 | 78 | 69 | 66 | 66 | 64 | 62 | 68 |
| M4 | 76 | 75 | 73 | 73 | 72 | 70 | 73 |
| S4 | 72 | 70 | 67 | 67 | 64 | 61 | 67 |
| M5 | 75 | 72 | 69 | 69 | 67 | 63 | 70 |
| S5 | 72 | 68 | 65 | 64 | 62 | 61 | 66 |
| M6 | 77 | 73 | 71 | 71 | 68 | 64 | 71 |
| S6 | 74 | 67 | 67 | 67 | 61 | 61 | 65 |
| M7 | 77 | 75 | 73 | 72 | 69 | 63 | 72 |
| S7 | 73 | 70 | 65 | 64 | 62 | 60 | 65 |

Table C-4

Noise Measurements: Lincoln Center Day Time

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 75 | 73 | 71 | 71 | 70 | 68 | 71 |
| S1 | 77 | 73 | 69 | 68 | 65 | 62 | 69 |
| M2 | 80 | 75 | 71 | 70 | 66 | 63 | 72 |
| S2 | 76 | 72 | 69 | 68 | 65 | 63 | 69 |
| M3 | 75 | 70 | 67 | 67 | 65 | 64 | 68 |
| S3 | 7 8 | 72 | 69 | 68 | 66 | 64 | 70 |
| M4 | 74 | 71 | 79 | 69 | 67 | 65 | 69 |
| S4 | 77 | 73 | 69 | 69 | 67 | 65 | 70 |
| M5 | 69 | 65 | 61 | 60 | 59 | 57 | 62 |
| S5 | 73 | 72 | 69 | 69 | 67 | 65 | 69 |
| M6 | 70 | 64 | 61 | 60 | 58 | 43 | 61 |
| S6 | 75 | 71 | 69 | 68 | 65 | 63 | 68 |
| M7 | 67 | 65 | 61 | 61 | 58 | 57 | 61 |
| S7 | 77 | 71 | 68 | 68 | 65 | 63 | 69 |
| M8 | 71 | 67 | 63 | 63 | 60 | 57 | 64 |
| S8 | 75 | 70 | 67 | 67 | 64 | 63 | 68 |

Table C-5

Noise Measurements: Lincoln Center Evening

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 79 | 77 | 75 | 75 | 74 | 72 | 75 |
| S1 | 73 | 70 | 68 | 68 | 66 | 65 | 68 |
| M2 | 83 | 79 | 75 | 74 | 70 | 68 | 75 |
| S2 | 75 | 71 | 68 | 68 | 66 | 63 | 69 |
| M3 | 77 | 74 | 73 | 72 | 71 | 70 | 72 |
| S3 | 73 | 71 | 69 | 68 | 67 | 65 | 69 |
| M4 | 80 | 77 | 75 | 76 | 75 | 74 | 76 |
| S4 | 79 | 72 | 69 | 69 | 67 | 65 | 70 |
| M5 | 71 | 65 | 61 | 61 | 59 | 57 | 64 |
| S5 | 78 | 71 | 69 | 68 | 66 | 64 | 70 |
| M6 | 70 | 65 | 62 | 62 | 60 | 59 | 63 |
| S6 | 75 | 71 | 65 | 68 | 66 | 65 | 69 |
| M7 | 68 | 62 | 60 | 59 | 58 | 57 | 60 |
| S7 | 73 | 70 | 67 | 68 | 66 | 65 | 68 |
| M8 | 66 | 63 | 61 | 60 | 58 | 56 | 62 |
| S8 | 71 | 69 | 67 | 66 | 64 | 63 | 66 |

Table C-6

Noise Measurements: GM Plaza

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 75 | 70 | 67 | 66 | 65 | 63 | 67 |
| S1 | 78 | 72 | 67 | 67 | 65 | 63 | 69 |
| M2 | 75 | 69 | 66 | 66 | 64 | 63 | 67 |
| S2 | 82 | 72 | 68 | 67 | 65 | 63 | 71 |
| M3 | 70 | 67 | 65 | 65 | 63 | 61 | 65 |
| S3 | 78 | 73 | 69 | 68 | 66 | 63 | 70 |
| M4 | 71 | 67 | 65 | 64 | 63 | 61 | 65 |
| S4 | 79 | 73 | 69 | 68 | 65 | 41 | 70 |
| M5 | 81 | 73 | 69 | 68 | 66 | 65 | 70 |
| S5 | 77 | 73 | 68 | 67 | 65 | 63 | 69 |

Table C-7

Noise Measurements: Grand Army Plaza

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 76 | 71 | 69 | 68 | 66 | 64 | 69 |
| S1 | 77 | 69 | 68 | 63 | 61 | 61 | 71 |
| M2 | 78 | 75 | 73 | 72 | 71 | 68 | 72 |
| S2 | 84 | 72 | 68 | 67 | 62 | 60 | 73 |
| M3 | 79 | 75 | 72 | 72 | 70 | 67 | 72 |
| S3 | 77 | 70 | 67 | 67 | 65 | 63 | 68 |
| M4 | 75 | 71 | 69 | 69 | 67 | 65 | 69 |
| S4 | 76 | 71 | 67 | 67 | 65 | 63 | 68 |

Table C-8

Noise Measurment Location: Plaza 400

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 83 | 77 | 73 | 71 | 66 | 62 | 74 |
| S1 | 80 | 75 | 70 | 69 | 65 | 63 | 71 |
| M2 | 76 | 72 | 68 | 67 | 63 | 60 | 70 |
| S2 | 79 | 74 | 70 | 69 | 66 | 65 | 71 |
| M3 | 82 | 78 | 74 | 72 | 67 | 63 | 74 |
| S3 | 81 | 76 | 71 | 70 | 65 | 63 | 72 |
| M4 | 81 | 78 | 75 | 74 | 71 | 68 | 75 |
| S4 | 81 | 76 | 71 | 70 | 67 | 65 | 72 |
| M5 | 80 | 76 | 75 | 74 | 73 | 72 | 75 |
| S5 | 83 | 76 | 71 | 69 | 66 | 65 | 72 |

Table C-9

Noise Measurement: KLM Plaza

A Weighted Sound Level - Decibels

| Measurement Location | $L_1$ | $L_{10}$ | $L_{33}$ | $L_{50}$ | $L_{90}$ | $L_{99}$ | $L_{eq}$ |
|---|---|---|---|---|---|---|---|
| M1 | 81 | 78 | 77 | 77 | 76 | 73 | 77 |
| S1 | 83 | 78 | 75 | 74 | 72 | 69 | 75 |
| M2 | 84 | 81 | 77 | 76 | 73 | 69 | 77 |
| S2 | 82 | 78 | 75 | 74 | 72 | 69 | 75 |
| M3 | 81 | 78 | 75 | 74 | 71 | 68 | 75 |
| S3 | 83 | 77 | 73 | 72 | 70 | 67 | 74 |
| M4 | 80 | 75 | 72 | 72 | 69 | 67 | 73 |
| S4 | 81 | 77 | 73 | 73 | 68 | 65 | 74 |



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16. ABSTRACT

This study consists of three reports which treat the subject of noise within the context of urban pedestrian areas. The main concern of the study is noise mitigation, although its contents cover a wide range of topics related to noise in the urban environment. The first report provides a description of existing noise mitigation techniques which have application to pedestrian improvement areas. The second report summarizes the actual application of noise mitigation techniques to pedestrian areas based on the results of a questionnaire sent to pedestrian projects throughout the country. The second report also includes the formulation of noise abatement criteria for the design of Broadway Plaza, a proposed pedestrian project in New York City. The third report analyzes actual noise levels and attitudes by pedestrians toward noise in several public plazas in New York City based on actual noise monitoring and attitudinal surveys in the plazas.

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