HIGHWAY NOISE

A REPRINT OF

THE AUDIBLE LANDSCAPE: A MANUAL FOR HIGHWAY NOISE AND LAND USE

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
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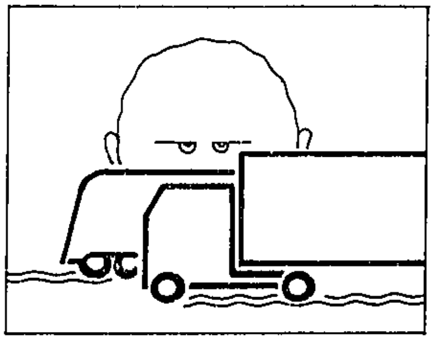

Effective control of the undesirable effects of highway generated noise requires a three-part approach:

1) Source emission reduction
2) Improved highway design, and
3) Land use control

The first two components are currently being addressed by private industry and by Federal and state agencies. The third area is traditionally an area of local governmental responsibility.

Cooperation among all levels of government, industry and the public in implementing the three part approach is essential to achieving noise reduction, because of the limitations of each noise control approach when applied separately.

Source emission reduction requires the development of quieter cars and trucks. Significant progress is being made in research to reduce vehicle engine and exhaust noise, but tire design, the major source of high speed traffic noise, may place limits on further improvements.

Improved highway design involves greater attention to noise impacts in choosing the route and layout of new highways. In April 1972, the Federal Highway Administration issued standards for highway noise levels in its Policy and Procedure Memorandum PPM 90-2, "Noise Standards and Procedures." These standards are not a complete solution to highway noise, but "represent a balancing of that which may be desirable and that which may be achieved." PPM 90-2 urges highway agencies to strive for even lower noise levels where they can "be achieved at reasonable cost, without undue difficulty, and where the benefits appear to clearly outweigh the costs and effort required." PPM 90-2 requires consideration of noise abatement measures for developed areas near new highways, but does not regulate noise in undeveloped areas, or along existing roads. Rather, it recognizes a dual responsibility where

"Highway agencies have the responsibility for taking measures that are prudent and feasible to assure that the location and design of highways are compatible with existing land use. Local governments, on the other hand, have responsibility for land development control and zoning."

Thus, land use control will continue to be a crucial component of the three-part approach to noise control. Local governments will continue to have the responsibility for discouraging the development of noise sensitive land uses (such as homes and schools) in highway noise impacted areas or for ensuring that any such development that does occur is planned to minimize the adverse effects of noise.

Introduction: The Federal Highway Administration commissioned the development of this manual to assist local government officials in dealing with the problems of noise-sensitive land uses. Its purpose is three-fold:

1) To indicate ways in which local governments can guide the development of undeveloped land in the vicinity of existing highways.
2) To indicate ways in which local governments can reduce the impact of highway-generated noise upon existing developed activities.
3) To recommend additional sources of information on these issues.

The manual does not attempt to present a single strategy for achieving noise compatibility, but recognizes that solutions to noise problems will depend on local conditions and community preferences. Therefore, a wide variety of potential techniques are presented and their applicability to differing local conditions evaluated. A summary of these solutions is presented in Section 2. Detailed descriptions of techniques available to local government officials to encourage noise compatible development are presented in Section 3. Section 4 describes methods which can be used by architects, developers and builders to achieve noise impact reductions. Section 5 outlines possible strategies for local governments to implement a noise compatible land use program, and describes some of the potential obstacles and further sources of information.

An Appendix describes three case studies of the applicability of the approach of this manual to the highway noise problems of local communities. A second Appendix reviews the noise measures and noise standards referred to in the manual.

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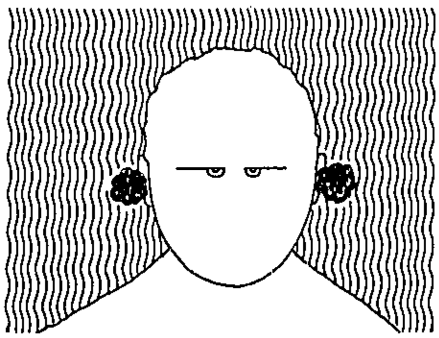


This manual describes a variety of techniques for achieving noise-compatible land uses near highways. The techniques are of two types: administrative techniques which can be used by local government officials to require or encourage improved noise compatibility, and the physical methods available to architects, developers and builders for achieving the desired noise impact reduction. This section provides a very brief summary of the administrative techniques and physical methods which are described in detail in sections 3 and 4, respectively.

2.1 Administrative Techniques

The administrative techniques available to local governments to encourage noise-compatible land use control near highways fall into five categories:

- .zoning
- other legal restrictions, such as subdivision laws, building and health codes
- municipal ownership or control of the land
- financial incentives for compatible use
- educational and advisory municipal services

Zoning

Zoning can be a strong local control on the type of new development, but has little control over existing land uses. The principal uses of zoning as a noise compatibility control are:

1) Exclusion of typically incompatible uses, such as residences, from a noise-impacted area by allowing only industrial or agricultural uses. This is a simple and effective technique. However, such zoning may conflict with other plans for community growth, and it may render the land worthless if no demand exists for industrial or agricultural land.
2) Regulation of specific details of development design or construction, such as limits on building height or requirements for buffer strips, noise barriers, and sound insulating construction. This is usually effective, but often the applicability of the requirements extends to buildings that do not need the special construction techniques to be noise compatible.
3) Zoning can permit special development concepts such as cluster and planned unit development. These forms of incentive zoning make possible developments with significant advantages over the conventional subdivision.

Other Legal Restrictions

Municipal ordinances other than zoning can act as noise compatible land use controls:

1) Subdivision or development standards can regulate details of larger develop-

Summary: ments to require acoustical site planning of the development or to require berms and barriers. These standards often do not apply to new construction on individual lots in a previously developed area.

2) Building codes can specify construction details such as acoustic insulation and sealed windows, or, they can require that certain noise levels not be exceeded within a building. However, they cannot specify such things as acoustical site planning, which may in many instances be a more desirable alternative than insulation and sealed windows.
3) Health codes can specify noise levels which are not to be exceeded if a building is to be habitable. Health codes have the potential of being one of the most consistently effective noise compatibility controls.
4) Local laws can require that an occupancy permit be received before a building can be used. Issuance of the permit can be withheld unless all provisions of zoning, subdivision, building, and health codes have been met. This can be an exceptionally effective enforcement mechanism.
5) A special permit procedure requiring individual review of each building application can exist either as part of a zoning ordinance or as a general municipal ordinance. Thus an administrative body in the municipal government can grant or deny the permit based on a judgement of the merits of each specific case. This has the advantage of individual case-specific judgement and the possible disadvantage of being subject to arbitrary decisions of a poorly staffed permit review board.
6) Environmental impact statements can be required in some states for new development projects. These can contain a noise impact section which would require site-specific acoustical analysis. This information can act as a valuable aid for municipal officials who must make decisions on the appropriateness of any permit applications.

Municipal Ownership or Other Control of the Land

If the municipality owns the noise-impacted land, it can keep the land vacant or see that it is developed only with noise compatible uses. Acquisition can be accomplished by several techniques:

1) The land can be purchased, but often at significant cost.
2) The land can be taken by eminent domain under certain situations, but this can be extremely costly and locally unpopular.
3) Land can be received as a gift, as a condition of subdivision approval, as a transfer from other government agencies, or in trade for other municipally owned land.
4) The municipality can obtain, through purchase or otherwise, an easement which restricts the land without an actual transfer of ownership. This may often represent a low cost way to obtain strict land use control.

Financial Incentives

While a financial incentive may not have the absolute strength of enforcement that municipal ownership and legal regulations have, it can be effective. Financial incentive can take two forms:

1) Undeveloped and underdeveloped land can be assessed at a low rate. This will reduce pressure on landowners to sell or develop land which they can no longer afford to keep because of high property taxes. Although this reduces the tax base, it also saves the significant costs of new municipal services which would be required if the land were developed.
2) Relaxation of enforcement of provisions of municipal regulations can, where legal, be used as an incentive to obtain voluntary acoustical site design and construction measures from developers and builders.

Educational and Advisory Municipal Services

Often, builders and developers are unaware of noise compatibility measures which can be incorporated into a development at little cost. The municipal government can, at very low cost, provide information to the builders, developers, architectural firms, and the public in general, to generate the necessary awareness. These municipal information services can take four forms:

1) An architectural review board can be created, consisting of part-time citizen volunteers who are skilled in architecture, acoustics, and related fields. This board can evaluate all new development plans. Its effectiveness is a function of the support given it by other municipal officials.
2) A municipal design service can exist either formally or informally as part of the various permit application review procedures.
3) An acoustical information library can be maintained by the municipality as a reference source for local builders and developers.
4) A public information effort can result in a public awareness of noise incompatibilities and their prevention. This, in turn,

could affect the marketability of incompatible homes and other development, placing financial pressure on builders and developers to achieve noise compatibility.

2.2 Physical Methods to Reduce Noise Impact

Physical noise reduction techniques can be grouped into four major categories:

- acoustical site planning
- acoustical architectural design
- acoustical construction
- noise barriers

These physical techniques vary widely in their noise reduction characteristics, their costs, and especially, in their applicability to specific locations and conditions.

Acoustical Site Planning Acoustical site planning uses the arrangement of buildings on a tract of land to minimize noise impacts by capitalizing on the site's natural shape and contours. Opportunities for successful acoustical site planning are determined by the size of the lot, the terrain, and the zoning. In general, conventional zoning patterns lack the flexibility necessary to permit innovative site planning techniques. A posssible way to achieve the needed flexibility is through the use of cluster and planned unit development techniques. Acoustical site planning techniques include:

1) Placing as much distance as possible between the noise source and the noise sensitive activity;
2) Placing noise-compatible activities such as parking lots, open space, and commercial facilities, between the noise source and the sensitive activity;
3) Using buildings as barriers;
4) Orienting noise-sensitive buildings to face away from the noise source.

Acoustical Architectural Design Acoustical architectural design incorporates noise-reducing concepts in the details of individual buildings. The areas of architectural concern include building height, room arrangement, window placement, and balcony and courtyard design. For example, in some cases, noise impacts can be reduced if the building is limited to one story; and if bedrooms and livingrooms are placed in the part of the building which is farthest from the noise source while kitchens and bathrooms are placed closer to the noise source.

Acoustical Construction Acoustical building construction is the treatment of the various parts of a building to reduce interior noise impacts. It includes the use of walls, windows, doors, ceilings and floors that have been treated to reduce sound transmission into a building. The use of dense materials and the use of airspaces within materials are the principle noise reduction techniques behind acoustical construction. Acoustical construction can be an expensive technique, especially when added to an existing building; however, it need not be prohibitively expensive in new construction. It is one of the most effective ways of reducing interior noise.

Noise Barriers Noise barriers can be erected between noise sources and noise-sensitive areas. Barrier types include berms made of sloping mounds of earth, walls and fences constructed of a variety of materials, thick plantings of trees and shrubs, and combinations of these materials. The choice between these depends on a variety of factors, including the desired level of sound reduction, space, cost, safety and aesthetics.

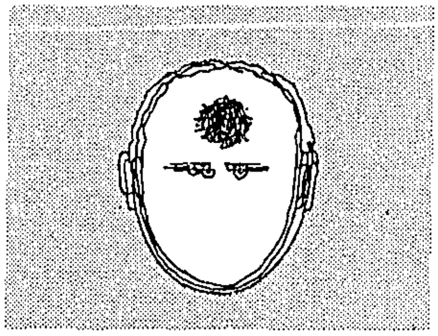
2.3 Implementation Strategies

An implementation strategy, using normal administrative structure, is presented for a noise compatibility land use control program. The strategy is divided into five major phases: 1) problem identification, 2) examination and selection of administrative techniques suited to the locality, 3) study of legal status, 4) study of State legislative changes, and 5) implementation. Since considerable time might be required to implement this strategy, a stopgap procedure is also presented.

The problems posed by the implementation of this manual are enumerated These problems include: 1) public apathy, 2) limitations under State laws, 3) financial cost to the municipal government, 4) negative physical and aesthetic side effects, 5) opposition with private interests, and 6) conflicts with local tradition.

Other sources of information regarding issues on highway noise control are listed. These sources provide comprehensive information in the area of acoustics, the effects of noise, noise standards, prediction techniques, impact reduction techniques, and noise control legislation.

3 Administrative Techniques



There are two basic types of tools available for the prevention of noise incompatible land use: the physical techniques which reduce noise impacts and the administrative methods available to local governments to encourage their use. Section 4 of the manual describes the range of design and construction techniques available. This section analyzes alternative administrative actions to ensure their adoption.

The available administrative techniques are categorized in this manual in five general groups:

1) Zoning
2) Other legal restrictions (subdivision control, building codes, health codes),
3) Municipal ownership or control of the land,
4) Financial incentives for compatible development, and
5) Educational and advisory services.

Usually, the best solution for the municipality will be a combination of several techniques chosen to cover the widest possible range of noise incompatibility situations.

In evaluating alternative administrative techniques, these factors must be kept in mind—

1) The authority for creation and enforcement of local laws and regulations of this manual usually comes from the "police powers" which are delegated to the local governments by the state. The enabling acts through which the various states delegate the police powers differ from state to state, and the ability of the local government to enact laws is limited to items specifically contained in the appropriate enabling act. Accordingly, techniques available to communities in one state may not be legal in other states. The legality under individual state enabling acts must be determined and resolved before any administrative technique is seriously considered.
2) Administrative costs associated with the use of each technique also vary across local governments. In general, it is most efficient to choose a strategy that is consistent with the already existing governmental structure for a particular situation, such as using existing officials to oversee the program rather than creating new positions.
3) Variations in terrain, traffic, population density and noise sensitivity occur within as well as between municipalities. Regulations must be flexible enough to allow the exercise of sound administrative judgment to treat each situation individually.

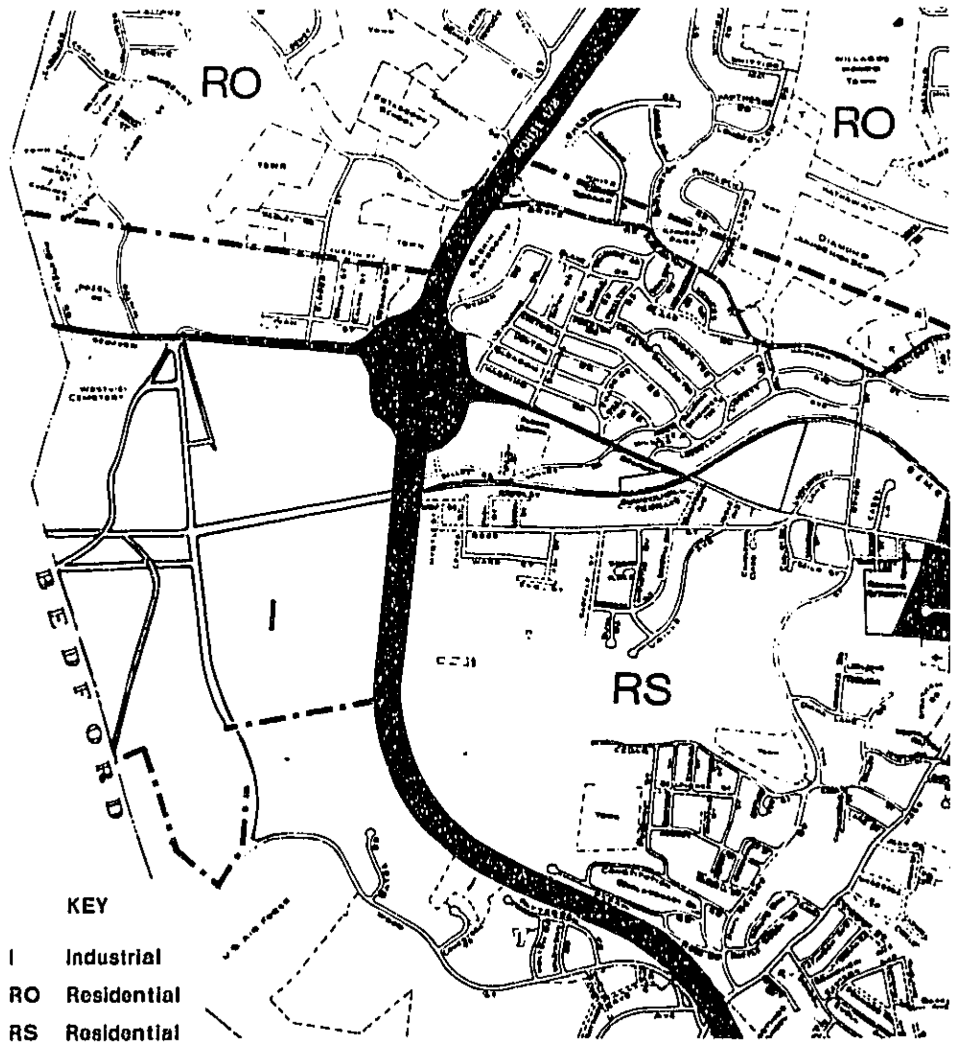
Despite the above limitations, the variety of available techniques is great enough to ensure that most communities will be able to find a combination of techniques appropriate to control local problems while remaining consistent with both state law and the administrative structure of the municipality.

One administrative technique not discussed in detail in this manual is the municipal noise ordinance. While a well written and properly enforced noise ordinance can be a major factor in the reduction of noise at its source, it can have little or no effect on controlling the compatibility of land uses constructed in areas where noise exists. Despite this limitation, a noise ordinance should be considered as an important component of a municipality's legal and administrative structure.

3.1 Zoning

Zoning is a commonly used local administrative technique to direct land use in accordance with a plan for orderly community growth. The zoning ordinance, or bylaw, specifies what type of land use is permitted in each zoning district. Zoning specifications have been used to control environmental emission, signs, off-street parking facilities, lot size, frontage, maximum building height, and ratio of open space to developed land. These precedents make zoning a useful tool for noise control in most localities.

Since the areas within a community which are impacted by excessive noise probably do not coincide with the traditional zoning districts, a method must be developed to define the areas where any acoustical regulations apply. One method would be the creation of a series of new noise impacted zones on the existing zoning map. For example, each residential zone could be split into two zones



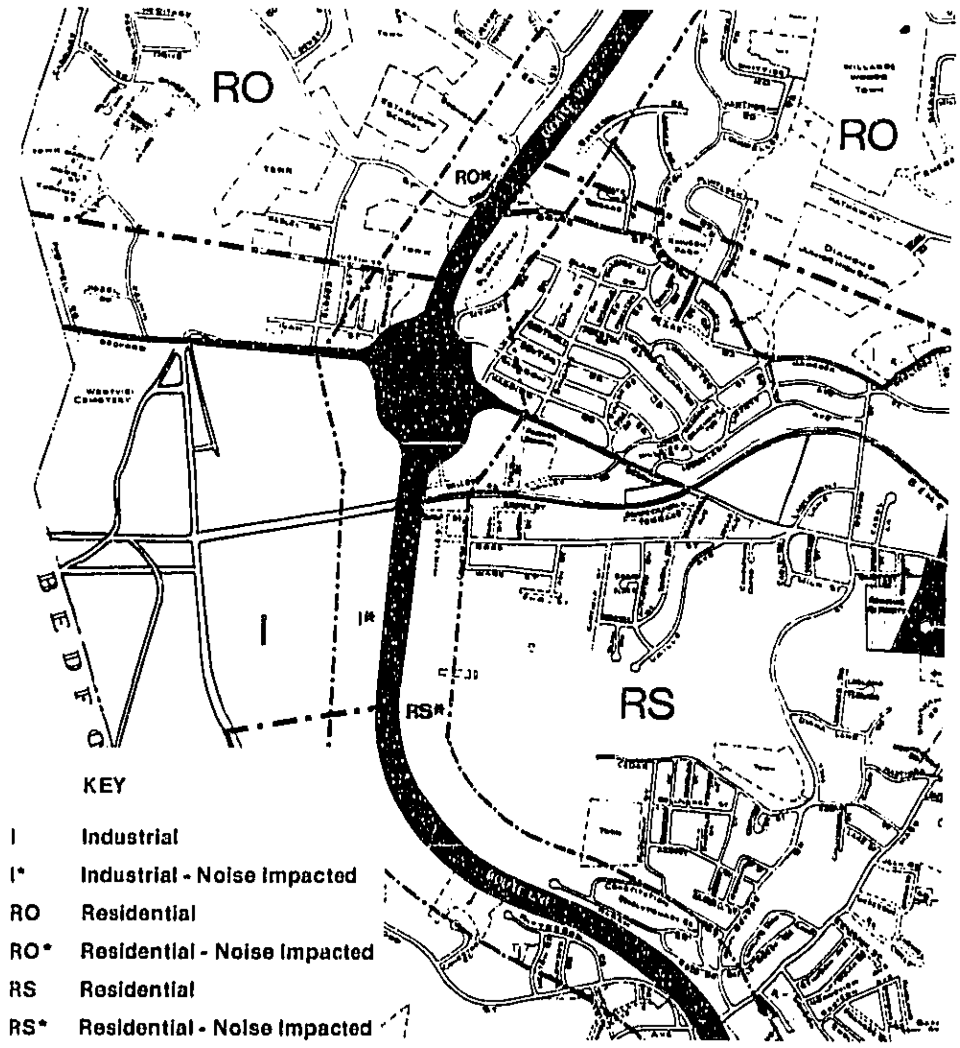
3.1 A portion of a zoning map without identification of noise-impacted areas.

identically controlled except for noise regulations. The same would hold true for each commercial, business or industrial zone (See Figs. 3.1 and 3.2).

A simpler alternative to the creation of an entire series of new zones is the creation of a single "overlay zone." An overlay zone is a special purpose zone which is superimposed over the regular zoning map (See Fig. 3.3). Often such zones are called "superimposed districts," and they are used for a variety of reasons including wetlands protection and airport compatibility.

In this case, the overlay zone could be all land which is exposed to noise over a certain level such as 65 dBA. Or it could be defined, more easily but less appropriately, as all land within a certain distance from the highway, such as 500 feet. Land which falls in such a zone would be subject not only to the regulations pertaining to the regular zone in which it lies, but also to the additional regulations pertaining to the overlay zone. Such a technique is much less cumbersome legally and administratively than the creation of an entire series of special zones (single family residential, multi-family residential, commercial, etc.) in the noise impacted portion of the community.

Enforcement of the provisions of a zoning law has traditionally been accomplished prior to development and construction through the approval of plans and permits. While this before-the-fact enforcement process has several obvious advantages, it does not always provide complete protection against conditions which only become apparent after con-



3.2 Identification of noise impacted areas by creation of a series of new zones struction is well underway. This is especially true for items such as noise levels and noise attenuation measures which can only be accurately measured after the construction is complete.

In recent years, an increasing number of municipalities have instituted an additional enforcement measure—the occupancy permit—which provides effective after-the-fact enforcement.

Zoning can be used in four ways to insure that future development will be compatible with nearby noise sources:

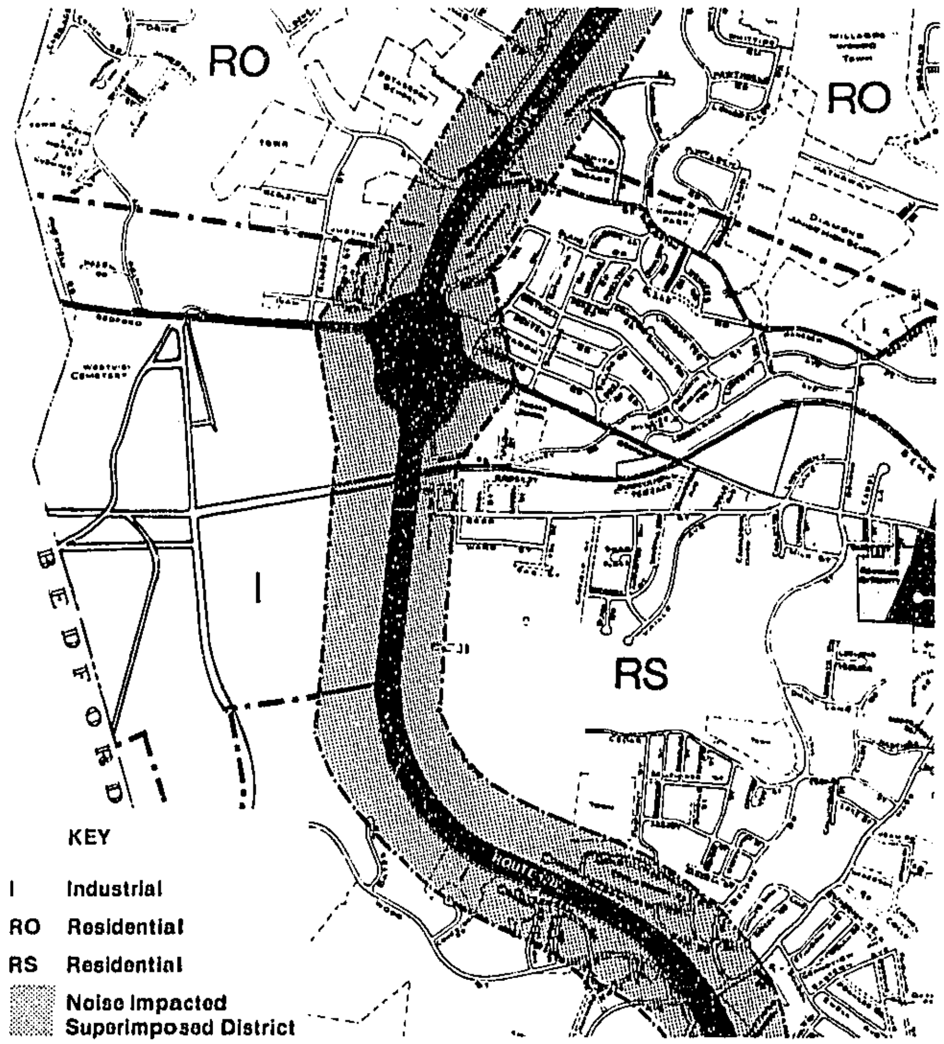
1) by exclusion of typically incompatible uses from noise impacted areas,
2) by regulating specific details of development design or construction,
3) by permitting special development techniques such as cluster and planned unit development which enable noise compatible site design, and
4) by defining the areas of applicability of other local regulations.

These four roles of zoning are discussed in the pages which follow.

3.1.1 Excluding Incompatible Land Uses

The land in a noise impacted area can be zoned for noise compatible uses, such as commercial, agricultural or industrial. It is a simple and direct technique which will work if the community has a non-cumulative[1] type of zoning law which prohibits, for example, residences or other sensitive uses in the industrial zone.

Unfortunately, there is usually not enough demand for such noise compatible land uses to afford every community



3.3 Identification of noise impacted area by overlay zone

[1]Under cumulative zoning, zones are ranked in some (high to low use) sequence such as heavy industrial, light industrial commercial, multi-family residential, single family residential. Any use permitted in a low use zone, such as a single family residential, is automatically permitted in higher use zones, such as heavy industrial, but the reverse is not true. Non-cumulative zoning does not automatically permit uses other than those specifically allowed in a given zone.

the luxury of lining both sides of all highways with them. If all the communities within a region were to adopt this technique, they would make the land involved useless. Thus there could be legal action against the community to recover damages for what could be considered a "taking without compensation."

Furthermore, this type of strip zoning may not be compatible with other plans for the orderly growth and development of the community, or it could be in direct conflict with the development patterns of adjacent communities.

The technique of zoning noise impacted areas for compatible land uses should only be considered if:

1) Non-cumulative zoning is legal under state law.
2) The locality has determined that (after thorough study) such a land use pattern is compatible with the growth plans, safety, and quality of life of the community and the region, as well as with the already existing land uses in the area.
3) A local noise control ordinance or a similar ordinance within the zoning bylaw will prevent the uses in the zone near the highway from in turn becoming noise sources objectionable to uses in adjacent zones.

3.1.2 Design and Construction Requirements

Zoning can require specific construction practices or site design details which tend to ameliorate potential noise incompatibilities. These include:

1) Buffer strips,
2) Noise barriers,
3) Height restrictions, and
4) Construction techniques.

There is a need for caution in the application of any of these requirements. While each of the techniques will usually reduce the effects of noise, there are peculiar factors about many sites which may render a given technique completely ineffective. It is also possible that other site-specific conditions have already reduced the noise impact thereby making the required techniques redundant. Either way, any extra money spent to satisfy the zoning requirement would not produce the desired beneficial effects. Thus, each requirement in a zoning ordinance for acoustical construction or site design practices should have a provision for exception if site-specific conditions so dictate. Local municipal structure will determine the exact form that the exception mechanism should take.

Buffer Strips An overlay zone incorporated into the zoning bylaws could require a buffer strip between all residential construction in that zone and the highway. This requirement can be directly stated in the zoning bylaw, or it can be included in local development standards or subdivision rules and regulations as being applicable in the overlay zone. Some provision for plantings or ground cover within the buffer can be incorporated.

This technique will be most practical in areas where required lot size is relatively large so that the incorporation of the buffer strip as part of one's backyard poses no unusual hardship. For example, in residential areas where minimum lot size is one acre (43,560 sq. ft.) and minimum lot width (frontage) is 125 feet, lots laid out with minimum frontage will be over 340 feet deep and could easily incorporate a buffer of 200 feet or more between the rear of the house and the rear lot line. (See Fig. 3.4) Lots of minimum frontage with house relatively close to the residential street are usually the most economical to create in a subdivision because of the high costs associated with street construction, driveways, and utilities. (See Fig. 3.5). Thus, no particular hardship is imposed on the developer. Conversely, areas zoned for 10,000 square-foot lots could not incorporate buffer strips of any significant width without, in effect, decreasing the total number of buildable lots that could be created out of a subdivision tract. Whether the economic hardship thus created is justified must be determined on a local basis.

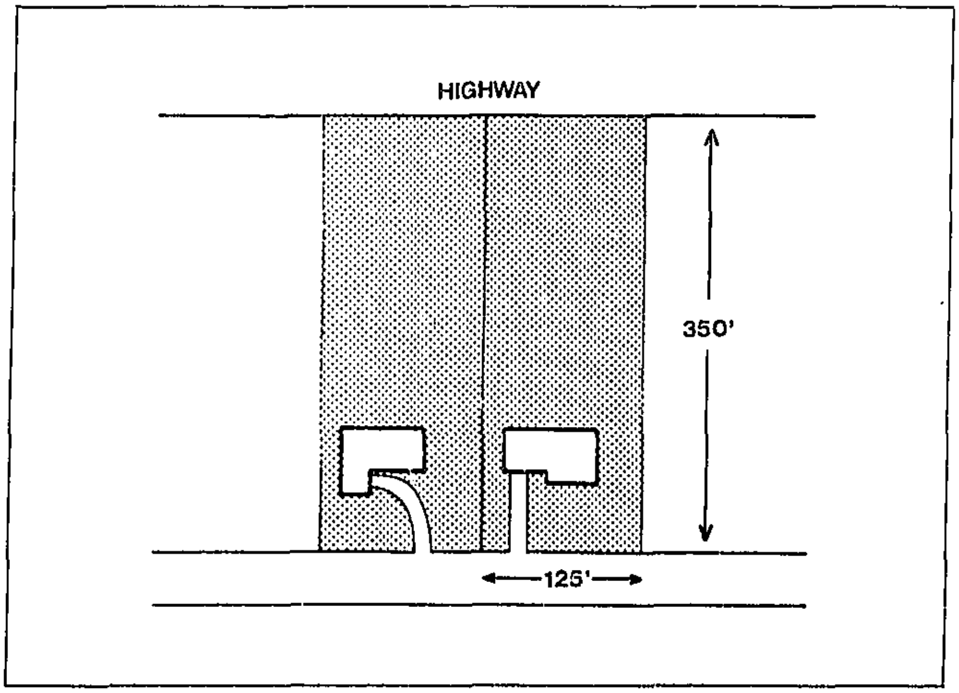
The following example of a model article incorporates the buffer requirement directly into the zoning bylaw.[1]

[1] The provisions for plantings in this model ordinance are primarily intended to insure that the buffer is aesthetically acceptable in addition to providing the desired distance between the noise source and the land uses.

Section_____. Screening and Buffers - Noise Impact Superimposed Districts

Screening and buffers shall be required in Noise Impact Superimposed Districts between permitted structures and the highway as follows: this strip shall be at least 100 feet in width; it shall contain a screen of plantings in the center of the strip. The screen shall be not less than 5 feet in width and 6 feet in height at the time of occupancy of such lot. Individual shrubs or trees shall be planted not more than three feet on center, and shall thereafter be maintained by the owner or occupants so as to maintain a dense screen year-round. At least 50 percent of the plantings shall consist of evergreens. A solid wall or fence, not to exceed 6 feet in height, complemented by suitable plantings, may be substituted for such landscape buffer strip by special permit. The strip may be part of the yard area.

No residential use, hospital, nursing home, church, school or daycare center shall be constructed within the buffer strip. No such use, previously existing at the time of enactment of this section shall be extended into or within the buffer strip. No structure within the buffer strip shall be converted to any such use.■



3.4 Houses placed near the front of long narrow lots have deep rear yards available to act as noise buffers.

Construction of Noise Barriers Construction of an earth berm or wall during development of a subdivision can be incorporated into the community's zoning bylaw or into the development standards or the subdivision rules and regulations. Large individual non-residential uses such as an office park can be protected from noise by berms or barriers if the proper stipulations are incorporated into the requirements for the appropriate development or building permits.

Barriers are not the ideal noise compatibility control in many geographical locations. There may be disadvantages of aesthetics, quality of life, and safety inherent in any barrier project which must be individually evaluated. Required construction of barriers can be limited to situations where other alternatives do not exist.

The following provisions, taken from the Development Standards of the City of Cerritos, California, could be adapted to local conditions elsewhere as permitted under state enabling legislation.

General Provisions

All proposed fencing, other than the fencing of an individual residential lot from another residential lot, shall be subject to review and approval of location, height, materials and color as follows—

1) Materials—
   All peripheral fencing shall be predominantly of slumpstone or masonry block construction or other material as approved by the Director of Environmental Affairs.

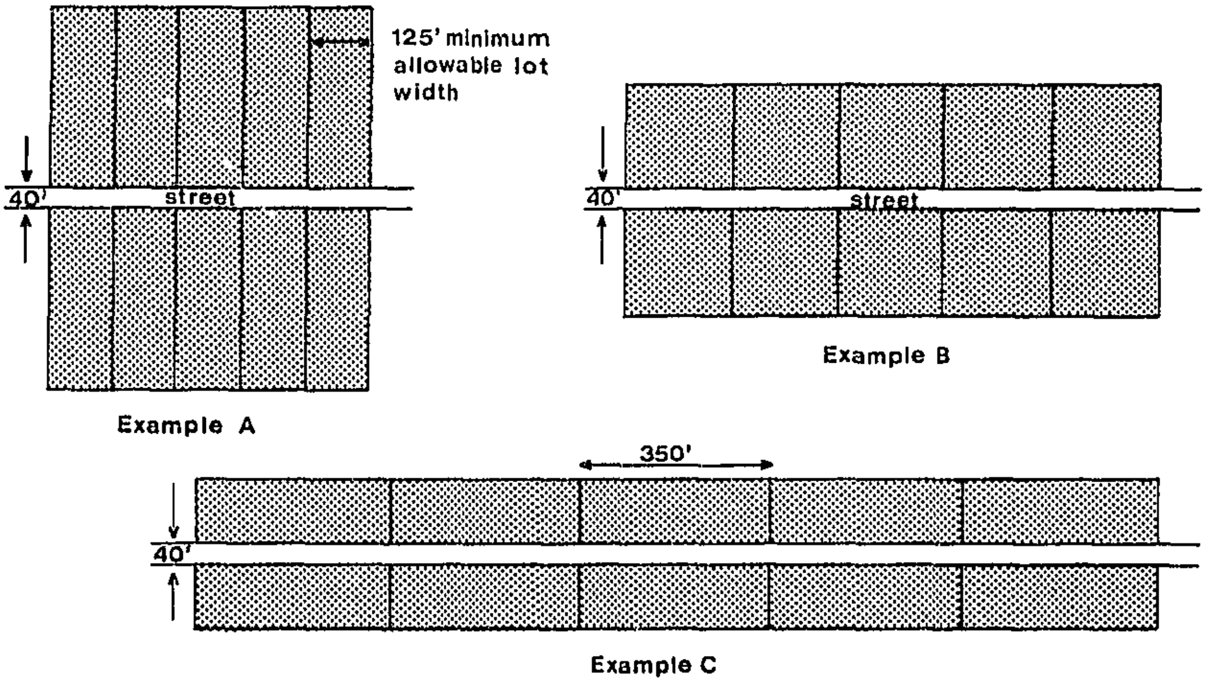
2) Color:
   The color of any proposed wall must be in harmony with nearby fencing. Any proposed continuation of an existing wall along an arterial street must provide for an identical match of color and materials.

3) Height:
   The minimum and maximum height of a proposed wall shall be subject to the approval of the Director of Environmental Affairs based upon the height of other walls nearby, the need for traffic sight distance, the desirability of preserving a sense of open space, and the need for privacy.

4) Walls shall be required for screening of storage areas, loading areas, parking areas, and other areas as designated in the Municipal Code and other provisions of these Development Standards. In addition, walls shall be required to separate major categories of land use as follows—

   a) Residential Subdivision Adjacent to an Arterial Street: Residential subdivisions may be buffered from arterial streets with a combination of fencing and landscaping, alternating frontage road buffer strips with solid decorative block walls and occasional wall breaks for wrought iron fencing, pedestrian access, and inset planters.

   b) Residential Subdivision Adjacent to a Freeway: Residential subdivisions shall be buffered from freeways and freeway on-and off-ramps with a combination of fencing and landscaped berms.■



Example	Lot size			Street size	
	width (Ft.)	depth (Ft.)	area (Ft.)	length (Ft.; 10 lots)	area (Ft.; 10 lots)
A	125	350	43750	625	5000
B	210	210	44100	1050	8400
C	350	125	43750	1750	14000

3.5 Three possible configurations for 1 acre minimum lots with 125 foot minimum frontage showing savings in street construction for minimum frontage lots. Note that example A, which utilizes minimum frontage, requires the shortest street length per lot; and the smallest total street area.

Height Restrictions Height restrictions to limit residential buildings to a single story or to a maximum height can be directly incorporated into the zoning regulations which apply to a noise impacted area. Height restrictions, when used in conjunction with natural or man-made barriers, can prevent some of the most severe highway noise directly hitting bedroom windows without banning all residential uses. Although very simple, this solution has some drawbacks:

A) It will only be effective if the terrain is such that single story buildings are effectively out of the line of sight of the noise source.
B) It may be more expensive for the builder than other techniques such as acoustical construction in places where land values are high.
C) It may not be necessary in the entire noise impacted zone, but only for the row of houses nearest the highway.
D) It may have negative effects of enforcing architectural uniformity and restricting the flexibility needed to make best use of the site.

One approach to height restrictions which overcomes some of the above drawbacks is to allow exception to the restriction if satisfactory evidence of alternative noise compatibility measures is presented.

Specific Construction Restrictions Specific requirements for acoustical construction methods in the Noise Impacted Zone can be delineated directly in the zoning bylaws in most states. An alternative, which may fit more appropriately into the administrative structure of many communities is to put the requirements into the Building Code and to use the Zoning Bylaw merely to define the geographical area where the requirements are applicable.

3.1.3 Special Development Concepts Certain noise amelioration measures on large scale developments are dependent on the amount of flexibility that the developer has. Cluster development and planned unit development (PUD offer a developer incentives to set aside major portions of a tract for buffer strips and to locate buildings in natural low-noise pockets on the tract. A well written and properly administered cluster or PUD provision in a zoning ordinance can grant this flexibility and still protect against unwanted advantage being taken of the cluster/PUD concept.

Cluster residential development is a zoning technique under which the residences on a large development tract are placed in small groups, or "clusters", while a major portion of the tract remains as open space. Usually this is accomplished by allowing a smaller individual lot size than zoning normally allows, but with a provision that the total number of units constructed will not be increased.

Planned Unit Development is similar to cluster development, except that the development is not completely restricted to residential uses. Under this technique, a large tract is developed as a somewhat self contained community with residential uses plus some shops or other commercial uses primarily intended for use by the residents of the tract. Often, some community facilities are also included in the PUD. PUD zoning contains provisions for reduction of lot size and creation of open space similar to those found in cluster zoning.

PUD and cluster are forms of "incentive zoning" in which the developer is given some special incentive in return for providing a development more desirable to the municipality. In cluster zoning, the developer gains by having to construct fewer and shorter streets and by often being able to create more marketable lots; while the municipality benefits from decreased public costs, such as road maintenance, shorter school bus routes, and fewer miles of police patrol routes. The municipality also receives the benefit of having permanent open space created at no cost. Under PUD, the developer also gains by being permitted to build valuable commercial uses in an otherwise residential zone, but in return he may be called upon to provide some community facilities such as recreational facilities or even land for schools as a part of the development.

Whether a cluster development or a PUD is a permitted land use is dependent on the state enabling acts. For example, communities in Massachusetts can adopt zoning which permits cluster development, although they cannot require it. At present, however, permitting a PUD is of questionable legality under the Massachusetts zoning enabling act.

Actually requiring that a tract be developed as a cluster or as a PUD is presently illegal in many states. The decision must be left to the developers, but properly structured incentives can motivate them strongly to choose the cluster or PUD option.

Cluster and PUD options will only work in areas where zoning density is low enough to allow the clustering of residences on smaller than usual individual lots without creating crowding. In areas of densities higher than two or three single family residences per acre, this type of development is not practical without use of multi-family buildings. Where space allows, cluster and PUD zoning can provide excellent noise compatibility control in addition to often providing for a quality of development unobtainable in more conventional subdivisions.

The concept of cluster and PUD development is too complex to be completely discussed in this manual, and should certainly not be adopted merely as a tool to obtain noise compatibility. If, however, a municipality has, or plans to adopt, a cluster or PUD provision, inclusion of noise compatibility into its regulatory structure would be appropriate.

3.1.4 Defining the Scope of Other Local Controls

Zoning can be used to define conveniently the geographical areas where local revision procedure or certain local regulations apply. The details of the applicable procedure or regulation need not appear as part of the zoning regulations. Four of these are possible methods to obtain noise-compatible land use development control:

Special Permits A zoning or other local law could require special permits prior to the construction of typically noise-incompatible land uses in a noise impacted area. Thus, such land uses would be permitted only if, in the judgement of the appropriate local official or board, they are deemed to satisfy certain pre-conditions. Exactly what permit conditions are possible under state enabling legislation varies considerably from state to state.

Environmental Impact Statements Whenever the state laws permit, the local requirement of an environmental impact report for any construction in a noise impact district could be a most useful tool to educate and motivate the developer. And, as state laws change, the impact report could become the basis of actual noise compatibility enforcement.

Building Code In municipalities where the building code is already administered by a well established municipal organization, additional specifications in the building code can be a convenient and inexpensive way to require acoustical construction practices such as sound insulation or sealed windows. An overlay zone on the zoning map can often be the most practical way of defining the geographical area where these additional specifications apply. Building code acoustical requirements are treated in detail in a subsequent section of this manual.

Acoustical Analysis by an Architectural Review Board The zoning regulations can also be worded to require acoustical analysis of all proposed development within areas of potential noise impact. Such areas could be defined by an overlay zone. The actual analysis might be done by a member of the municipal staff or by an architectural review board. The role of architectural review boards is discussed in a subsequent section of this manual.

3.2 Other Legal Controls

Zoning is not the only legal tool available to local governments to control noise incompatible land use. Subdivision control laws, building codes, health codes, occupancy permits, special permit procedures and environmental impact statement requirements can all be used to prevent incompatible land uses from coming into existence.

3.2.1 Subdivision Control Laws

Although in many states subdivision control laws and zoning are closely related, they are usually separate laws sometimes administered by different local authorities. In Massachusetts, for example, the building inspector of a town is the zoning officer who must enforce the town's zoning bylaw. The Planning Board, on the other hand, administers subdivision control through the rules and regulations which it has adopted.

Subdivision control law is administered on the local level by a planning board or planning officer using subdivision rules and regulations, development standards or similar documents. These rules and regulations contain the various requirements which must be met by a developer in the creation of a subdivision. Such things as storm drainage, pavement type, curbs, sidewalks, maximum grades in streets, street width, underground utilities, and recreational land can all be specified in these requirements.

The requirements which a planning board can build into its rules and regulations are very specifically delineated in the state laws on subdivision control. Whether a noise compatibility element can be required as part of a subdivision submittal or whether requirements can be made for acoustical site planning or architectural review is dependent on the state laws. It may be possible, for example, to require a buffer strip or to require acoustical site planning in the area near a highway. It may also be possible to specify acoustical limits in decibels which cannot be exceeded without acoustical construction techniques.

In addition to direct specification of acoustical criteria for developments, the subdivision control rules and regulations can be used as a bargaining tool to obtain acoustical considerations from developers. In many states, the rules and regulations adopted under subdivision control law may be waived for sufficient reason by the planning board or planning office. Thus, there is an implicit ability to bargain for acoustical improvements.

3.2.2 Building Codes

Local building codes can be a powerful tool to insure that any of a series of noise compatibility measures are taken. Requirements can take four basic forms:

1) Requirements for specific construction techniques such as double glazed windows, double studded walls, or air conditioning.
2) Requirements for specific attenuation characteristics from construction in terms of a mandatory Sound Transmission Class (STC) level.
3) Specification of certain noise levels after construction such as peak levels in bedrooms at night.
4) Interpretive regulations with precise standards left up to the discretion of the building inspector in each specific case.

As with most legal techniques, the choices range from laws which are very specific but not always appropriate in a given case to laws which are vague but which can be interpreted to optimize each individual situation. The key in writing a viable noise compatibility section for a building code is to make it strong enough to be enforceable and yet discretionary enough to be flexible. One way to attempt to satisfy both of these goals is to define the specific requirements as being applicable only in areas where the expected or actual exterior noise levels exceed certain levels.

Building codes have two weaknesses when used alone as a noise compatibility control:

- They generally do not control the use of the land surrounding the buildings and thus cannot require barriers, site planning, or planted buffers. As a result, they may not result in the most cost-effective noise reduction strategy, unless they contain mechanisms to allow the use of less expensive techniques of site planning and design where appropriate to achieve desired noise levels.
- They have no applicability to existing buildings.

Specific Construction Techniques The hypothetical section of a building code which follows attempts to combine strength with appropriate applicability by granting the local building inspector the ability to waive any provisions when the specific conditions so warrant. Thus, the required construction requirements could be reduced, for example, to involve only those walls of a building directly facing a noise source. Or, some provisions could be waived entirely if the conditions involved in the individual case make them unnecessary.

The particular wording presumes that the local building inspector has some way of defining areas of the community where a noise compatibility problem may occur. Alternative wordings could be chosen to define the applicable areas by measurement with a sound level meter, by a noise contour map, by an overlay zone on the zoning map, or by including all areas within a specified number of feet (such as 500) of certain highways. Also, an alternative wording could make some person other than the building inspector responsible for interpretation of applicability of the code provisions.

Section ____ Acoustical Construction Requirements

In all areas determined by the building inspector to have the potential of significant noise impact, the following design requirements shall apply—

A) All windows shall be double glazed with a minimum glass thickness of 3/16 inch and a minimum sealed airspace between the panes of 2 inches.

B) All residential and office buildings, hospitals, rest homes and day care centers shall have air-conditioning adequate, in the opinion of the building inspector, to cool the rooms to 68 degrees when the outside temperature is 95 degrees.

C) All exterior walls shall be constructed with staggered studs to isolate interior from exterior sides of the wall. The resulting gap shall contain a continuous layer of acoustical blanket at least 2½ inches thick.

Provisions of this section may be waived or otherwise reduced when, in the opinion of the building inspector, the walls as designed will have a Sound transmission Class of 50 dB, or when, in the opinion of the building inspector, the interior noise levels after occupancy will not exceed 45 dBA more than six minutes out of each hour. If these requirements are so waived or otherwise reduced, the building inspector shall require satisfactory proof of achievement of expected noise reductions prior to issuance of an occupancy permit.■

Specification of Exterior and Interior Noise Levels After Construction Instead of requiring in a building code that certain acoustical construction materials be used, a performance standard could be set requiring the attainment of specific interior noise levels. An example of exterior and interior performance standards which might be applied are those adopted by the U.S. Department of Housing and Urban Development for use by builders of federally funded housing. (See Fig. 3.6)

Exterior	
discretionary - normally acceptable	65dBA - L_{33} (not to be exceeded more than 8 out of 24 hours.)
clearly acceptable	45dBA - L_2 (not to be exceeded more than 30 min. out of 24 hrs.)

Interior	
clearly acceptable	45dBA - L_{33} (not to be exceeded more than 8 out of 24 hrs.)
	55dBA - L_4 (not to be exceeded more than 1 out of 24 hrs.)
	45dBA - L_6 (night) (not to be exceeded more than 30 min. out of 8 hrs.)

3.6 HUD Noise Level Criteria[1]

[1] US Department of Housing and Urban Development, *Departmental Circular 1390.2, Noise Abatement and Control: Departmental Policy, Implementation Responsibilities, and Standards* (Washington, D.C., August 4, 1971).

Noise Attenuation Requirements Requirements for noise reduction can be definitive, requiring, for example, a sound transmission class of 55 dB. Definitive regulations are clear and easy to enforce, but unfortunately they are not always appropriate for each individual case due to the differences in ambient noise levels.

Interpretive Regulations The prime disadvantage to any regulation which requires acoustical construction techniques is that such techniques are not always the optimum solution to noise incompatibility problems because they are so expensive. Certainly, site planning, plantings and acoustical design are much more desirable solutions to a noise problem. For this reason, it is important that the regulation contain a mechanism for exception if other methods will achieve the desired low noise levels.

Precise noise standards can be left to the interpretation of a local official by requiring, for example, that the Building Inspector specify an adequate STC in each particular case. Interpretive regulations can take advantage of human judgment to provide the optimum solution for each case, but they are subject to the human frailties of possible arbitrary, emotional, or even dishonest decisions. Interpretive decisions may be more likely to result in court actions than definitive regulations, particularly if the interpretation is thought to be arbitrary or otherwise inconsistent with local precedents. In the following sample section of a building code[1], a compromise between definitive and interpretive regulations is achieved by including a provision for waiver at the discretion of the building inspector.[2] Whether this is the solution for a given community can only be determined by a careful review of local conditions.

Section ____, Acoustical Construction Characteristics - Noise Impact Superimposed Districts

No residential use, hospital, nursing home, church, school, or daycare center shall be constructed within the Noise Impact Superimposed District unless evidence is given that a Sound Transmission Class of at least 55 dB will exist in all exterior walls which face toward the highway, are perpendicular to the highway or are placed at any angle between facing the highway and perpendicular to the highway. No such use shall be constructed unless evidence is given that all other exterior walls will have an STC of not less than 50 dB.

Within 200 feet of the highway in the Noise Impact Superimposed District, no such use shall be constructed unless all rooms of the building are served by an air-conditioning system adequate in the opinion of the Building Inspector (or other appropriate official) to maintain a constant temperature of 68 degrees.

The provisions of this section may be waived or otherwise reduced if, in the opinion of the Building Inspector, the particular location and surroundings of the proposed building are unique to the area and will provide for peak noise levels less than 45 A-weighted decibels (45 dBA) within the living and sleeping areas of the building.■

[1] The numbers used in all the sample codes are only illustrative and not meant as recommended levels. Local evaluation is needed to set appropriate levels for individual communities.

[2] Any other local official could be chosen in place of the building inspector if local conditions so dictate.

3.2.3 Health Codes

Local and county health codes exist almost universally throughout the United States. Many of them could be adapted easily to include a provision for noise compatibility in new construction. In some respects, the health code has distinct advantages over the other legal and administrative techniques listed in this manual:

- The health code can stand on its own as a complete legal entity. It does not require the concurrent existence of zoning, subdivision control, or building codes in order to function.
- Health codes are generally backed by strong state legislation, and they are frequently administered by a strong local organization.
- Since the health code and its administrative structure exist in almost every community, there is often no need to set up new administrative agencies to handle the noise compatibility control.
- Enforcement of a health code's noise provisions would be technically simple. A single direct measurement on a sound level meter which is easily used and costs only a few hundred dollars is sufficient to determine if the standard has been met. If it has not been met, an occupancy permit[3] is not issued.
- Most health boards have some latitude in what they can include in their code. Inclusion in the health code of maximum noise levels as a condition for issuance of an occupancy permit has much less risk of a court challenge than the inclusion of the same requirements in the zoning bylaws or the building codes.

An example of the simplicity of using the health code as a noise compatibility control can be seen in the case of Orange County, California. The County's zoning, subdivision, building and health codes apply to all of the unincorporated areas of the county.

The County Health Department requires that the United States Department of Housing and Urban Development (HUD) requirements for acceptable interior and exterior noise levels, as outlined in HUD Departmental Circular 1390.2, be met.

The submittal of any development plan requires, under the California Environmental Quality Act (CEQA), that an Environmental Impact Report (EIR) be submitted. A mandatory element of the EIR is a description of actual and predicted noise levels at the site and a description of methods proposed to mitigate any excessive noise impacts.

The County evaluates the submittal so as to confirm the expected noise levels both inside and outside the proposed buildings. If it is clear that the HUD standards will be met, the plan receives approval with respect to noise compatibility. If there is some doubt whether the HUD standards will be met, the approval is made conditional on an occupancy permit which will not be issued unless actual measurements, taken after construction is complete, confirm that the standards have been met. Development plans which appear incapable of meeting the HUD standards are disapproved unless revision is made.

The Orange County system is slightly more complicated than merely requiring achievement of certain standards before issuance of an occupancy permit in that the county does evaluate the potential noise levels at the time of submittal.[4] such an evaluation is helpful because it gives the developers knowledge of what to expect early in the development process before excessive money has been spent on construction. This in turn reduces the chances of successful court action against the county, should an occupancy permit actually be refused.

3.2.4 Occupancy Permits

Compliance with all of the administrative techniques previously discussed - zoning, subdivision laws, building codes and health codes - can be made mandatory by conditioning the issuance of an occupancy permit on it. An occupancy permit, or certificate of occupancy, is a document issued by some local authority such as the Building inspector or the Board of Health. It certifies that a building meets certain minimum standards and is therefore fit to be occupied.

An occupancy permit, as opposed to a building permit, comes after construction or modification of a building has been completed. If the building is judged by the appropriate local official or officials to be adequate for the intended use, then the occupancy permit is issued. Without such a permit, the building cannot be occupied.

Some of the approvals that might be needed *prior to issuance of an occupancy* permit include approval from the plumbing, electrical, and building inspectors of the construction and workmanship; approval of the fire department regarding fire safety; and approval by the health de-

[3] Occupancy permits are discussed later in this section.

[4] Orange County uses HUD Technical Bulletin TE/NA 171 for all noise level evaluation except in relation to barriers when it uses HUD Technical Bulletin TE/NA 172.

partment concerning various provisions of the sanitary code.

If an occupancy permit procedure exists within the local government, incorporation of noise standards into it is usually an easy task. If such a procedure is legal under state law but doesn't exist in the local government it should be considered not merely as a noise compatibility tool, but also as a method of easy enforcement of other local building standards.

The occupancy permit's strengths lie in the fact that it is based on simple direct measurement and it is the final step in the land development process. Its principal weakness comes from the potential financial hardships which it may impose by denying use of a building after considerable construction expenditures.

Although the occupancy permit procedure can successfully stand by itself as a noise compatibility control procedure, its use in conjunction with other control techniques which identify potential problems at an earlier time is less likely to cause financial hardship for the builder and possible lawsuits for the local government.

A sample section of a zoning bylaw which requires a certificate of occupancy follows. This particular sample makes the Building Inspector the enforcing authority. It could be rewritten to specify the Board of Health, the planning office, or some other appropriate municipal authority.

"Section ____
Certificate of Occupancy Required.

It shall be unlawful to occupy any structure or lot for which a building permit is required herein without the owner applying for and receiving from the Building Inspector a certificate of occupancy specifying thereon the use to which the structure or lot may be put. Failure of the Building Inspector to act within ten days of his receipt of the notice of completion of the building and the application for an occupancy permit shall be considered approval.

The certificate of occupancy shall state that the building and use comply with the provisions of the Zoning Bylaw and of the Building Code of the Town of ________ in effect at the time of issuance. No such certificate shall be issued unless the building and its use and its accessory uses and the uses of all premises are in conformity with the provisions of this Bylaw and of the Building Code at the time of issuance. A certificate of occupancy shall be conditional on the provision of adequate parking space and other facilities as required by this Bylaw and shall lapse if such areas and facilities are used for other purposes.

A certificate of occupancy shall be required for any of the following in conformity with the Building Code and this Bylaw:

1) Occupancy and use of a building hereafter erected or structurally altered.
2) Change in use of an existing building or the use of land to a use of a different classification.

Certificates of occupancy shall be applied for coincidentally with the application for a building permit, and shall be issued within ten days after the lawful erection or alterations of the building is complete. Such certificates of occupancy shall be posted by the owner of the property in a conspicuous place for a period of not less than ten days after issuance.■

3.2.5 Special Permit Procedures

Where zoning ordinances exist, some land uses are often allowed only under special permit. Some municipalities which do not have zoning have a special permit procedure as part of their general municipal ordinances. The specific land uses are permitted only if, in the judgment of the appropriate local official or board, they are deemed to satisfy certain preconditions. A zoning or other local law could require special permits prior to the construction in a noise impacted area. Exactly what permit conditions are possible under state enabling legislation varies considerably from state to state.

The principal advantage of the special permit procedure over other more specific types of restrictions is that each situation is treated individually. This is often desirable if a sound and rational solution is to be reached since the many variables involved, including terrain, traffic, and noise sensitivity, do not lend themselves to generalized solutions. What is needed is a site by site analysis and application. No law, no matter how carefully written, can cover all of the factors concerning a given situation in as complete a manner as can a sound administrative judgement.

Another advantage is that the local rules governing a special permit procedure can be structured to require the appropriate acoustical analysis as part of the permit application. Thus, the potential developer, rather than the local government would bear much of the expense involved.

The very advantage of the special permit procedure — the inclusion of human judgement — is also the major disadvantage. While the judgement of capable, knowledgeable and dedicated people is far better than mere application of inflexible standards, a poorly administered judgement process is subject to emotional, arbitrary, or even dishonest decisions.

This does not mean that the special permit procedure should be discarded as too much of a risk. The potential benefits to be gained are too significant. Rather, certain questions must be satisfactorily answered in considering the special permit procedures:

1) Does the state legislation enable such procedures ?
2) Does a local mechanism for the granting of special permits exist ?
3) If such a mechanism exists, does it have the time and ability to handle noise compatibility decisions ?
4) What checks exist to ensure that the local mechanism will be consistent, non-arbitrary, honest, technically sound, and relevant ?
5) How can the system be insulated from political pressures of local special interests ?
6) Can it be funded either through fees or a general tax ?

Properly structured and administered, the special permit procedure is a powerful and just method of achieving noise compatibility.

In the following sample[1] of a special permit section for a zoning bylaw, provision is made for use of an occupancy permit as a further tool of the special permit procedure. Where legal, this minimizes the possibility of the local permit issuing authority being misled by false technical data during the special permit procedure. Obviously, this requires that occupancy permits and their issuance be defined elsewhere in the bylaw.

Also, the sample section presumes that some "Board"[2] exists or can be created and that the Board has some standards or "rules and regulations" regarding the content of special permit application submittals. If this is not the case, such standards may be incorporated into the zoning bylaw.

If a local community desires a provision for exception to these noise criteria, at the judgement of the Board, this can be achieved by a slight rewording of the sample section.

[1] Noise standards within sleeping quarters were taken from U.S. Department of Housing and Urban Development, Departmental Circular 1390.2. *Noise Abatement and Control: Departmental Policy, Implementation Responsibilities and Standards.* August, 1971.

[2] The "Board" can be any municipal official or agency that is appropriate under local circumstance.

Section ____.
Special Permit Procedure for Noise Impact Superimposed District

No residential use, hospital, nursing home, church, school or daycare center shall be constructed within the Noise Impact Superimposed District except by special permit of the Board. No such use previously existing at the time of the adoption of this bylaw may be expanded into or within the Noise Impact Superimposed District except by special permit of the Board. No existing structure within the Noise Impact Superimposed District shall be converted to such use except by special permit of the Board.

Applications for such special permits shall contain all information required in the rules and regulations of the Board plus the following:

1) A plan showing the existing and anticipated noise levels in dB(A) that are or will be expected on the site and in the immediate vicinity of the site.
2) A description of the site plan construction techniques, architectural designs, and other measures expected to be taken to reduce ambient noise levels. Such description shall include sufficient plans and other drawings to enable the Board to accurately identify the noise reduction measures expected to be taken.
3) Calculations showing the resulting noise levels expected within and near the planned structures.

Prior to issuance of special permits required by this section, the Board shall determine that the noise levels will be successfully reduced to the following standards.[1]

1) Within sleeping quarters noise levels shall not exceed:
   A) 55 dB(A) for more than an accumulation of 60 minutes in any 24-hour period and
   B) 45 dB(A) for more than 30 minutes during night time sleeping hours from 11 p.m. to 7 a.m., and
   C) 45 dB(A) for more than an accumulation of eight hours in any 24-hour day.
2) Within other interior areas normally occupied: noise levels shall not exceed 55 dB(A) for more than six minutes in any hour.

The Board may include as a condition of the special permit, a requirement for actual measurement after completion of construction to confirm that the standards set forth in this section have been achieved before an occupancy permit shall be issued. ■

[1] These standards are meant as examples. As in other sample regulations, they must be adapted to local conditions and preferences.

3.2.6 Environmental Impact Statement Requirements

There is a rapid trend toward requiring that developers identify and analyze all impacts that a proposed development will have on the environment. Air and water pollution, noise, impacts on open space, and impacts on wildlife are a few of the factors for which analysis may be required. The results of the analysis, when submitted to permit granting public authorities, becomes a useful tool to identify problems and to decide which situations must be rectified before a permit is granted.

State laws vary considerably in the requirements for submittal of environmental impact statements and plans to mitigate adverse impacts. California, for example, requires an extensive environmental impact report (EIR) on most private and public construction projects large enough to require a building permit. These reports are required to contain a detailed noise element. Several other states have adopted legislation requiring environmental impact statements, or an equivalent procedure. However, most of these treat noise in a general fashion, if at all. Also, these procedures are not applicable to all projects on the local level. For example, a ruling in Massachusetts has limited the local scope of environmental impact proceedings to projects involving redevelopment and housing authorities.

3.3 Municipal Ownership

No law, regulation, or financial incentive controlling the use of land owned by others can ever be as absolute as actual ownership by the municipality of the land or of restricted easements on the land. This section describes alternative types of municipal ownership and methods of acquiring land or easements.

While municipal purchases of massive amounts of land might create unacceptable financial burdens in direct outlays and lost tax revenues, the actual circumstances of municipal ownership are often quite the opposite. There are several ways that a municipality can acquire clear title to land at a minimal cost. Easements, an effective form of partial ownership of the land can also often be obtained for less money than outright purchase. Finally, the loss in tax revenue due to the removal of municipally acquired land from the assessed tax base may be much less expensive than the demand for new municipal tax revenue that would have been necessary to fund the municipal services that would have been required if the land were developed.

The pages that follow elaborate on some of the factors involved in municipal ownership of noise-impacted land. The options to the community are to leave the land undeveloped, to develop it with compatible uses, or to sell it with appropriate covenants on the deed to insure that only compatible uses are developed.

3.3.1 Municipal Land Acquisition

There are two factors which a municipality must consider in deciding the appropriateness of land acquisition as a policy to promote noise compatible land use:

1) The money cost of acquisition
2) The social costs and social benefits associated with ownership of the land.

1) **Acquisition Costs** The primary acquisition cost to the municipality is the purchase price of the land. If this purchase is financed by municipal bonds, the interest on those bonds must also be included in the purchase price. Additional hidden costs to the municipality include:

- Fees involving transfer of land, including legal costs, engineering surveys, land transfer taxes and the like;
- Capital improvements costs, including necessary repairs to or demolition of structures on the property, and costs for providing appropriate security arrangements such as fences and lighting;
- Maintenance of the property.

The primary determinant of the land acquisition cost to the community is the mode of acquisition used by the municipality. Five alternative methods can be considered: 1) Outright purchase 2) Eminent domain taking 3) Gift 4) Public land acquisition under subdivision development 5) Transfer from other governmental agencies.

Each of these methods, appropriate under certain circumstances, will be discussed in the paragraphs that follow.

Purchase The purchase of property by a municipality is an effective, but expensive way to achieve noise compatible development. Usually the fact that the municipality has a plan to purchase land adjacent to highways will drive up the price of land on the open market.

Eminent Domain Taking Eminent domain proceedings are limited by state law. The purpose of the takings, and the intended use of the land, are the major factors in determining whether the eminent domain is legal. The major criterion is the extent to which there is a public purpose served by the taking, a condition which must be satisfied if eminent domain is to be valid.

The public purposes served by eminent domain takings for noise compatibility are subject to question in the courts. However, strong arguments can be made that public health is preserved by prevention of human exposure to excessive noise levels, and that the quality and value of the community as a whole is improved by not having residences or other incompatible land uses in a noise impacted area.

The eminent domain process runs the risk of being subject to local opposition because of the involuntary nature of the land acquisition. Furthermore, the cost of the taking is set by the court and may be considerably higher than the community originally anticipated. Both of these factors must be evaluated carefully prior to implementation of an eminent domain proceeding.

Gifts Gifts, particularly restricted gifts, represent a frequently overlooked source of municipal land. There are often significant tax advantages (both property tax and personal income tax) to the individual who gives land to the community. Furthermore, restrictive covenants (such as forever maintaining land as open space) can make the donation of such land more attractive.

Acquisition under Subdivision Development Another method of acquisition of land at little or no cost to the community is that of receiving land as part of the subdivision process. This is most practical in cluster subdivision and planned unit development situations because both of these situations usually require the creation of public open space as the condition of reduced lot sizes. A properly worded zoning law, combined with appropriate administrative procedures, can insure that a portion of such land be a buffer between a highway and adjacent land uses. The municipal uses of land received in this manner would be restricted primarily to open space, conservation, and recreational uses, helping to solve the noise compatibility problem. This type of land acquisition is quite dependent on the bargaining ability of the local officials at the time that they are considering the plans for approval.

Transfer from Other Governmental Agencies Some of the land acquired during the development of new highways may be of little or no use to the highway department. For example, highway regulations may permit the purchase of an entire parcel of land even if only a small portion of it is required for the actual right of way. The transfer of this land to the municipality can both relieve the highway department of the responsibility of its maintenance and also serve the municipal goals of noise compatibility control.

2) **Social Costs and Benefits of Continued Public Land Ownership** Local municipalities must consider not only the initial costs incurred in acquiring land, but the costs and benefits associated with the continued public ownership of that land. Five components of municipal ownership are:

- Value of alternative use of acquired land,
- Tax loss,
- Loss in private projects not taken,
- Gain in noise compatibility, and
- Savings in municipal services that would otherwise be required.

Municipalities can use land acquired in noise impacted areas in three ways: passive municipal uses, active municipal uses, and non-municipal uses.

Passive municipal uses include:

- Linear parks, including riding trails, hiking trails, and scenic overlooks.
- Other recreational uses such as swimming facilities and playgrounds.
- Conservation and agricultural uses such as a watershed protection, or a town forest, or a wildlife sanctuary.

Active municipal uses include:

- Normally compatible uses such as a municipal storage facility, public works garage, or a fire station.
- Other municipal uses which can be readily soundproofed to adequate levels such as municipal office buildings.

Non-municipal uses include:

- Agricultural or other essentially non-occupied uses conducted by private individuals and restricted by covenants or other deed restrictions.
- Uses by other governmental agencies restricted by legal agreement to noise compatible uses.
- Buildings constructed to appropriate soundproofing standards by a redevelopment authority or similar agency, and sold to appropriate private buyers.
- Privately constructed and occupied buildings whose use and construction are controlled by covenants or other deed restrictions imposed by the municipality as a condition of sale by the municipality.
- Pre-existing buildings purchased by the municipality, soundproofed, and then resold to appropriate buyers.

3.3.2 Easements and Conservation Trusts

Restrictive easements are often obtained by municipalities to protect scenic views, watersheds, well sites, and conservation land. After having granted a restrictive easement, the land owner can use the land only in ways not prohibited by the terms of the easement. For example, an easement can be written to restrict the owner from building on the land covered by an easement.

Easements for noise compatibility purposes could restrict buildings in the portions of the land nearest the highway or other noise sources. They could prohibit the cutting down of trees which presently form a natural buffer, or the destruction of an existing hill which presently acts as a barrier. Or, the easement could merely restrict certain types of buildings such as residences unless specified acoustical construction techniques are used.

An important advantage of municipal possession of an easement is that it can often achieve effective control over land at a much lower cost than actual municipal ownership. Easements can be obtained by five of the methods as previously listed for obtaining ownership: purchase, eminent domain, gifts, subdivision conditions, and transfer of other governmental agencies. The difference, however, is that title to and limited use of the land remains with the original owner, thus making the cost of obtaining easements much less than the cost of outright ownership.

For the land owner, the giving of an easement can often result in a significant reduction in his property and income taxes. A property tax reduction can be arranged as a condition of the easement to reflect the lessened value of the land because of the existence of the easement. It may be necessary to write some guarantee of this lower property tax assessment into the easement agreement in order to convince the property owner of the benefits of granting the easement to the municipality. Significant income tax reductions may also occur because the owner may deduct the entire value of the easement as a "charitable contribution."

The cost of an easement to the municipality varies with the terms of the easement. First, the price is a function of the value of the rights which the owner is giving up. If the easement causes little or no change to the land use options available to the landowner, then the cost of the easement should be small or perhaps free. If, however, the easement greatly restricts uses which could otherwise have been possible, then the easement cost will approach that of actual purchase. Careful attention should be given to insure that no unnecessarily restrictive (and therefore costly) conditions are written into easements.

Conservation Trusts A variation of an easement is a conservation trust. The owner of a parcel of land gives land to the community to be held in a conservation trust for a specified length of time. Since the gift is for a specified period of time, the original owner retains residual rights to the land as a long-term investment. If a local conservaton commission or similar agency exists, it can, depending on its legal status, become the holder of this land.

While the land remains in the conservation trust, no taxes are paid on it by the land owner. The land owner retains residual rights for future possible use of the land, and is guaranteed the fact that the land will not be developed. This can be particularly advantageous to the land owner who is feeling pressures (due to increasing taxes or increasing land value) to sell land which is valued for scenic or other qualities.

To the community, this represents an inexpensive way of controlling land to regulate orderly community growth as well as potential noise incompatibility. However, safeguards should be built into a conservation trust program to insure that the trust benefits the municipality in general and is not merely a way in which one land owner gets protection for his or her forest preserve at the expense of the taxpayers.

The cost of significant municipal services which can be saved by preventing development of the parcel is a benefit to the municipality only if the parcel would, in fact, be developed if the trust did not exist. The prevention of future noise incompatibility problems or the gaining of public access to desirable woodlands also may benefit the municipality. In general, land held in conservation trust should fit into a municipal or regional open space plan, and not be randomly chosen on the sole basis of availability.

3.4 Financial Incentives

In addition to direct legal controls on potential developers, financial incentives in the forms of tax reductions and reduced costs exist. This section examines some of these techniques.

3.4.1 Tax Incentives

One often overlooked, but very effective tool to shape land use development is the municipal property tax. Tax incentives can be used to discourage development of incompatible land uses, to encourage the creation of buffer strips, and to encourage the use of acoustical construction techniques. All too often however, the effect of a municipal tax policy is to encourage rather than discourage such development.

Municipal tax incentives can take several forms:

A) Undeveloped land or agricultural land can be assessed as such rather than as a much more valuable collection of vacant but buildable lots. The resulting tax acts as an incentive for the owner to keep the land in its undeveloped state.

B) Lots in a noise impacted area can be assessed at a flat rate regardless of size rather than on a "per square foot" basis. This encourages larger lots which make on-lot buffer strips possible.

C) The extra cost (and value) of acoustical construction such as insulation, air conditioning, or double glazed windows can be assessed at little or no value.

The most effective of these tax incentives is the first: assessment to discourage the development of land. Yet, all too often, local assessment policy has just the opposite effect in that it encourages and sometimes forces the development of land.

A widespread policy among local assessing bodies is to tax all property at its potential "highest and best use", thereby creating the broadest possible tax base. The logic behind this type of policy is that a given amount of municipal revenue can thus be raised with the smallest possible tax per dollar of assessed valuation. In theory, this will keep everyone's tax bill to a minimum. If the municipality's interests are best served by the land's *not* being developed, the object would be to assess the undeveloped land as *low* as possible rather than assessing it according to its "highest and best use". Conversely, high taxes on undeveloped land may give the owner no financial alternative other than selling to a developer.

However, such an assessment policy will not be without potential problems and these problems should be addressed and overcome. The potential problems fall into three general areas:

A) Legality under state laws,
B) Equity of application, and
C) Public acceptance.

Each of these will be treated in turn.

The *legality* of incentive assessment policies varies from state to state. If state law requires "full and fair evaluation" without specific exemption of undeveloped land, this assessment policy may not be legal. Even in states which permit specific exemptions (such as Massachusetts, which allows agricultural land to be assessed as such) there is question whether the scope of these exemptions can be expanded (such as to include wooded areas, open spaces, or underdeveloped land). The legal constraints must be evaluated for each given state.

A second issue which reflects on the legality of incentive assessment policies is the *equity* with which the policy is applied. If, for example, it is desired to apply such an assessment policy to all agricultural land near a major highway, then it will probably be necessary to apply the same policy to all agricultural land throughout the municipality. Whether such universal applicability of low value assessments is compatible with other municipal goals is a question to be answered on a local basis.

Perhaps the most frequent problem associated with an incentive assessment policy is that of obtaining *public acceptance* of it. It is obvious that any action which lowered the assessment value of property would narrow the tax base of the municipality and thus raise the tax rates and the tax bills of those whose property was not reassessed. (This assumes that the total amount of money to be raised through the property tax does not decrease.) And an increase in tax bills is by no means a guaranteed method to inspire enthusiastic public acceptance.

Often, however, these assessment policies will actually prevent much of the future increase in taxes that would otherwise have been necessary. This is true whenever the increased costs of providing municipal services to new developments are greater than the additional tax revenues that the new developments will generate.

The chance of obtaining public acceptance can be increased if it can be demonstrated to the public that a greatly increased tax rate (due to increased demand for public services) is the alternative to a lesser increase due to narrowing of the tax base. Also, the desirability of maintaining the land in its present state for other than financial reasons can also be used as an argument.

3.4.2 Relaxation of Local Regulations

A major financial incentive to encourage builders and developers to utilize noise compatible construction and development techniques is to relax enforcement of certain provisions of some local regulations. Often, local regulations or codes such as development standards, and subdivision regulations allow local officials some discretion in their enforcement. This discretion can become an important bargaining tool to bring about various noise compatible development or construction techniques. Thus, the builders or developers can financially benefit from relaxation of local regulations or codes, if in turn they agree to provide for appropriate acoustical development or construction.

For example, a local regulation might ordinarily require sidewalks on both sides of all streets within a new subdivision. Perhaps this requirement could be waived on one side of some of the shorter streets without any adverse effect on the quality of the subdivision. The resulting savings could be enough to compensate the developer for the cost of acoustical site layout or construction of a barrier or berm. Likewise, a waiver which allows substitution of molded asphalt or bituminous concrete curb for ordinarily required granite curb can save the developer several dollars per foot of road. The developer might find such a saving to be well worth the added cost of providing a subdivision that is acoustically compatible with neighboring noise sources.

The specific noise impact reduction techniques that can be obtained in this fashion include acoustical site planning, berm or barrier construction, buffer strips, acoustical architectural design, insulation, and other construction techniques.

Certain potential problems should be addressed and overcome if such a policy is to be attempted. These problems fall into five categories:

A) The relaxation of the local code should not cause a significant negative effect.
B) The policy must be legal.
C) The application of the policy should not be arbitrary.
D) Undesired precedents should not be set.
E) The person who benefits from the code relaxation must be capable of providing the desired acoustical benefit.

3.5 Municipal Services

A municipality can provide a variety of services to insure that new development is compatible with nearby noise sources. Some of these services are surprisingly effective. Municipal educational services cannot be as definite as legal regulations or as absolute as ownership of the land but they can, for a very low cost, supplement these other administrative methods.

Four municipal services will be discussed in the pages that follow:

1) Architectural review boards,
2) Municipal design services,
3) Builders information libraries, and
4) Public information programs.

3.5.1 Architectural Review Boards

One of the many benefits that a local community can derive from an architectural review board is noise compatible design control.

An architectural review board (ARB) is a local board—either official or unofficial—composed of citizens expert in architecture and related fields who analyze proposed development and construction and who provide the appropriate municipal officials with advice based on this analysis. Often the ARB is composed of members who have volunteered their part-time services to this community project.

Although it is often not an official branch of the municipal government, the ARB can derive significant strength from the support which it receives from the agencies and officials who receive its advice. Conversely, an ARB, no matter how skilled its members may be, is of no real value if its advice is not heeded or if its decisions are not supported by the local officials who have the legal authority to enforce such decisions. This support, or lack thereof, is perhaps the key determinent of whether or not the ARB will be a successful influence on the quality of community growth.

In the area of noise-compatibility control, the ARB can recommend any of a vast number of physical techniques such as site design, architectural building design, insulation, acoustical windows, subdivision layout, buffer strips, and berms and barriers. Again it should be emphasized that noise compatibility control is only one of several benefits that will accrue because of an architectural review board. Other benefits such as continuity of architecture, community planning, and quality of design and construction can be equally important.

3.5.2 Municipal Design Services

For a municipality which has the technical ability on its staff, an informal design review service can be the optimum way to insure that future development and construction is compatible with existing nearby noise sources.

An effective design review service can consist of nothing more than an employee of the municipal engineering, planning, or building departments who specifies certain minimum requirements for insulation, window construction, wall construction, barriers, berms, or buffer strips on a copy of the plans as submitted by the developer. The employee can also be one who would normally review the plans during the permit or subdivision approval process, and the addition of the noise specifications would thus add only a few minutes to the review process. The developer would then have a clear indication of the noise compatibility measures which the municipality desired.

The specifications passed on to the developer could be requirements, the subject of negotiation, or mere suggestions, depending on the strength of local laws and the specific wording of state enabling legislation. Even specifications which are mere suggestions stand a good chance of being followed especially if they do not represent a major added cost to the developer or builder, or if they can be expected to improve the market value of the buildings.

It should be remembered that the developers or builders do not necessarily know the expected noise impact on a planned building, the amount of noise attenuation that is desirable, or the optimum way to achieve that attenuation. As such, the builder is likely to welcome the advice of a municipal employee who is reasonably cognizant of noise attenuation measures and expected local noise levels.

3.5.3 Builder's Information Library

A passive form of municipal design service consists of merely maintaining a convenient library of acoustical design and construction techniques along with some background literature on expected noise levels. This is an appropriate venture in many smaller communities where the municipal planning and engineering offices may be part-time or combined with other municipal functions. It is very inexpensive. It requires a minimum of personal attention by municipal officials or employees. And, it provides the local designers, builders, or developers with otherwise unavailable information which they may be quite willing to use in their planning.

Even a library consisting of this manual, a map showing the areas of noise impact,[1] one or two of the references listed in section 5.3 and a handful of advertising brochures from manufacturers of insulation or other acoustical building materials would provide an information source significantly greater than that readily available to the average builder. A single shelf in the town hall or the local library may be all that is needed.

While this may seem to be a naively simple solution to a complex problem, it should again be remembered that many designers and the vast majority of all builders and developers have had little or no experience with noise compatible construction and design. The library, perhaps set up and maintained by a citizen volunteer who has some knowledge in this topic, can provide the builder or developer with the appropriate information. Actual use of such a service can be urged by the local departments which issue permits or which approve subdivision plans.

3.5.4 Public Information Services

Public awareness of the severity of noise impacts and the physical techniques that can lessen these impacts can be an important factor in determining the marketability of a building, especially a home. This can have a direct financial effect on the builder through both price and quickness of sale. Accordingly, public awareness can be a welcome tool in a municipality's efforts to achieve noise compatibility control.

The format of a public information service will vary from community to community depending on local skills and facilities. A very simple yet effective technique would be to indicate areas of noise impact on all municipal maps. Since prospective home buyers often obtain such a map, they would thus be aware of the potentiality of the noise incompatibility. While certainly not all potential buyers will be aware of this information, the fact that some of them will may be enough to motivate the builder or developer.

More sophisticated public information services could use maps displayed prominently in the library or at the municipal offices. Publicity in the local press or cooperation from a local public service organization such as the Chamber of Commerce can be effective in some localities.

Like several of the other administrative techniques listed in this manual, a public information service will not by itself be the cure to all the community's noise compatibility problems. It can, however, be a useful force when used in conjunction with other administrative techniques.

3.6 Conclusions

The various administrative techniques which may bring about noise compatible land use are listed in Figure 3.6. While some communities may consider a single technique—such as the health code—adequate to provide the desired control, most local governments will find that a

[1] Available from state highway department data.

combination of several techniques is best in terms of effectiveness, cost, and desirability of results.

One such combination might be zoning to require buffer strips, health code standards enforced by occupancy permit, and an architectural review board. Under such a combination, the near-absolute authority of the health code is complemented by two other methods (zoning and the ARB) that will tend to bring about the most desirable physical solutions. Also, the required buffer strips and the architectural review should significantly reduce the number of instances where enforcement of the health code requires expensive modifications to buildings after they have been constructed. This combination would work well in municipalities where low expected land use density made buffers practical, where an effective architectural review board could be established, where the health code could be made appropriately strong, and where existing development in and near the noise impacted area was slight.

A combination more appropriate in a municipality where high land values dictate relatively dense land use development might be industrial zoning of major tracts with building code requirements for acoustical insulation in the remainder of the noise impacted area.

Several variables must be individually evaluated on the local level to determine an appropriate combination of techniques:

Timing If major land use development is not expected for some time, the municipality has the luxury of being able to set up incentive zoning (cluster and PUD) programs and to utilize an architectural review board for long range planning. Conversely, the threat of extensive rapid development may limit the municipal choice to such things as building and health codes which can be quickly implemented and which apply to individual construction sites even after subdivision layouts have been planned.

Existing Development If there is no existing development in the area, the choice of physical and administrative techniques is quite wide. If, however, the area is partially developed, it may be exempt from zoning or subdivision control and it may be beyond the scope of any scheme such as planned unit development or acoustical site planning that requires coordinated development of major areas.

Physical Techniques Desired Some physical techniques such as acoustical subdivision design are not within the scope of some administrative techniques such as building codes. If a particular physical solution is desired, an appropriate administrative technique must be chosen.

Degree of Control Desired Some administrative techniques such as municipal ownership are absolute controls. Other techniques, such as educational services, incentive zoning, and financial incentives are voluntary. In situations where a most desired administrative technique such as incentive zoning might not always be sufficiently strong, desired control can be assured by having an additional control such as health codes which could be used where necessary.

Financial Considerations The cost of municipal acquisition of land, and the cost of adopting and enforcing municipal regulations can be significant and must be considered in determining which administrative techniques are to be employed. Other relevant financial considerations are the future tax base and the future demand for municipal services. Both of these, which vary depending on how the land is developed and used, are influenced by the noise compatibility land use control strategy chosen.

Administrative Structure of Local Government Any administrative technique can only be effective if there is a willingness and a capability within the municipality's governmental structure to actually administer the technique.

The Local Political Situation If the local legislative body will not adopt a desired regulation, or if it will not vote funds for land purchase or administrative costs, the desired administrative technique—regulation or purchase—is impossible. Likewise, strong opposition by local officials can hamper any attempt to effectively enforce existing regulations.

Applicability Under State Law If a technique is not legal under state law, it cannot be considered as a valid noise compatible land use control.

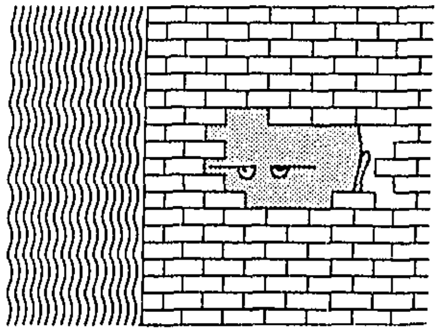
Administrative Technique	Physical Result	Situations Where Most Applicable
Zoning to Exclude Typically Incompatible Land Uses	Prevention of Incompatible Land Use	Where Demand for Typically Compatible Land Uses is Significant
Zoning to Require Buffer Strips	Buffer Strips	Where Land Values and/or Lot Sizes Permit
Zoning to Require Berms and Barriers	Path Disruption	Where Other Physical Techniqes are Not Practical
Zoning to Limit Building Height	Path Disruption	When Terrain Makes this Technique Effective
Zoning to Require Acoustical Building Techniques	Insulation, Isolation, Absorption	Where Other Measures are Inadequate
Zoning to Allow Cluster or Planned Unit Development	Buffer Strips, Site Design, Path Disruption	Where Large Undeveloped Areas Exist
Subdivision Control Law	Buffers, Berms, Barriers, Site Design, Path Disruption	Where Large Developments Rather Than Individual Buildings are Anticipated
Building Codes	Insulation, Isolation, Absorption	Where Individual Lots Are Being Developed
Health Codes	Most Techniques	Anywhere State Laws Permit
Special Permit Requirements	Most Techniques	Anywhere That the Permit Granting System Exists or Can Be Started
Environmental Impact Statements	Most Techniques	Anywhere Legal Under State Law
Municipal Purchase of the Land	Buffer Strips, Prevention of Incompatible Land Use	Where Development Pressures Make Less Absolute Measures Inadequate
Other Municipal Acquisition of Land	Buffer Strips, Prevention of Incompatible Land Use	Where Possible
Partial Ownership—Easements and conservation	Buffer Strips, Prevention of Incompatible Land Use	Where Possible at Low Cost
Property Tax Incentives	Prevention of Incompatible Land Use	Where Tax Pressures Exist on Owners of Undeveloped Land
Relaxation of Municipal Codes as a Financial Incentive	Most Techniques	Only Where Code Enforcement can be Relaxed Without Negative Side Effects
Architectural Review Boards	Most Techniques	Where Appropriate Ability Exists on the Municipal Staff
Municipal Design Services	Most Techniques	Anywhere

3.7 Administrative Noise Compatibility Land Use Control Techniques

ectiveness	Cost to the Municipality	Enforcement Mechanism	Comments
jh	Insignificant if Zoning Exists	Note 1	May Make Land Worthless
h		Note 1	Easy to Implement in Low Density Areas
les with Terrain		Notes 1, 2, & 3	Often not Aesthetically Desirable
les with Terrain		Note 1	Effective in Limited Situations
h for Interiors, Low for eriors		Notes 1, 2, & 3	Can Cause Unnecessary Building Costs
h	Additional Review Procedure	Approval Procedure	Significant Potential Benefits, but Can be Misused
h	Insignificant if Subdivision Control Mechanism Already Exists	Notes 1 & 2	Not Always Applicable
h for Interiors, Low for eriors	Insignificant if Building Code Enforcement Already Exists	Notes 1 & 2	Limited to Few Physical Techniques
h	Insignificant Addition to Present Health Department Costs	Varies	Highly Effective
n	Limited Cost if Special Permit Mechanism Already Exists	Note 1	Site Specific Analysis for Each Case
es	Varies with Enforcement Mechanisms	Varies	Comprehensive
n	High	Possession	Can be Undesirable Policy for Municipality
	Often Insignificant	Possession	Effective
	Often Insignificant	Possession	Effective and Often Inexpensive
es with Response	Varies	Incentive	Easy to Implement, Inexpensive
s	Insignificant	Incentive	Inexpensive
Dependent on rcement Mechanism	Often Insignificant; Depends on Administration	Varies	Site Specific Analysis for Each Case
	Insignificant	Information; Public Pressure	Very Expensive

Note 1: Denial of Building or Special Permits
Note 2: Occupancy Permits
Note 3: Performance Bond

4 Physical Techniques to Reduce Noise Impacts



This section describes some of the physical methods which architects, developers and builders can employ to reduce noise impacts. There are four major actions which can be taken to improve noise compatibility for any type of land use or activity. These are site planning, architectural design, construction methods, and barrier construction.

Acoustical site design uses the arrangement of buildings on a tract of land to minimize noise impacts by capitalizing on the site's natural shape and contours. Open space, non-residential land uses, and barrier buildings can be arranged to shield residential areas or other noise sensitive activities from noise, and residences can be oriented away from noise.

Acoustical architectural design incorporates noise reducing concepts in the details of individual buildings. The areas of architectural concern include building height, room arrangement, window placement, and balcony and courtyard design.

Acoustical construction involves the use of building materials and techniques to reduce noise transmission through walls, windows, doors, ceilings, and floors. This area includes many of the new and traditional "soundproofing" concepts.

Noise barriers can be erected between noise sources and noise-sensitive areas. Barrier types include berms made of sloping mounds of earth, walls and fences constructed of a variety of materials, thick plantings of trees and shrubs, and combinations of these materials.

These physical techniques vary widely in their noise reduction characteristics, their costs, and especially, in their applicability to specific locations and conditions. This section is not designed to provide complete criteria for selecting a solution to particular noise problems and is not intended as a substitute for acoustical design. Rather, its purpose is to illustrate the wide range of possible alternatives which could be considered in the architectural and engineering planning process. Knowledgeable municipal officials can provide valuable assistance to designers, developers, and builders who may not be familiar with sound attenuation techniques that are most applicable locally.

4.1 Acoustical Site Planning

The arrangement of buildings on a site can be used to minimize noise impacts. If incompatible land uses already exist, or if a noise sensitive activity is planned, acoustical site planning often provides a successful technique for noise impact reduction.

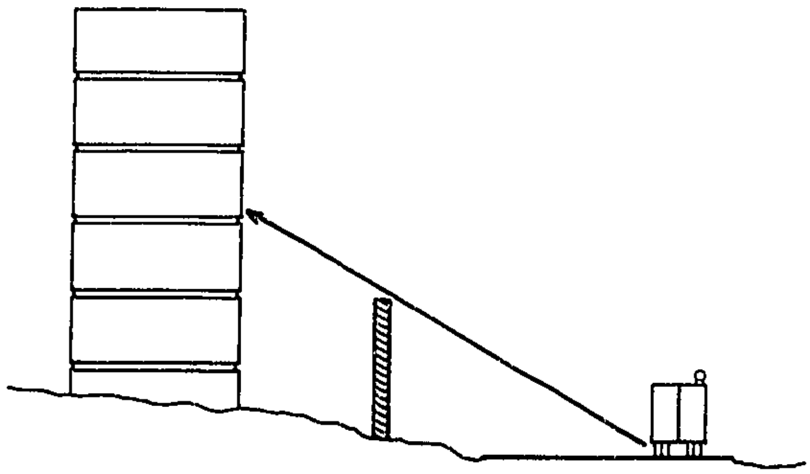
Many site planning techniques can be employed to shield a residential development from noise. These can include:

1) increasing the distance between the noise source and the receiver;
2) placing non-residential land uses such as parking lots, maintenance facilities, and utility areas between the source and the receiver;
3) locating barrier-type buildings parallel to the noise source or the highway; and
4) orienting the residences away from the noise.

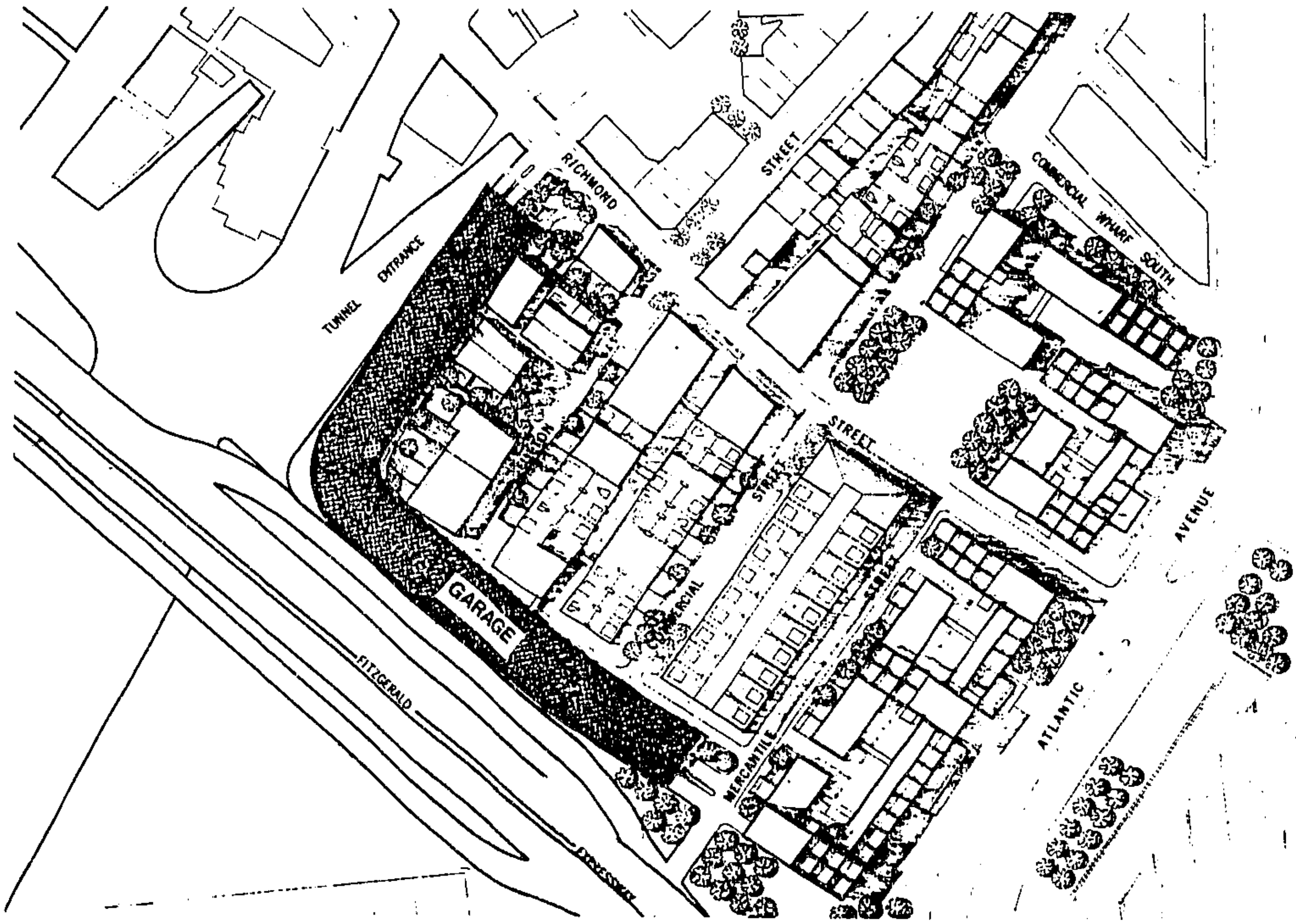
The implementation of many of the above site planning techniques can be combined through the use of cluster and planned unit development techniques.

Distance Noise can be effectively reduced by increasing the distance between a residential building and a highway. Distance itself reduces sound: doubling the distance from a noise source can reduce its intensity by as much as 6 dBA. In the case of highrise buildings, distance may be the only means, besides acoustical design and construction, of reducing noise impacts. This is because it is nearly impossible to provide physical shielding for the higher stories from adjacent noise. (See Figure 4.1.)

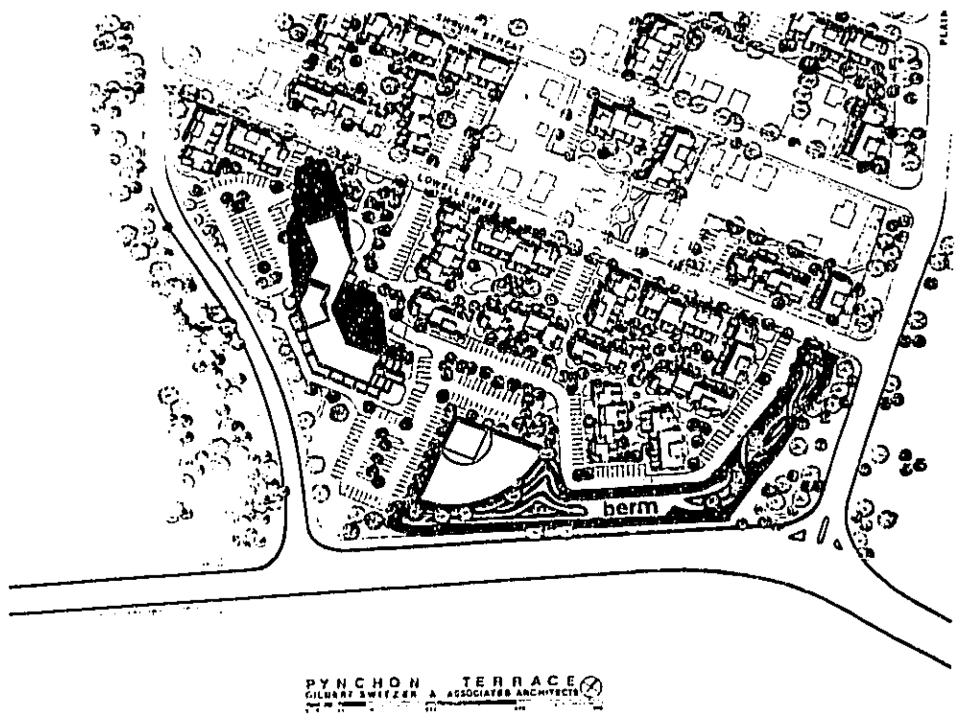
Noise Compatible Land Uses as Buffers Noise protection can be achieved by locating noise-compatible land uses between the highway and residential units. Whenever possible, compatible uses should be nearest the noise source. Figure 4.2 which follows shows a proposed parking garage along two sides of a development in Boston. Both the Fitzgerald Expressway and the entrance to the Callahan Tunnel which are shown on the site plan are major and noisy traffic routes. In addition to protecting the resi-



4.1 Noise barriers can shield only the lowest floors of a building.



4.2 Parking Garage to shield residential area.



4.3 Parking spaces, end of buildings, and a baseball diamond are placed near the highway. A berm is constructed and trees are planted to shield residences from traffic noise.

dential development from the noise and dirt of highway traffic, the parking garage provides needed facilities for the residents.

Figure 4.3 provides another example of locating noise-compatible uses near a highway (West Street) in Springfield, Massachusetts. From the plan, one can see that parking spaces, ends of buildings, and a baseball diamond are near the highway.

Buildings as Noise Shields Additional noise protection can be achieved by arranging the site plan to use buildings as noise barriers. A long building, or a row of buildings parallel to a highway can shield other more distant structures or open areas from noise. One study shows that a two-story building can reduce noise levels on the side of the building away from the noise source by about 13 dBA.[1]

If the use of the barrier building is sensitive to highway noise, the building can be soundproofed. This technique was used in a housing project under construction in England where a 3,900 foot long, 18 foot wide and 45-70 foot high wall (depending on the terrain) serves as both residence and a sound shield.[2]

The wall/building will contain 387 apartments in which the kitchens and bathrooms are placed towards the noise, and the bedrooms and living rooms face away from the highway. The wall facing the highway will be soundproofed and windows, when they exist, are sealed. Substantial noise reductions are expected.

Orientation The orientation of buildings or activities on a site affects the impact of noise, and the building or activity area may be oriented in such a way as to reduce this impact.

Noise impacts can be severe for rooms facing the roadway since they are closest to the noise source. The noise impact may also be great for rooms perpendicular to the roadway because a) the noise pattern can be more annoying in perpendicular rooms and b) windows on perpendicular walls do not reduce noise as effectively as those on parallel walls because of the angle of the sound. Road noise can be more annoying in perpendicular rooms because it is more extreme when it suddenly comes in and out of earshot as the traffic passes around the side of the building, rather than rising and falling in a continuous sound, as it would if the room were parallel to passing vehicles.

Whether the noise impact is greater on the perpendicular or the parallel wall will depend on the specific individual conditions. Once the most severely impacted wall or walls are determined, noise impacts may be minimized by reducing or eliminating windows from these walls.

Buildings can also be oriented on a site in such a way as to exploit the site's natural features. With reference to noise, natural topography can be exploited and buildings placed in low noise pockets if they exist. If no natural noise pockets exist, it is possible to create them by excavating pockets for buildings and piling up earth mounds between them and the noise. Such a structure would obstruct the sound paths and reduce the noise impacts on the residences.

Cluster and Planned Unit Development A cluster subdivision is one in which the densities prescribed by the zoning ordinance are adhered to but instead of applying to each individual parcel, they are aggregated over the entire site, and the land is developed as a single entity. A planned unit development, or P.U.D., is similar but changes in land use are included, such as apartments and commercial facilities in what would otherwise be a single-family district. Examples of grid, cluster and P.U.D. subdivisions follow in Figures 4.4, 4.5, and 4.6.

From Figure 4.4 it can be seen how the conventional grid subdivision affords no noise protection from the adjacent highway. The first row of houses bears the full impact of the noise. In contrast, the cluster and P.U.D. techniques enable commercial uses and open space respectively to serve as noise buffers. Examples of this are shown in Figures 4.6 and 4.7. A word of caution is necessary: in a cluster development, the required open space can be located near the highway to minimize noise to the residences. However, many recreation uses are noise sensitive, and when one takes advantage of the flexibility of cluster development to minimize noise, care must be taken not to use all of the available open space in buffer strips, thus depriving the development of a significant open space area. Where high noise levels exist, a combination of buffer strips and other techniques (such as berms and acoustical sound proofing) can be employed.

The flexibility of the cluster and planned unit development techniques allows many of the above site planning tech-

[1] Hans Bernard Reichow, "Town Planning and Noise Abatement," *Architect's Journal*, 137-7 (February 13, 1963) pp. 357-360.

[2] "Live-in Wall, 3,900 Feet Long, is Also a Sound Shield," *Engineering Record*, (September 6, 1973).

niques to be realized and effective noise reduction achieved.

4.2 Acoustical Architectural Design

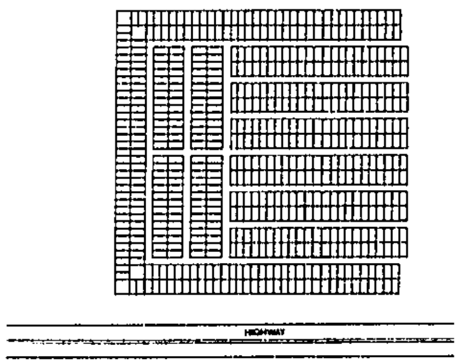
Noise can be controlled in a building with proper architectural design. By giving attention to acoustical considerations in the planning of room arrangement, placement of windows, building height, balconies, and courtyards, the architect may achieve significant noise impact reduction, without the need for costly acoustical construction.

Room Arrangement Noise impacts can be substantially reduced by separating more noise sensitive rooms from less noise sensitive rooms; and placing the former in the part of the building which is furthest away from the noise source. The less sensitive rooms should then be placed closest to the noise source where they can act as noise buffers for the more sensitive rooms.

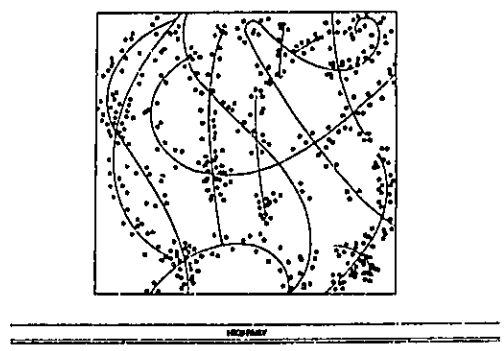
Whether or not a room is noise sensitive depends on its use. Bedrooms, livingrooms, and diningrooms are usually noise sensitive, while kitchens, bathrooms, and playrooms are less so. Figure 4.8 shows a layout designed to reduce the impact of highway noise. This technique was used extensively in England in a 100 acre residential development adjacent to a planned expressway.[1] Kitchens and bathrooms were placed on the expressway side of the building, and bedrooms and living rooms were placed on the shielded side. In addition, the wall facing the expressway is sound insulated.

Solid Walls Noise can be reduced by eliminating windows and other openings

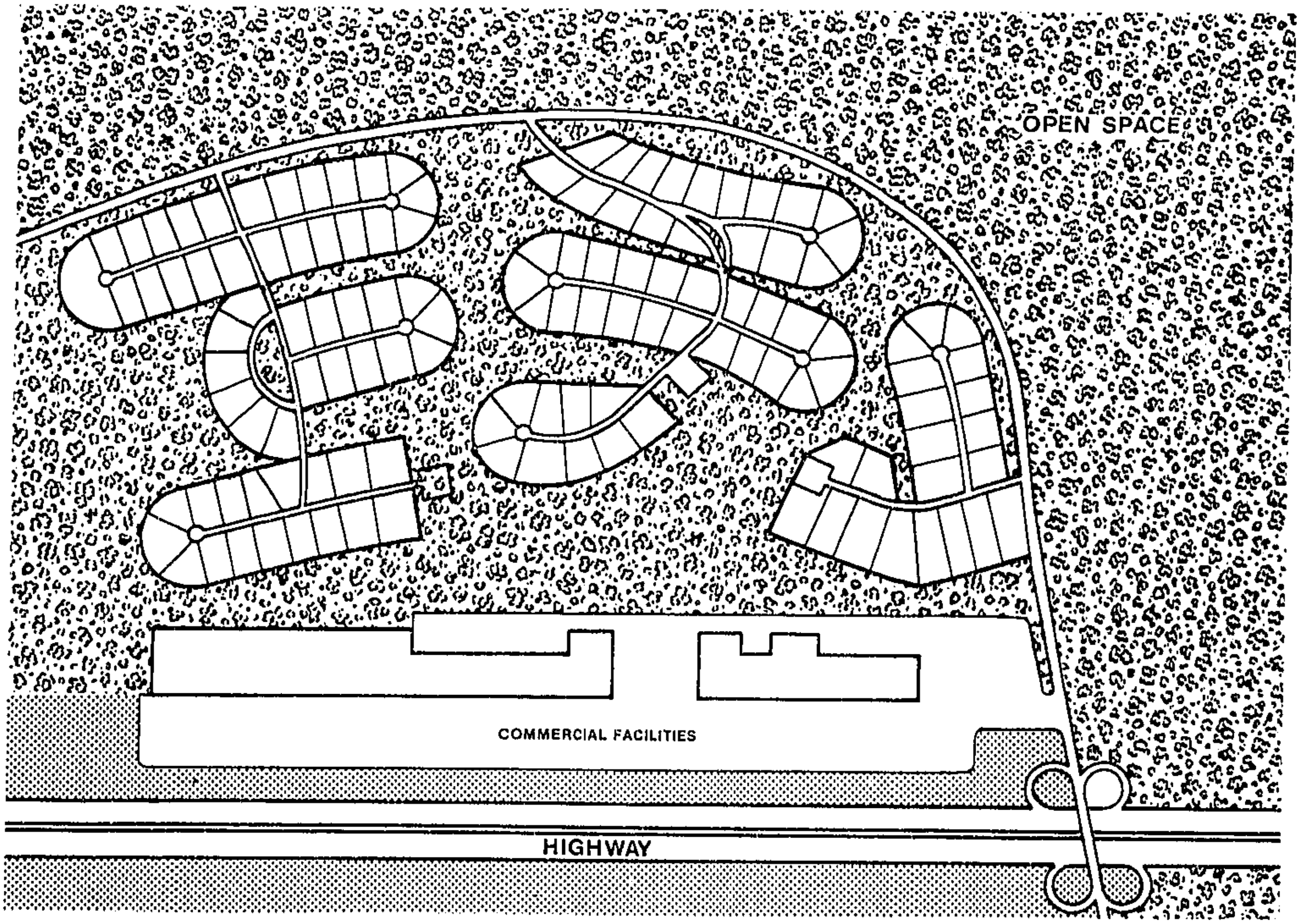
[1]"Live-In Wall is Also Sound Shield", *Engineering News-Record,* September 6, 1973.



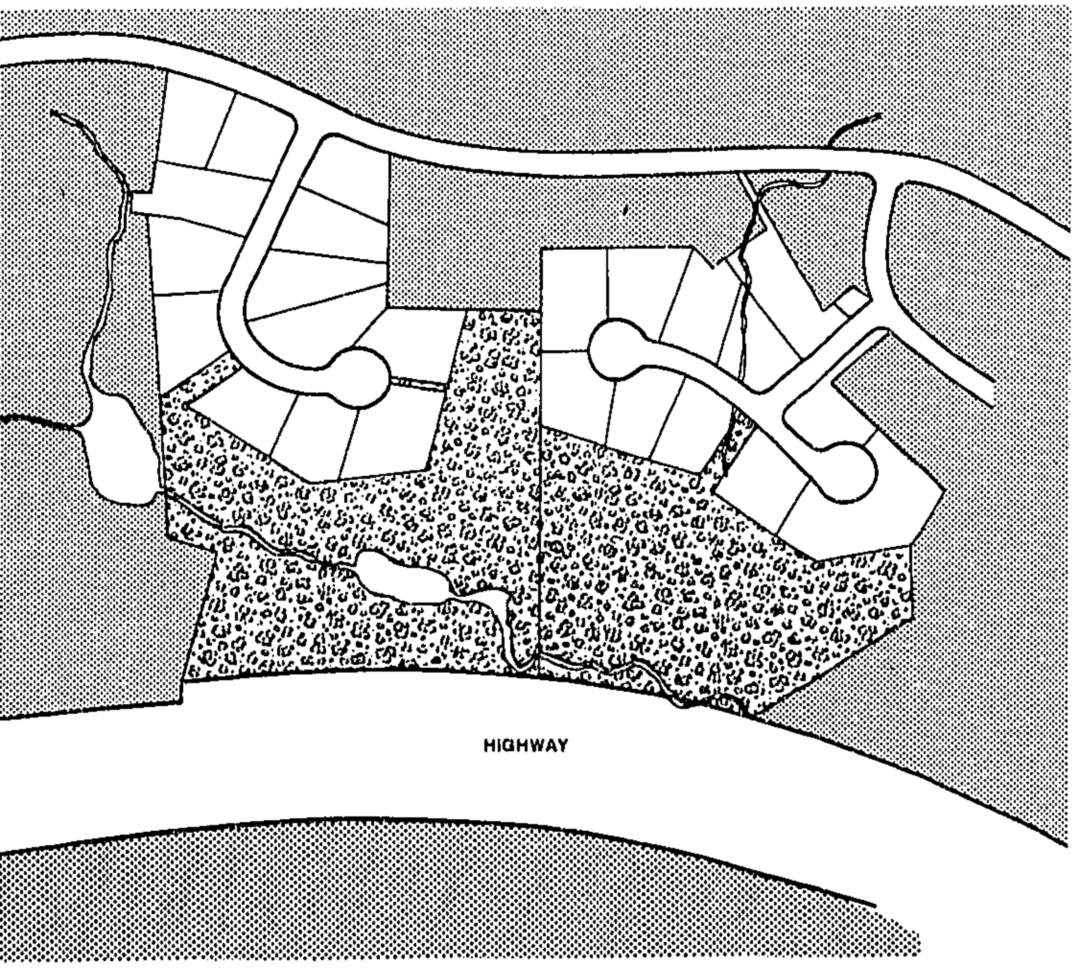
4.4 Conventional Grid Subdivision



4.5 Cluster Subdivision



4.6 Placement of noise compatible land uses near highway in Planned Unit Development



4.7 In cluster development, open space can be placed near the highway to reduce noise impacts on residences from the walls of a building close to noise sources. The solid wall can then have the effect of a sound barrier for the rest of the building. As previously discussed in Figure 4.1, walls directly adjacent, and those perpendicular to the noise source can be the most severely impacted. When a solid wall is impractical, illegal, or highly undesirable; the same effect can be achieved by reducing window size and sealing windows airtight. This technique is used in the housing project described above.[1]

One Story Houses In cases where either the house or the highway is slightly recessed or a barrier has been placed in the sound path, the noise impact may be further reduced if the house has only one story[2] (See Figure 4.9). If the single story design is inefficient, the split level design may be effective. In any case the path of the sound waves should be assessed before the building design is drawn.

Balconies If balconies are desired they should be given acoustical consideration. The standard jutting balcony, facing the road, may reflect traffic noise directly into the interior of the building in the manner illustrated in Figure 4.10. In addition to reflecting noise into the building, the balcony may be rendered unusable due to the high noise levels. This problem is particularly applicable to high rise apartment buildings where balconies are common. If balconies are desired, the architect may avoid unpleasant noise impacts by placing them on the shielded side of the buildings.

Courtyards Proper architectural design may also provide for noise reduction in an area outside of the building. The court garden and patio houses can provide outdoor acoustical privacy. (See Figure 4.11). Schools, rest homes, hotels, and multi-family apartment dwellings can also have exterior spaces with reduced noise by means of court yards.

4.3 Acoustical Construction

Noise can be intercepted as it passes through the walls, floors, windows, ceilings, and doors of a building. Examples of noise reducing materials and construction techniques are described in the pages that follow.

To compare the insulation performance of alternative constructions, the sound transmission class (STC) is used as a measure of a material's ability to reduce sound. Sound Transmission Class is equal to the number of decibels a sound is reduced as it passes through a material. Thus, a high STC rating indicates a good insulating material. It takes into account the influence of different frequencies on sound transmission, but essentially it is the difference between the sound levels on the side of the partition where the noise originates and the side where it is received. For example, if the external noise level is 85 dB and the desired internal level is 45 dB, a partition of 40 STC is required. The Sound Transmission Class rating is the official rating endorsed by the American Society of Testing and Measurement. It can be used as a guide in determining what type of construction is needed to reduce noise.

A) **Walls** Walls provide building occupants with the most protection from exterior noise. Different wall materials and designs vary greatly in their sound insulating properties. Figure 4.12 provides a visual summary of some ways in which the acoustical properties can be improved:

- Increase the mass and stiffness of the wall.
  In general, the denser the wall material, the more it will reduce noise. Thus, concrete walls are better insulators than wood walls of equal thickness. Increasing the thickness of a wall is another way to increase mass and improve sound insulation. Doubling the thickness of a partition can result in as much as a 6 dB reduction in sound.[3] However, the costs of construction tend to limit the feasibility of large increases in wall mass.

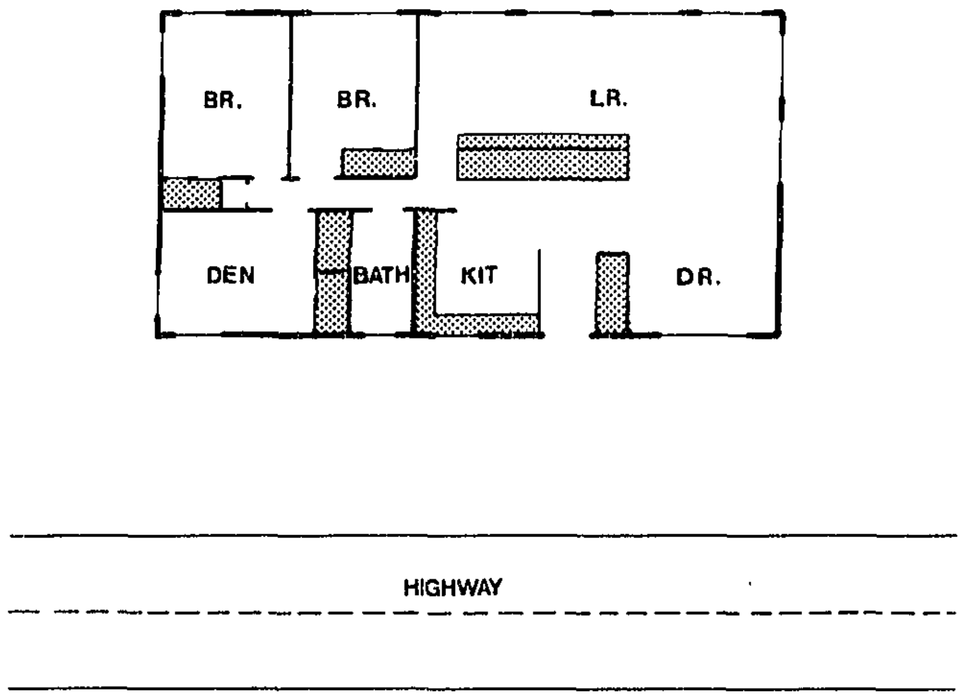
  The relative stiffness of the wall material can influence its sound attenuation value. Care must be taken to avoid wall constructions that can vibrate at audible frequencies and transmit exterior sounds.
- Use cavity partitions.
  A cavity wall is composed of two or more layers separated by an airspace. The airspace makes a more effective sound insulator than a single wall of equal weight, leading to cost savings.
- Increase the width of the airspace.
  A three inch airspace provides significant noise reduction, but increasing the spacing to six inches can reduce noise levels by an additional 5 dBA. Extremely wide air spaces are difficult to design.
- Increase the spacing between studs.
  In a single stud wall, 24 inch stud spacing gives a 2-5 dB increase in STC over the common 16 inch spacing.[4]
- Use staggered studs.

[1] "Live-In Wall . . ."

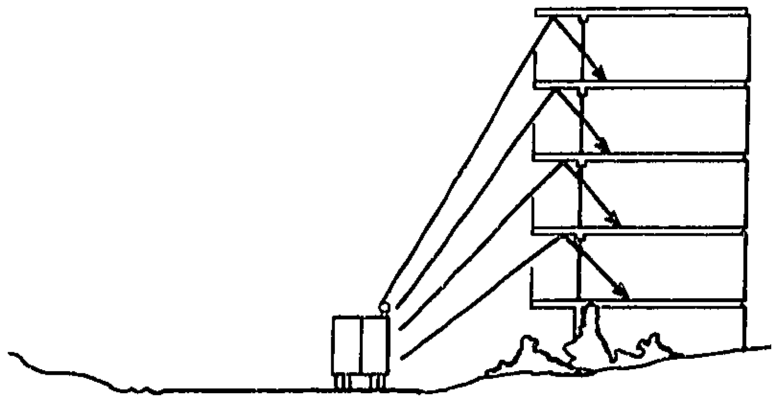
[2] This technique is used extensively in Cerritos, California.

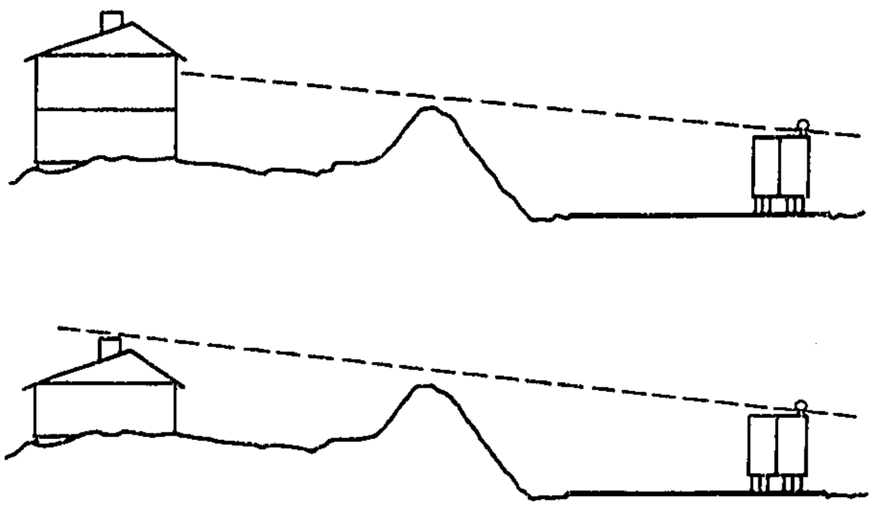
[3] R.K. Cook and P. Chrzanowski, "Transmission of Noise Through Walls and Floors," Cyril Harris, ed., *Handbook of Noise Control,* McGraw-Hill Book Company, Inc. (New York, 1957).

[4] Leslie T. Doelle, *Environmental Acoustics,* (New York, McGraw-Hill Book Company, 1972), pp. 232-233.



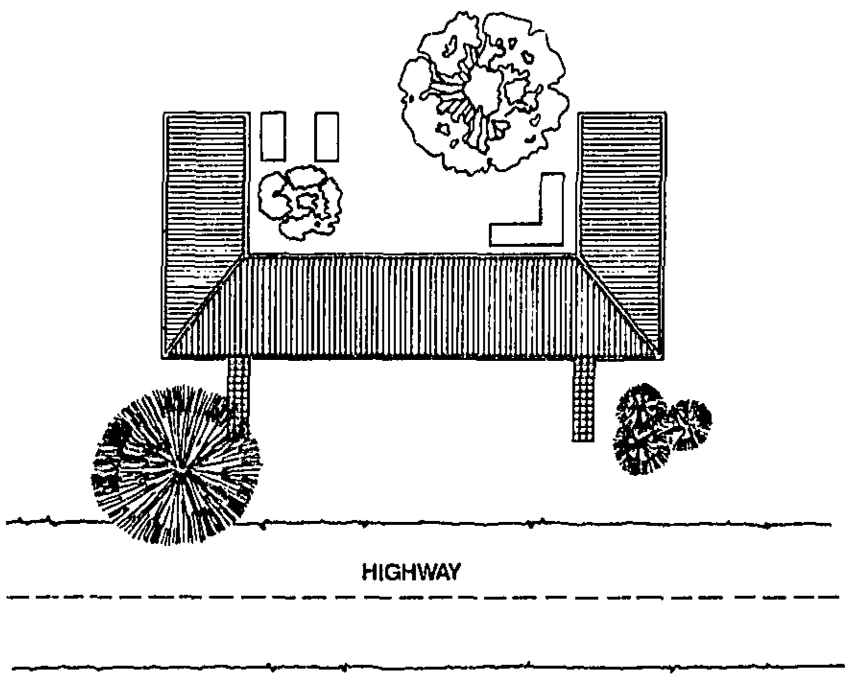
4.8 Use of acoustical architectural design to reduce noise impacts on more noise sensitive living spaces.



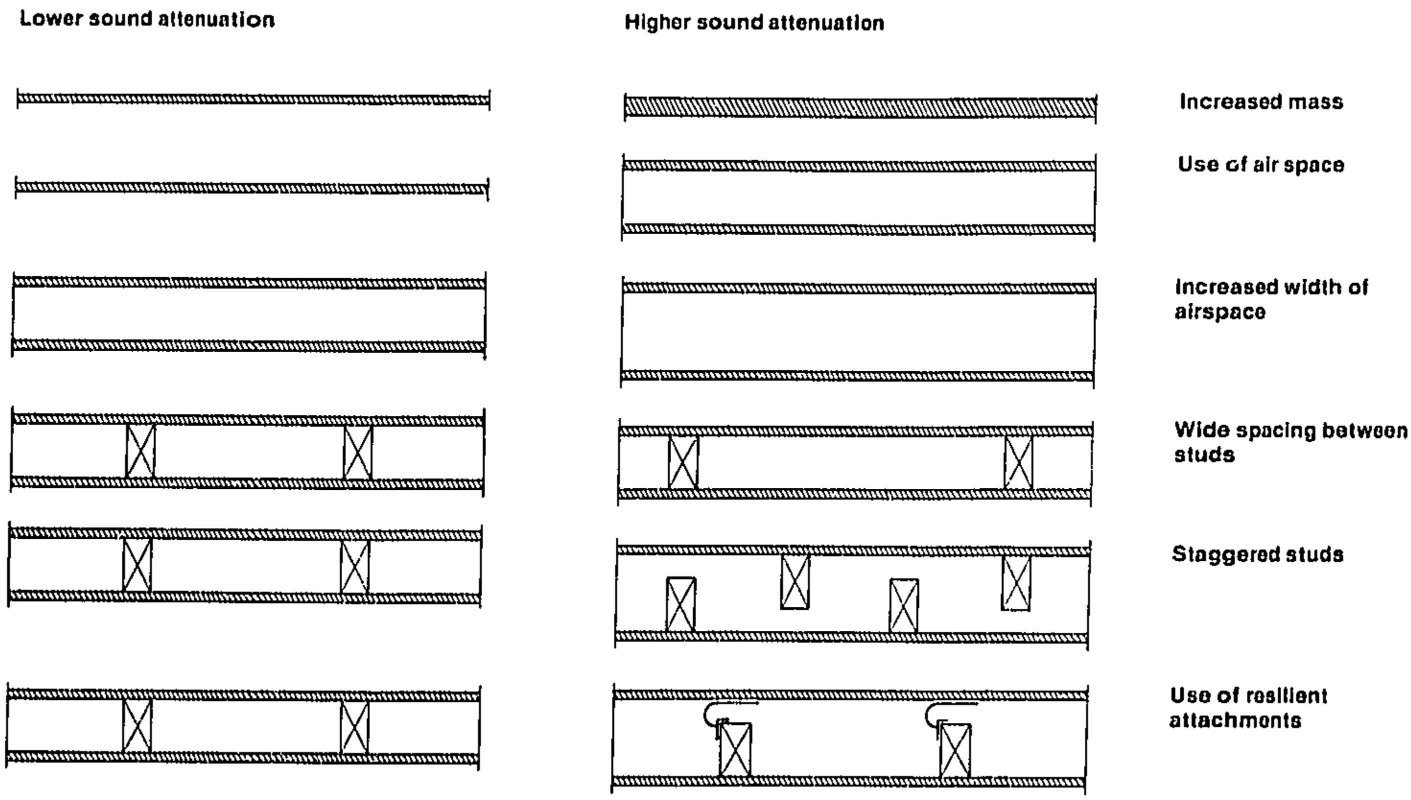


4.9 Noise impacts can be reduced by use of single story houses.

4.10 The standard jutting balcony facing the road may reflect traffic noise directly into the interior of the building.

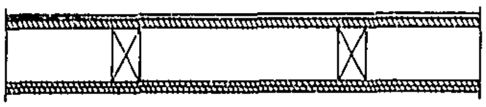


4.11 Use of courtyard house to obtain quite outdoor environment

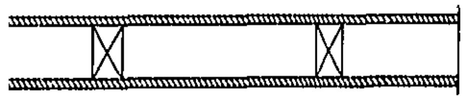


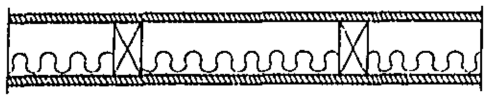
4.12 Factors which influence sound attenuation of walls wer sound attenuation

Higher sound attenuation

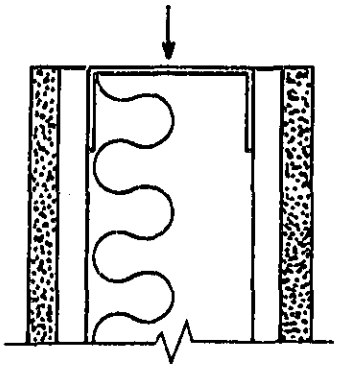


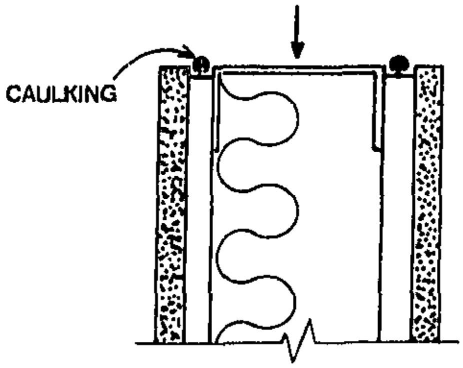
Dissimilar panels





Sound absorbing blanket
in airspace





Well sealed
cracks and edges

Sound transmission can be reduced by attaching each stud to only one panel and alternating between the two panels.

- Use resilient materials to hold the studs and panels together.
  Nails severely reduce the wall's ability to reduce noise. Resilient layers such as fiber board and glass fiber board, resilient clips, and semi-resilient attachments are relatively inexpensive, simple to insert, and can raise the STC rating from 2-5 dB.[1]
- Use dissimilar leaves.
  If the leaves are made of different materials and/or thicknesses, the sound reduction qualities of the wall are improved.[2]
- Add acoustical blankets.
  Also known as isolation blankets, these can increase sound attenuation when placed in the airspace. Made from sound absorbing materials such as mineral or rock wool, fiberglass, hair felt or wood fibers, these can attenuate noise as much as 10 dB.[3] They are mainly effective in relatively lightweight construction.
- Seal cracks and edges.
  If the sound insulation of a high performance wall is ever to be realized, the wall must be well sealed at the perimeter. Small holes and cracks can be devastating to the insulation of a wall. A one-inch square hole or a 1/16 inch crack 16 inches long will reduce a 50 STC wall to 40.[4]

  Figure 4.13 shows a sample of wall types ranging from the lowest to the highest sound insulation values. The cost of these walls in dollars per square foot is given for comparison of cost effectiveness.[5]

B) **Windows** Sound enters a building through its acoustically weakest points, and windows are one of the weakest parts of a wall. An open or weak window will severely negate the effect of a very strong wall. Whenever windows are going to be a part of the building design, they should be given acoustical consideration. Figure 4.14 illustrates the effects of windows on the sound transmission of walls. For example, if a wall with an STC rating of 45 contains a window with an STC rating of 26 covering only 20% of its area, the overall STC of the composite partition will be 33, a reduction of 12 dB.

The following is a discussion of techniques that can be used to reduce noise in a building by means of its windows. These techniques range from a blocking of the principal paths of noise entry to a blocking of the most indirect paths.

- **Close windows** The first step in reducing unwanted sound is to close and seal the windows. The greatest amount of sound insulation can be achieved if windows are permanently sealed. However, openable acoustical windows have been developed which are fairly effective in reducing sound.[6] Whether or not the sealing is permanent, keeping windows closed necessitates the installation of an air-conditioning system. The air conditioning system may in addition provide some masking of noise. (Masking is discussed below). If windows must be openable, special seals are available which allow windows to be opened.[7]
- **Reduce window size** The smaller the windows, the greater the transmission loss of the total partition of which the window is a part. Reducing the window size is a technique that is used because (a) it precludes the cost of expensive acoustical windows, and (b) it saves money by cutting down the use of glass. The problems with this technique are (a) it is not every effective in reducing noise; e.g., reducing the proportion of window to wall size from 50% to 20% reduces noise by only 3 decibels; and (b) many building codes require a minimum window to wall size ratio.
- **Increase glass thickness** If ordinary windows are insufficient in reducing noise impacts in spite of sealing techniques, then thicker glass can be installed. In addition, this glass can be laminated with a tough transparent plastic which is both noise and shatter resistant. Glass reduces noise by the mass principle; that is, the thicker the glass, the more noise resistant it will be. A ½-inch thick glass has a maximum STC rating of 35 dB compared to a 25 dB rating for ordinary 3/16 inch glass.

  However, glass thicknesses are only practical up to a certain point, when STC increases become too insignificant to justify the cost. For example, a ½ inch thick glass can have an STC of 35; increasing the thickness to ¾ inch only raises the STC to 37. However, a double glass acoustical window consisting of two 3/16 inch thick panes separated by an airspace will have an STC of 51 and can cost less than either solid window.

  In addition to thickness, proper sealing is crucial to the success of the window. To prevent sound leaks, single windows can be mounted in resilient material such as rubber, cork, or felt.
- **Install Double-Glazed Windows** Double-glazed windows are paired panes sepa-

[1] Ibid, p. 172.

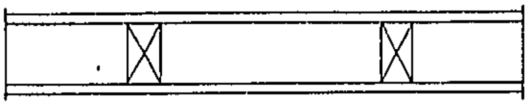
[2] Ibid, p. 162

[3] Doelle, p. 20.

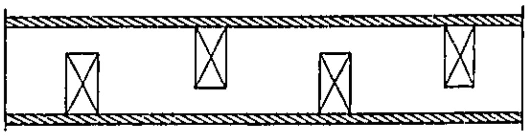
[4] United States Gypsum, *Sound Control Construction; Principles and Performance* (Chicago, 1972), p. 66.

[5] Costs taken from *National Construction Estimator, 1970-1*, 18th Edition, Craftsman Book Company (Los Angeles, 1970).

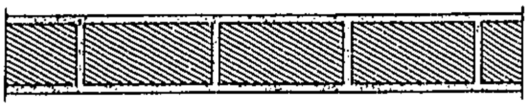
[6] U.S. Department of Housing and Urban Development, *A Study of Techniques to Increase the Sound Insulation of Building Elements*, Report No. WR 73-5, Washington, D.C., June 1973.



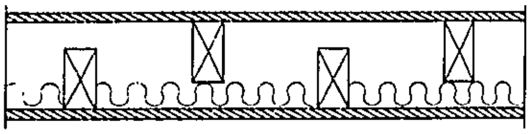
Common Stud Wall
STC = 35
cost = .87/ft²



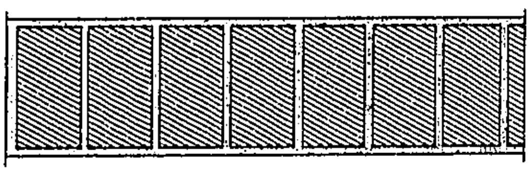
Staggered Stud Wall
STC = 39
cost = 1.12/ft²



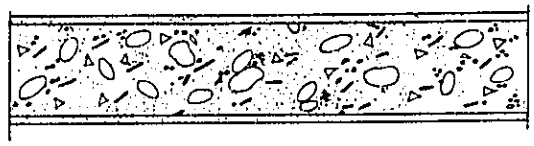
4" Brick Wall
STC = 40
cost = 2.00/ft²



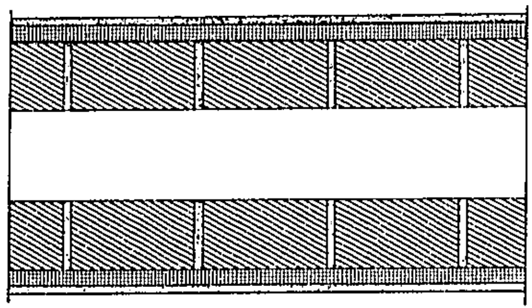
Staggered Stud Wall with Absorbent Blanket
STC = 43
cost = 1.25/ft²



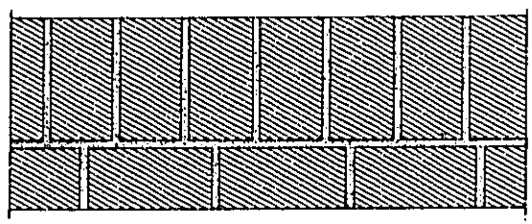
9" Brick Wall
STC = 52
cost = 2.52/ft²



7" Concrete Wall
STC = 52
cost = 1.97/ft²



Double Brick Wall
STC = 53
cost = 2.80/ft²



12" Brick Wall
STC = 54
cost = 4.25/ft²

4.13 Wall Types with STC Rating and Approximate Cost.

7 Los Angeles Department of Airports, *Guide to the Soundproofing of Existing Homes Against Exterior Noise*, Report No. WCR 70-2, March 1970, pp. 9-11, 22-30. In this report, the function and performance of a number of operable seals are described.

rated by an airspace or hung in a special frame. Generally, the performance of the double-glazed window may be increased with:

(a) increased airspace width
(b) increased glass thickness
(c) proper use of sealings
(d) slightly dissimilar thicknesses of the panes
(e) slightly non-parallel panes

In general the airspace between the panes should not be less than 2-4 inches if an STC above 40 is desired. If this is not possible, a heavy single-glazed window can be used. The use of slightly non-parallel panes is a technique employed when extremely high sound insulation is required, such as in control rooms of television studios.

The thickness of double-glazed panes may vary from 1/8 to 1/4 inch or more per pane. Although thickness is important, the factors which most determine the noise resistance of the window is the use of sealant and the width of the airspace.

As in the case of all windows, proper sealing is extremely important. To achieve an STC above 43, double-glazed windows should be sealed permanently. If the windows must be openable, there are available special frames and sealers for openable windows which allow a maximum STC of 43.[1]

Permanently sealed double-glazed windows often require an air pressure control system to maintain a constant air pressure and minimal moisture in the airspace. Without this system, the panes may deflect, and, in extremely severe cases, pop out of the frames.

To further insure isolation of noise between double-glazed panes, the panes could be of different thicknesses, different weights, and slightly non-parallel to each other. This prevents acoustical coupling and resonance of sound waves.

C) **Doors** Acoustically, doors are even weaker than windows, and more difficult to treat. Any door will reduce the insulation value of the surrounding wall. The common, hollow core door has an STC rating of 17 dB. Taking up about 20% of the wall, this door will reduce a 48 STC wall to 24 STC. To strengthen a door against noise, the hollow core door can be replaced by a heavier solid core door that is well sealed[2] and is relatively inexpensive. A solid core door with vinyl seal around the edges and carpeting on the floor will reduce the same 48 STC wall to only 33 dB.[3] An increased sound insulation value can be achieved if gasketed stops or drop bar threshold closers are installed at the bottom edge of the door. (See Figure 4.15)

The alternative solution to doors is to eliminate them whenever possible from the severely impacted walls and place them in more shielded walls.

D) **Ceilings** Acoustical treatment of ceilings is not usually necessary unless the noise is extremely severe or the noise source is passing over the building. The ordinary plaster ceiling should provide adequate sound insulation except in extremely severe cases. An acoustically weak ceiling which is likely to require treatment is the beamed ceiling.[4] Beamed ceilings may be modified by the addition of a layer of fiberglass or some other noise resistent material. Suspended ceilings are the most effective noise reducers but they are also the most expensive.

E) **Floors** In the case of highway noise, floors would only require acoustical treatment if the highway were passing under the building. In this case, flooring would have to provide protection against structural vibrations as well as airborne sound.

Two ways to insulate a floor from noise are to install a solid concrete slab at least 6 inches thick or install a floating floor. In general, the floating floor gives the greatest amount of sound and vibration insulation; however, it is extremely expensive. Basically, a floating floor consists of a wood or concrete slab placed over the structural slab, but separated by a resilient material. The resilient material isolates the surface slab from the structural slab and the surrounding walls.

F) **Interior Design** Overall interior noise levels can be reduced by the extensive use of thick, heavy carpeting, drapes, wall hangings, and acoustical ceiling tiles. These materials absorb sound. They cannot prevent noise from coming through the walls, but they can reduce overall sound levels by reducing sound reverberations.

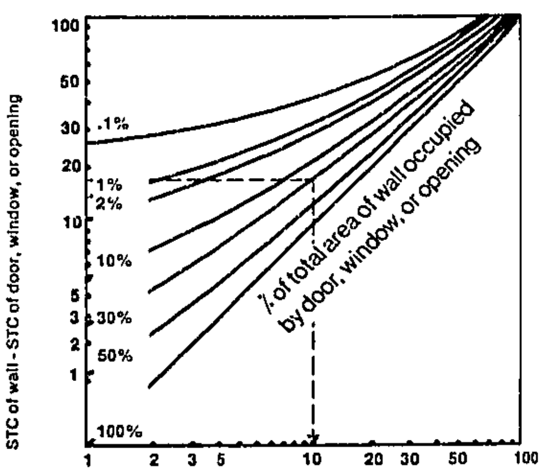
G) **Masking** Another way of coping with noise is to drown it out with background noise. This technique is known as masking. It can be very effective in reducing noise fluctuations which are often the most annoying aspects of noise. Masking can be produced by air conditioning and heating systems, soft music, or elec-

[1] *Ibid.*

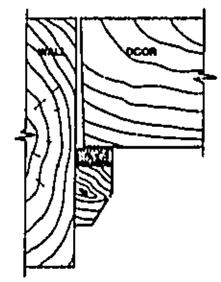
[2] D.E. Bishop and P.W. Hirtle, "Notes on the Sound Transmission Loss of Residential-Type Windows and Doors," *Journal of the Acoustical Society of America*, 43:4 (1968).

[3] U.S. Gypsum, *Sound Control*. . ., p. 100.

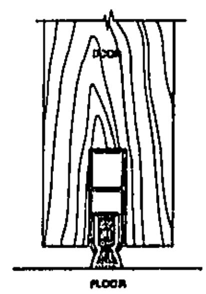
[4] *Ibid.*, p. 15.



Decibels to be subtracted from STC of wall to obtain effective STC of composite barrier.



Gasketed door stop



Drop bar threshold closer

4.14 Graph for calculating STC of composite barriers.

4.15 Increased sound insulation can be achieved with gasketed door stops or drop bar threshold closers.

tronic devices.

4.4 Barriers

A noise barrier is an obstacle placed between a noise source and a receiver which interrupts the path of the noise. They can be made out of many different substances:

a) sloping mounds of earth, called berms
b) walls and fences made of various materials including concrete, wood, metal, plastic, and stucco
c) regions of dense plantings of shrubs and trees
d) combinations of the above techniques

The choice of a particular alternative depends upon considerations of space, cost, safety and aesthetics, as well as the desired level of sound reduction. The effectiveness of the barrier is dependent on the mass and height of the barrier, and its distance from the noise source and the receiver. To be effective a barrier must block the "line of sight" between the highest point of a noise source, such as a truck's exhaust stack, and the highest part of the receiver. This is illustrated in Figure 4.16.

To be most effective, a barrier must be long and continuous to prevent sounds from passing around the ends. It must also be solid, with few, if any, holes, cracks or openings. It must also be strong and flexible enough to withstand wind pressure.

Safety is another important consideration in barrier construction. These may include such requirements as slope, the distance from the roadway, the use of a guard rail, and discontinuation of barriers at intersections.

Aesthetic design is also important. A barrier constructed without regard for aesthetic considerations could easily be an eyesore. A well designed berm or fence can aesthetically improve an area from viewpoints of both the motorist and the users of nearby land.

A) **Earth Berms** An earth berm, a long mound of earth running parallel to the highway, is one of the most frequently used barriers. Figure 4.17 shows a cross-section of a berm.

Berms can range from five to fifty feet in height. The higher the berm, the more land is required for its construction. Because of the amount of land required, a berm is not always the most practical solution to highway noise. Different techniques must be applied in urban as distinct from rural settings.

A berm can provide noise attenuation of up to 15 dBA if it is several feet higher than the "line of sight" between the noise source and the receiver. This is comparable to the noise reduction of various walls and fences which are used as barriers. However, earth berms possess an added advantage: instead of reflecting noise from one side of the highway to another, as walls do,[1] and thus increasing the noise heard on the opposite side, they deflect sound upwards. Figure 4.18 illustrates this phenomenon.

The cost of building a berm varies with the area of the country and the nature of the project. In California, the state-wide average for building a berm is about $1 per cubic yard when the earth is at the site.[2]

In planning a berm, one must include seeding and planting in figuring cost. Also to be included are land costs and maintenance in relation to erosion, drainage, snowplowing, mowing, and perhaps future seeding. It costs approximately $1,000 per acre per year to maintain a berm which is accessible to maintenance equipment.[3]

B) **Walls and Fences as Barriers** In addition to the more usual function of keeping people, animals and vehicles from entering the highway right of way at undesired locations, a properly designed fence or wall can also provide visual and acoustical separation between highway noise sources and adjacent land areas. This method can reduce noise as much as 15 dBA.[4]

The vertical construction and minimal width of walls and fences makes installation possible when space is severely limited. This is especially important when land costs are high, and where buildings are already adjacent to the highway. The advantages and disadvantages of wall and fence barriers are summarized in Figure 4.19.

The number of design variations for fence and wall barriers is virtually unlimited.

Acoustically, any solid continuous structure will suffice, provided that it is high enough, and provided that the barrier is of adequate mass and density.

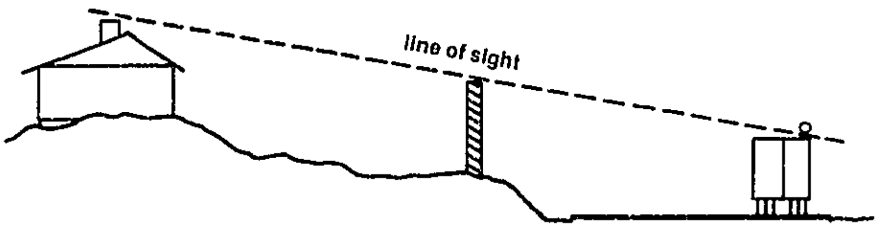
The cost of a fence or wall type barrier can vary considerably according to the type of construction, the material used, local availability of materials and skills, and the barrier's dimensions. Not all

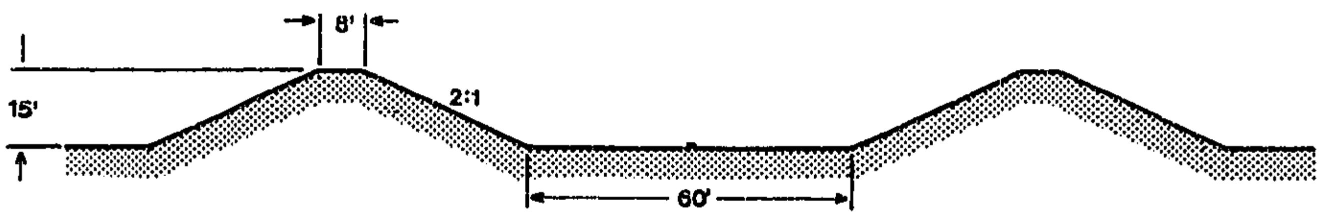
[1] Reflection of noise from one side of the highway to another can increase sound levels by 3 dBA. Scholes, Salvidge, and Sargent, "Barriers and Traffic Noise Peaks," *Applied Acoustics*, 5:3 (July 1972) p. 217.

[2] This estimate was provided by the California Highway Department.

[3] *Ibid.*

[4] California Division of Highways, *Highway Noise Control, A Value Engineering Study*, (October 1972).





4.16 To be effective, a barrier must block the "line of sight" between the highest point of a noise source and the highest part of a receiver.

4.17 Cross section of a berm

types of barriers are suited for all climates, and local conditions may cause significant differences in the maintenance cost of the various barrier types. The cost questions must be evaluated on a local basis.

Some of the frequently used materials for fence and wall construction are masonry, precast concrete, and wood.

Masonry noise barriers can be made of concrete blocks, brick or stone. A concrete block barrier might range in cost from $10 a linear foot for a 6-ft. high wall, to $75 a linear foot for a 12-ft. high wall. This latter figure includes a safety railing. In general, a concrete block wall would cost $50 to $60 a linear foot.[1] To alleviate the monotony of a long run of wall, pilasters can be used: a 20 ft. high concrete wall with pilasters might cost $300 per linear foot.[2] Brick and stone are extremely expensive and should only be used for special aesthetic considerations.[3]

Precast concrete panels offer opportunities for cost reduction. A 13' 4" high wall in Fairfield, California constructed of pre-cast concrete panels cost only $29.50 per linear foot.

Wood noise barriers are another possibility. They tend to be less expensive than other methods but are not as durable. An estimated cost for a 6' high 5/8" plywood fence is $5.00 per linear foot.[4]

C) **Plantings** Plants absorb and scatter sound waves. However, the effectiveness of trees, shrubs, and other plantings as noise reducers is the subject of some debate. Some conclusions can, however, be drawn:

- Plantings in a buffer strip, high, dense, and thick enough to be visually opaque, will provide more attenuation than that provided by the mere distance which the buffer strip represents. A reduction of 3-5 dBA per 100 feet can be expected. Shubs or other ground cover are necessary in this respect to provide the required density near the ground.
- The principal effect of plantings is psychological. By removing the noise source from view, plantings can reduce human annoyance to noise. The fact that people cannot see the highway can reduce their awareness of it, even though the noise remains.
- Time must be allowed for trees and shrubs to attain their desired height.
- Because they lose their leaves, deciduous trees do not provide year-round noise protection.

In general, plantings by themselves do not provide much sound attenuation. It is more effective, therefore, to use plantings in conjunction with other noise reduction techniques and for aesthetic enhancement.

The cost of plantings varies with the species selected, the section of the country, the climate, and the width of the buffer strip. For deciduous trees and evergreens, costs range from $10 to $50 a linear foot. The width of such a strip would be approximately 40 feet for deciduous trees and 20 feet for evergreens. Planting shrubs between the trees so as to form a dense ground cover would double the price.

D) **Combinations of Various Barrier Designs** Often, the most economical, acoustically acceptable, and aesthetically pleasing barrier is some combination of the barrier types previously discussed.

For example, the Milwaukee County Expressway and Transportation Commission feels that barriers constructed of pre-cast concrete on top of an earth berm provide maximum benefit for the cost.[5] They estimate that such a combination costs $51 per linear foot.

In addition to cost advantages, an earth berm with a barrier wall on top of it possesses several other advantages over both a wall or a berm alone: 1) it is more visually pleasing than a wall of equivalent height; 2) the berm portion of this combination is less dangerous for a motorist leaving the roadway; 3) the non-vertical construction of the berm does not reflect noise back to the opposite side of the highway the way a wall does; 4) the combination requires less land than would be required for a berm of equivalent height and slope; and 5) the wall provides a fencing function not provided by a berm.

Another combination to be considered is that of plantings in combination with a barrier. Not only do plantings and ground cover provide some additional noise attenuation, but they also increase visual appeal.

4.5 Conclusion

Figure 4.19 provides a summary of the physical techniques which can be used by designers, builders, and developers to reduce highway noise impacts. Some

[1] Figure provided by an official of the California Highway Department.

[2] Representative cost estimates of materials and labor of construction but excluding real estate acquisition; private

[3] California Division of Highways, *Highway Noise Control, Value Engineering Study*, (October 1972), p. 33.

[4] California Division of Highways, *Highway Noise Control, Value Engineering Study*, (October 1972) p. 46.

[5] Milwaukee County Expressway and Transportation Commission, *Noise Impact Study of the Airport Spur*, V. II: *Technical Report*, (March 1973), pp. 7-21.

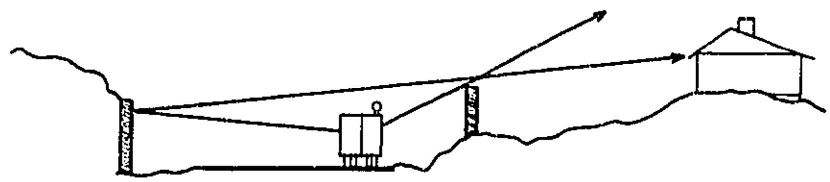
conclusions follow which may be useful in getting them implemented.

As is indicated by the chart below, five factors which must be considered in the selection of noise reduction measures include the following:

1) Noise reduction desired
2) Situation where the physical technique would be most effective
3) Cost
4) Relevant administrative techniques
5) Aesthetics

Noise Reduction The physical techniques discussed vary in their noise reduction capabilities. For example, the effectiveness of the less expensive techniques, such as site planning and acoustical architectural design, is limited to situations where there is some distance between the buildings and the noise source. If the noise source is nearby and significant noise reduction is desired regardless of the expense, then more expensive measures, such as acoustical soundproofing and barrier construction, may be necessary.

Situation where a technique is most applicable The applicability of a technique is determined by the population density of an area and the point in the development process at which the technique is to be used, i.e., its timing. In a densely populated area, site planning (perhaps in conjunction with construction of a berm and a region of plantings) can often solve the noise problem. In a high density area where land is scarce and expensive, a better alternative would be barrier construction and acoustical soundproofing of the buildings.



4.18 Wall barriers may reflect sound from one side of the highway to the other.

Physical Technique	Potential Effectiveness	Situations Where Most Effective
Acoustical Site Planning	Good-excellent: depends on size of lot and natural terrain	Before building construction, before subdivision development
Acoustical Architectural Design	Fair	Before building construction
Acoustical Construction	Excellent for interior, poor for exterior	During building construction best. More costly after construction
Barriers	Fair-excellent, depends on height and mass	Varies with type of barrier
Earth Berms	Good-excellent	Best during road construction when earth is available. Costly after road construction. Impractical in densely populated areas where land is scarce.
Walls and Fences	Poor-excellent, depends on height and mass	Any time
Plantings	Poor	After road construction After building construction
Combinations	Good-excellent	Depends on particular combination

4.10 Summary of Physical Techniques to Reduce Noise Impacts

Cost	Relevant Administrative Technique	Comments
Low, only costs are fees of acoustical consultant and site planner	Zoning, subdivision rules, building code	Fairly inexpensive but requires space which may be unavailable. Has limited sound reduction. Positive aesthetic impacts.
Low: only cost is that of acoustical consultant	Building code* Health code	Low cost but limited effectiveness
Varies with amount of noise reduction desired but generally high, especially after construction	Building code* Health code	Most effective noise reduction for interiors, but very costly. Note that exterior noise levels are not reduced. Individual components (acoustical walls, windows, ceilings, doors) must be used together to be effective.
Moderate-high: varies with type of barrier, see below.	Zoning, subdivision rules, health code	High noise reduction and potentially low cost. Achieves exterior noise reduction. Can have adverse aesthetic impacts.
Moderate-high: depends on availability of earth		Good noise reduction properties and aesthetic appeal, but requires space and requires maintenance
Low-high: depends on height and thickness		Requires little space and no maintenance, but may be aesthetically unappealing and can reflect noise to other side of road.
Moderate-high: depends on size of buffer strip		Poor noise reduction but often necessary for aesthetic appeal. Best used in combination with other techniques
Moderate-high: depends on type barriers used.		Potentially high noise reduction and aesthetic appeal.

*Administrative techniques which can achieve any physical technique are health codes, occupany permit procedures, architectural review boards, and municipal design services.

The timing of a technique also determines whether or not it is applicable. There are three points at which physical noise reduction measures can be used: in the planning phase; during building construction; and after construction. Techniques applicable during the planning phase include acoustical site planning and acoustical architectural design. During the construction phase, those techniques most applicable for highways are berms and barriers, since building materials are available at the site; and during building construction the most appropriate measure is acoustical soundproofing. It is possible to undertake noise reduction measures after construction, but costs are much higher.

Cost Cost is a very important consideration in the selection of a physical noise reduction technique. Generally, cost is determined by the amount of noise reduction desired and whether the noise measure is a preventative or ameliorative one.

The most effective noise reduction measures are often the most expensive. These include barrier construction and acoustical soundproofing. However, if action is taken as a preventative measure in the planning stage, there is often no need for the more expensive techniques.

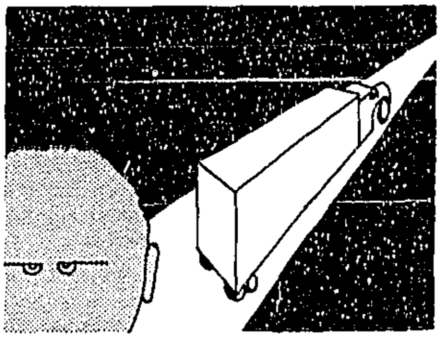
Relevant administrative techniques All these physical techniques depend upon administrative actions for implementation. It is possible that physical measures to reduce noise would be taken without local government action, but since they involve extra expense, it is unlikely that they would be adopted on any significant scale. Many administrative means exist to achieve each physical noise reduction technique. For example, a noise impacted area can be zoned to specify details of development design or construction. In such an area, buffer strips (acoustical site planning), acoustical arrangement of living spaces (acoustical architectural design), building insulation (acoustical construction techniques), and barrier construction could be required. Similar requirements could be included in the subdivision laws. Building and health codes, enforced by withholding an occupancy permit, are effective ways to bring about acoustical soundproofing. As explained in the section on Building Codes, particular acoustical construction materials can be required or specific performance standards established.

Aesthetics Aesthetic and quality of life considerations are another important area of concern. They depend largely on local preferences and climate, and opinions of what is aesthetically pleasing will vary among communities.

Whatever the aesthetic judgement, aesthetic considerations must be incorporated into the planning and construction process to insure that the solution which results is not offensive to the community. This can save a great deal of time and money in the long run.

Finally, it should be stressed that no single technique or combination of techniques is best for all situations, and that technique which is best will depend on the nature of the project. The factors which are discussed above (i.e., noise reduction, cost, applicability, and aesthetics) must be balanced against each other to determine which technique or combination of techniques will be most effective in a given situation.

5 How To Implement a Noise Compatible Land Use Control Program



This section is intended to help local government officials actually institute a noise compatibility land use control program which would use one or more of the administrative techniques discussed in Section 3 to bring about chosen physical methods discussed in Section 4. Accordingly, this section is divided into three parts:

1) An outline of two strategies that can be followed, based on the urgency of the situation.
2) A discussion of some of the problems that may be faced in implementing a noise compatibility land use control program.
3) A collection of sources of further information.

5.1 Stages of Implementation

The actual effort necessary to determine and implement a noise compatibility control program for a specific community involves analysis of the various possible physical and administrative techniques in order to choose the combinations that will best suit the local situation. This work can be done by an elected official, by a member of the municipal staff or by a citizen committee appointed specifically for this reason. The amount of analysis and the type of action taken in this effort is dictated primarily by the urgency of the community's potential noise incompatibility problem:

1) Immediate stopgap response is necessary in situations where development of incompatible land uses is underway or is contemplated in the near future. Under this strategy a community quickly institutes regulations which tend to temporarily prevent incompatible development. This is done as a holding action to give the community time to consider and adopt a more permanent noise control program. Immediate stopgap response is not an ideal strategy, but it may be the only option open to a community.

- Stopgap procedures which are legal in some states include:
- Zoning all undeveloped land for agricultural use
- Zoning all land adjacent to the highway for industrial use
- Institution of a moratorium on all construction until a master plan or new zoning or other regulations can be formulated and adopted
- Passing strict zoning, subdivision, or building codes which might discourage development.

2) Normal administrative implementation is the strategy that most communities will probably follow. It allows for orderly analysis of the potential incompatibility problems, the available physical solutions, and the possible administrative techniques. Analysis can be made to determine which combination of tech-

niques can best solve the community's noise compatibility problems at a reasonable cost.

Another dimension can be added to the administrative process by the inclusion of master planning. Master planning provides the important advantage of considering the various noise compatibility control options as part of a larger set of community goals and plans. As such, master planning can identify and avoid situations where certain noise compatibility control measures would conflict with other community goals.

In its master plan, a community or regional planning agency can guide the development of the town or region to minimize noise impacts. For example, it can recommend that industrial and commercial uses and open space recreational areas be located along highways, and residential areas be placed in quieter zones. Linear parks along a highway can provide needed open space for the community and natural beauty for the passing motorist. They can also provide a good use for land which is too noisy for residential development. An example of an effective use of linear parks with playgrounds, biking and hiking trails, and ponds is shown in Figure 5.1.

Master planning does have some significant drawbacks which make it impractical to implement in all communities.

- Because it is an expensive process, it should not be undertaken solely to promote noise compatible development, but should apply to all aspects of the community's land use policies and objectives.
- It is a long process inappropriate in situations where the development of incompatible land uses is imminent.
- A master plan has no power of enforcement and is frequently ignored during subsequent municipal decision-making situations. Thus the recommendations of the master plan may never come to exist. And no matter how well the municipal future is planned a master plan is worthless if it is not implemented.

Inclusion of noise compatibility land use control considerations into any local master planning effort is most desirable. It is not, however, adequate unless the administrative controls necessary to implement the master plan are adopted and immediate noise incompatibilities are dealt with.

A strategy of normal administrative implementation can be divided into five major phases:

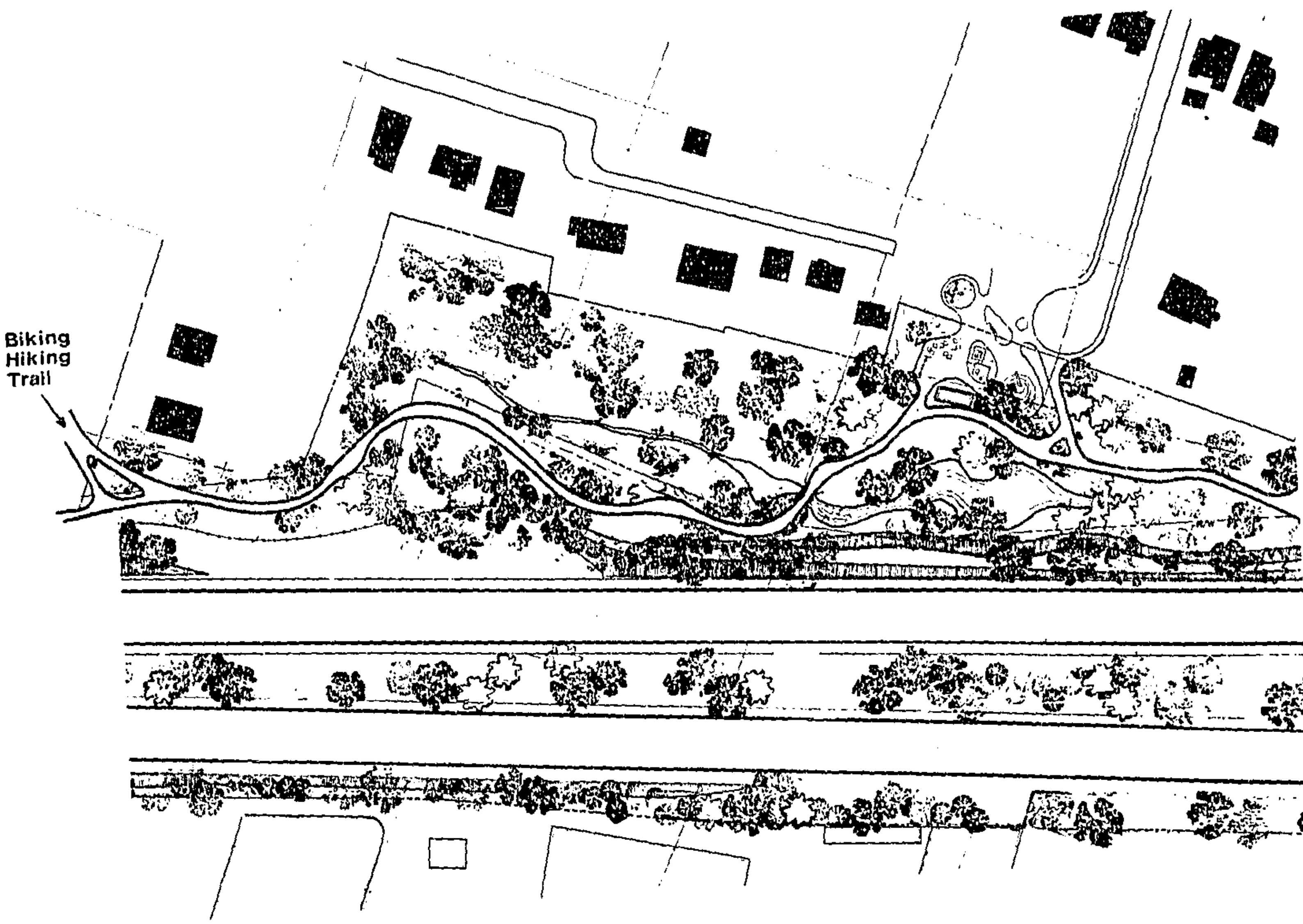
a) Problem identification
b) Examination and selection of administrative techniques suited to the locality
c) Study of legal status
d) Seek state legislative changes where necessary
e) Implementation

Timing is crucial in this strategy. Several of the most desirable physical solutions, such as buffer strips, acoustical site design, and acoustical construction methods, become impractical or impossible once incompatible land uses have been located near highway noise sources. Also, many of the administrative techniques such as zoning are not applicable once development has started or has reached the advanced planning stage. Thus, it is most important for a community to begin its noise compatible land use control program well before the potential incompatibilities exist.

Identify the Problem Existing and potential noise incompatibilities can be identified by determination of both noise levels and potential land uses in noise impacted areas. Usually this can be done without employing an acoustical consultant, and often the larger and better staffed localities may wish to have their own measuring equipment. Noise levels often can be determined from state highway department data. If some technical skill is available within the municipal staff, the noise predictors listed later in this section will be helpful.

The master planning process can provide assistance at this point by providing an inventory of existing and potential land uses in noise impacted areas and by defining noise compatibility goals for the community. Typically these goals will be based both on ideal compatibility standards and on realistic practical limitations imposed by the local conditions. Hence, the earlier the planning process is started, the less restrictive these limitations will be.

Examination and Selection of Administrative Techniques Suited to the Locality The existing local administrative structure should be studied to see which of the administrative techniques listed in Section 3 of this manual are presently possible. If an existing administrative structure exists capable, with minor change, of implementing the most desirable physical solutions, the implementation process becomes relatively easy. For example, if the community is experiencing rapid growth and developers are



5.1 Linear parks along a highway can provide needed open space for the community and natural beauty for motorist.[1]

[1]Provided by Environmental Planning and Design of Pittsburgh

anxious to build, the town's subdivision rules and regulations could be rewritten to incorporate noise reduction considerations, and building permits could be made contingent upon strict compliance.

Study of Legal Status If existing administrative structures are not capable of implementing the most desirable physical solutions, the next step would be to determine what administrative mechanisms could be set up under the state's laws.

For example, a community might be able under state law to assess undeveloped land at a low value, thus providing a financial incentive. Or, a community might decide to adopt zoning or subdivision control to implement noise compatibility control. If the necessary administrative procedures are not permitted by state enabling acts, pressure can be applied to revise the state legislation.

Implementation If an acceptable new administrative technique can be adopted capable of implementing noise compatibility control programs, the implementation process now becomes relatively easy. What is needed, however, is constant re-evaluation of the noise compatibility goals and possibly the master plan.

5.2 Problems of Implementation

The problems posed by the introduction of incompatible land uses to areas near existing noise sources—highway or otherwise—are significant in terms of economics, health, and quality of life. The solutions available are many, especially before any land development has taken place. It would seem that this combination of significant potential problems and readily available solutions is a clear indicator that the goals of the manual will be achieved rapidly in all parts of the country.

However this may not be the case: The obstacles to the implementation of this manual are many and must be overcome if noise-compatible land use development is to be possible. They include:

- public apathy
- limitations under state laws
- financial cost to the municipal government
- negative physical and aesthetic side effects
- opposition with private interests
- conflicts with local tradition

Public Apathy It is an unfortunate fact that little public awareness of noise incompatibility exists. The resulting apathy makes it difficult for officials to implement noise compatibility programs, especially when high municipal costs or extensive restrictions are involved. The term "noise pollution" is a relative newcomer to popular environmental jargon, having got a much slower start than air and water pollution. It is now becoming increasingly more the subject of public attention. Perhaps this increasing public awareness will soon overcome existing apathy. Until then, local officials can make efforts through the press or through citizens' groups to inform the public of the significant financial and social costs of noise incompatibility.

Legal Limitations Legal limitations exist on powers of local governments to restrict and regulate land use control. The powers granted by state enabling acts vary greatly from state to state. Such things as occupancy permits, required environmental impact statements, and incentive tax assessments are not legal in all states. This obstacle can only be overcome by action in the various state legislatures.

Cost The adoption and enforcement of any regulation or restriction will entail administrative costs. This can include legal costs and court ordered payments if lawsuits result from improper administration of regulations. Finally, the costs of municipal land purchase can be significant.

A careful choice of administrative noise compatibility control techniques can minimize these costs. Often a combination of techniques is less expensive than a single technique. For example, a policy of zoning restrictions combined with municipal purchase of only the most threatened land is far less costly than a policy of massive municipal purchase. Likewise, the costs of administering and enforcing a health code noise regulation could be lessened if the community also had an architectural review board which inspired builders to voluntarily construct noise compatible dwellings.

Negative Side Effects While some noise impact reduction techniques, such as linear parks in a buffer zone, are aesthetically pleasing, other techniques, such as high barrier walls, can be eyesores. Likewise, the sealed environment within an acoustically insulated house, or the enclave effect created by extensive barrier walls can be quite displeasing to the residents. All of these negative physical effects can be overcome in many instances if planning for a noise compatibility control program is begun early enough to allow a wide variety of physical techniques and if the administrative structure is such that a choice can be made between the various physical techniques. However, in situations where there is an inflexible administrative system or extensive existing development, the limited choice of physical techniques will make some negative side effects *unavoidable.*

Private Interests Most noise compatibility control programs inevitably restrict the options available to builders, developers, and owners of land near a highway. As such, these people will have a natural opposition to the program and may exert pressure against its adoption. This opposition can be neutralized by seeing that the restrictions are limited to only those that are necessary, offering practical alternatives such as cluster development, and by informing the public of the relevant issues thus enlisting public support for the program.

Tradition Lastly, a noise compatibility land use control program may represent a sharp break with established local tradition. Zoning, restrictive codes, municipal land purchase, and various physical techniques all may be new concepts in a community. Such traditions are often tenaciously held, and an extensive public information effort may be required to break them. Usually, a clear knowledge of all of the effects of a program will lessen the public fears associated with it.

5.3 Other Sources of Information For additional information on issues of highway noise control, there are a number of useful sources which provide comprehensive information in the areas of acoustics, the effects of noise, noise standards, prediction techniques, impact reduction techniques, and noise control legislation.

The Fundamentals and Abatement of Highway Traffic Noise[1] is an excellent general text on highway noise providing basic technical information on most of the areas mentioned above. For a less technical, more general review of acoustics and noise control, *Noise*[2] by Rupert Taylor is highly recommended. Two texts which provide a comprehensive review of findings on the effects of noise are *Noise as a Public Health Hazard - Proceedings of the Conference*,[3] a publication of the American Speech and Hearing Association; and the *Report to the President and Congress on Noise.*[4] *Community Noise*[5] contains information on the community's reaction to noise. A review of studies to determine compatible noise levels is contained in *Evaluating the Noise of Transportation; Proceedings of a Symposium on Acceptability Criteria for Transportation Noise.*[6]

For a review of Federal Noise Standards, see (a) *The Noise Control Act of 1972,*[7] (b) HUD Circular 1390.2, "Noise Abatement and Control, Department Policy and Implementation Responsibilities and Standards,"[8] and (c) the FHWA Policy and Procedure Memorandum 90-2: "Noise Standards and Procedures."[9]

Two highway noise prediction techniques are described respectively in (a) *Manual for Highway Noise Prediction,*[10] and (b) National Cooperative Highway Research Program Report #117, *Highway Noise: A Design Guide for Highway Engineers.*[11]

Texts on physical techniques for noise impact reduction tend to concentrate on specific techniques. A relatively comprehensive text on physical techniques is *Environmental Acoustics*[12] by Leslie T. Doelle. This book contains acoustical information on site planning, architectural design, and building construction. The *Handbook of Noise Control*[13] also provides a somewhat comprehensive coverage of noise control techniques. It is particularly useful for the article on acoustical construction entitled "Transmission of Noise Through Walls and Floors" by R.K. Cook and P. Chrzanowski. Two important documents on acoustical construction techniques are *Guide to the Soundproofing of Existing Homes Against Exterior Noise,*[14] and *A Study of Techniques to Increase the Sound Insulation of Building Elements.*[15]

For extensive descriptions of various types of noise barriers, see *Highway Noise Control: A Value Engineering Study.*[16] *The Fundamentals and Abatement of Highway Traffic Noise* described above also contains an informative discussion on barriers. For a comprehensive overview of the use of plants in design and noise control, see *Plants, People, and Environmental Quality.*[17]

Although it is not directed at noise control, *Cluster Zoning in Massachusetts*[18] contains useful illustrations of cluster zoning techniques, some of which can be used to reduce highway noise impacts.

Informative literature on administrative techniques for local government noise compatible land use control is scarce.

The most helpful literature for further study in this area is legislation.

On the Federal level, the *National Environmental Policy Act of 1969*[19] requires environmental impact statements, which include noise impacts, for certain Federal projects. On the state level, local governments should review their state enabling acts that allow the various administrative techniques described in Chapter 3. In addition, the State of California's Environmental Quality Act[20] provides an example of a state requirement for environmental impact statements for all public and private development.

Some local legislation which may be useful as examples of noise compatible land use control are the *Development Standards for the City of Cerritos*,[21] and the *Health Code* of Orange County.[22] These and others are discussed in more detail in Chapter 3.

Footnotes

1 U.S. Department of Transportation, Federal Highway Administration, *Fundamentals and Abatement of Highway Traffic Noise*, June 1973, Report No. FHWA-HHI-HEV-73-7976-1.

2 Rupert Taylor, *Noise*, Dell, 1970.

3 W. Dixon Ward and James E. Fricke, eds. *Noise as a Public Health Hazard—Proceedings of the Conference*, ASHA Reports 4, The American Speech and Hearing Association, Washington, D.C., Feburary 1969.

4 U.S. Congress. Senate. *Report to the President and Congress on Noise*, S. Doc. 92-63, 92nd Congress, 2d session, 1972.

5 U.S. Environmental Protection Agency, *Community Noise*, December 31, 1971. Report No. 69-04-0046.

6 Chalupnik, James D. (ed.), *Evaluating the Noise of Transportation; Proceedings of a Symposium on Acceptability Criteria for Transportation Noise*, Washington, D.C., April 1970.

7 *Noise Control Act of 1972*, P.L. 92-574 October 27, 1972.

8 Department of Housing and Urban Development, HUD Circular 1390.2, "Noise Abatement and Control, Departmental Policy Implementation Responsibilities and Standards," Washington, D.C., August, 1971.

9 U.S. Department of Transportation, Federal Highway Administration, Policy and Procedure Memorandum 90-2, "Noise Standards and Procedures," Transmittal 279, February 8, 1972.

10 U.S. Department of Transportation, Transportation Systems Center, *Manual for Highway Noise Prediction—Technical Report*, Washington, D.C., 1972.

11 *National Cooperative Highway Research Program Report #117, Highway Noise: A Design Guide for Highway Engineers*, Washington, D.C., 1971.

12 Leslie T. Doelle, *Environmental Acoustics*, McGraw-Hill, New York, 1972.

13 Cyril M. Harris, ed., *Handbook of Noise Control*, McGraw-Hill, New York, 1957.

14 Los Angeles Department of Airports, *Guide to the Soundproofing of Existing Homes Against Exterior Noise*, Report No. WCR-70-2, March 1970.

15 U.S. Department of Housing and Urban Development, *A Study of Techniques to Increase the Sound Insulation of Building Elements*, June 1973, Report No. NR-73-5.

16 California Division of Highways, *Highway Noise Control: A Value Engineering Study*, October 1972.

17 U.S. Department of the Interior, *Plants, People, and Environmental Quality*, 1972.

18 Kulmala, Katharine A. (with the Planning Services Group, Inc.), *Cluster Zoning in Massachusetts*, Cambridge, Massachusetts, 1970.

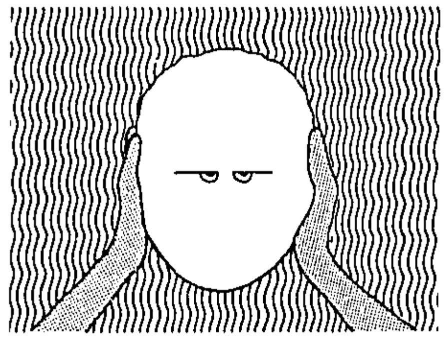
19 *National Environmental Policy Act of 1969*, p. 6, 92-574 (October 27, 1972)

20 State of California, *California Administrative Code*, Title 14. Natural Resources, Division 6, Chapter 3.

21 City of Cerritos, California, *Development Standards of the City of Cerritos*.

22 Orange County, *Health Code*.

Appendix A: Case Studies



The discussions of administrative techniques and physical methods in earlier sections of this manual emphasized the need to consider specific local conditions in selecting an effective strategy for reducing highway noise impacts. To illustrate variations in community requirements and to evaluate some strategies that have been or might prove to be effective, case studies of three communities' efforts to control noise impacts were carried out as part of the preparation of the manual. Within each community, a parcel of undeveloped noise impacted land was chosen for specific focus. The communities selected—Somerville, Massachusetts; Cerritos, California; and Marshfield-Pembroke, Massachusetts—represent widely divergent population densities, community backgrounds and goals, political environments, state laws, and topographical characteristics. From these case studies, it can be seen how these factors shape the noise reduction strategies chosen and their relative successes.

Population density seems to be a major determinant of a community's strategy. The low density of Marshfield-Pembroke, the medium density of Cerritos, and the high density of Somerville clearly are reflected in the three respective chosen strategies of zoning, barrier construction with residential sound insulation, and site planning in an urban renewal situation. Although these three communities were not chosen on the basis of population density, they clearly demonstrate the effects of this variable.

The local political environment and community goals constitute another major determinant of noise compatibility control strategies. In Cerritos, a powerful and capable local government, supported by public attitude, has been able to implement land use controls that would not be possible in many other communities. Marshfield and Pembroke, with the open town meeting and part time municipal officials, provide an excellent example of strong citizen control over the policies that the town officials can implement. The technique of zoning the potential noise impact area for industrial uses only may have to be reversed at a later date. Any changes to this strategy face the possibility of battles on the town meeting floor and all of the uncertainties that the open town meeting provides. The third case, Somerville, is an example of how local community and political pressures have forced a change from a strategy of urban industrial zoning to that of acoustically protected residential use.

The town's maturity also plays a role in determining the land use strategies involved. Incorporated in 1956, Cerritos is a relatively young town which is experiencing intense pressures for development. Because development is occurring at such a rapid pace, the public is aware of the need for controlled growth and the importance of environmental considerations. Also, developers realize that if they want to build, they must comply with stringent noise compatibility standards. In contrast, Somerville is an old city with most of its housing constructed before 1940. It developed without specific regard to noise compatibility problems which have only recently become matters of concern. Unfortunately, residential areas and traffic patterns are established, and it is therefore difficult to deal effectively with traffic noise problems.

A final major determinant of the techniques which a locality can utilize to promote land use compatibility with noise is the existing state legislation in this area. California, for example, has both a powerful environmental quality act which applies to almost every construction project, and a strict requirement that each community have an extensive local master plan. The Cerritos case study shows the effect that this type of support can have on the local government's ability to act in a forceful manner.

The three case studies all show that highway noise and adjacent land compatibility is an existing or potential problem. While there is a wide range of people's perception of the problem and an equally wide range of possible solutions, the problem is real and must receive careful local attention.

Each case study follows the same basic format:

1) A general background of the community including its residents, political structure, existing land uses, and noise sources.
2) A discussion of a selected noise-impacted site within the community, emphasizing land uses, history, noise sources, and existing land use controls.
3) An evaluation of alternative noise compatibility land use control strategies, including actions presently being taken, alternative actions rejected as being unworkable, and potentially valid alternative actions.

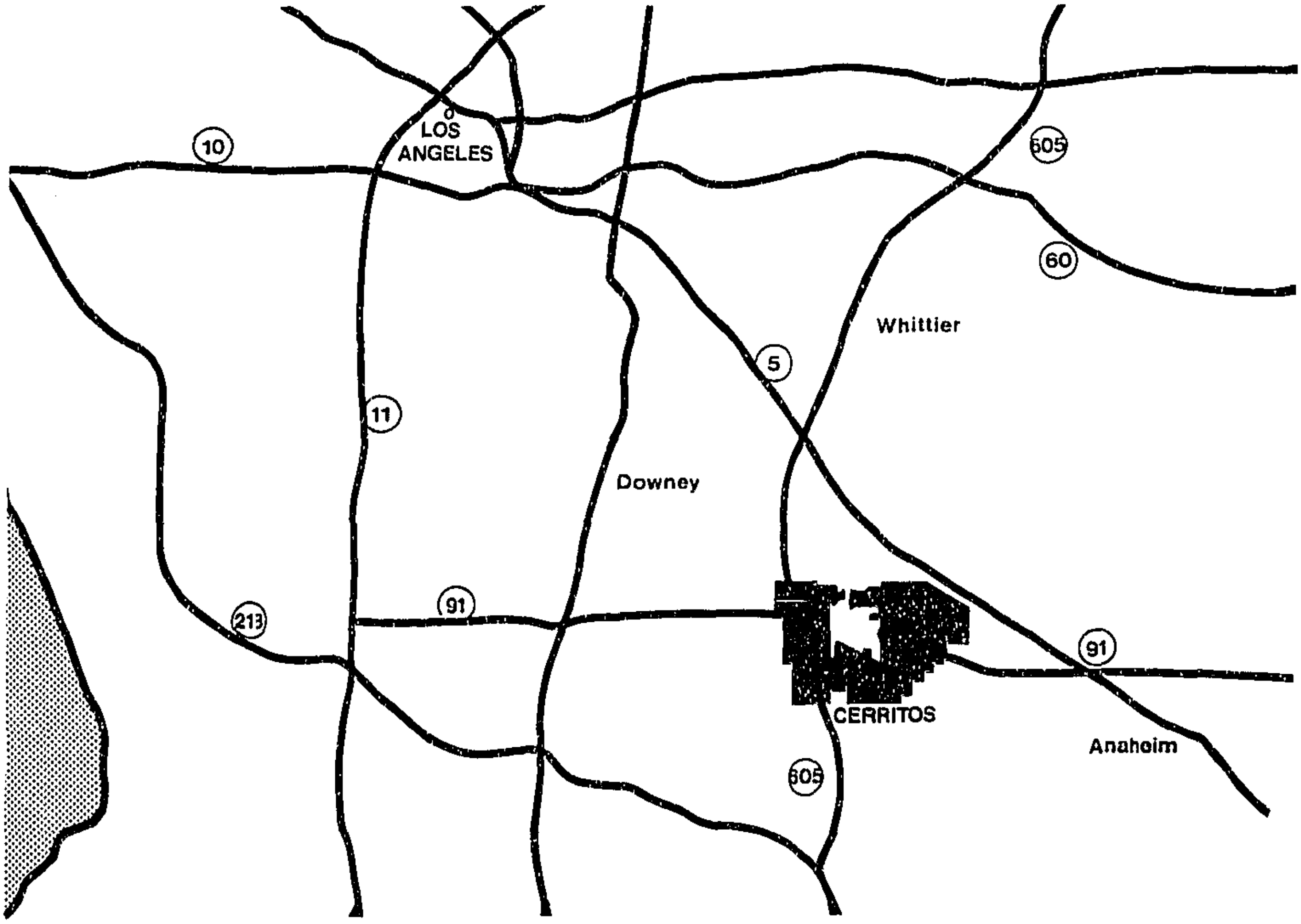
They are presented successively below.

Case Study 1:
Cerritos, California

Cerritos, California, located in suburban Los Angeles County, is a rapidly developing residential community facing severe highway noise impact from three major freeways (see Figure A-1). A construction boom has transformed Cerritos from a dairy farming community of less than 4,000 people to a city of 40,000 in less than a decade. The residents are primarily young, well educated middle and upper-middle income families. Although the demand for new homes has led to residential development in noise-impacted zones adjacent to the freeway right of way, the problems of highway noise have not been ignored. An active city government with strong public support has endorsed stringent noise standards for new residential construction. Developers are required to incorporate acoustical considerations in site planning and architectural design, to use sound-proofing construction materials and techniques, and to erect noise barriers.

Role of Local Government Although Cerritos is not unique in having land use and land development as key political issues, its city government has responded to these issues in an unusually effective manner. The government has an executive and legislative form of government consisting of a city manager and city council respectively. It has a Department of Environmental Affairs which contains a city planning staff of eight full-time employees, a considerable number for a city its size. The planning staff takes a very active role in all aspects of urban development in Cerritos. Its activities go beyond the formulation and enforcement of the general plan for land uses. Plans for development of particular land parcels are scrutinized at all levels from overall site planning to construction materials and architectural details. In fact, the City of Cerritos acts in many ways as a site planner and architectural consultant to all new developments, and has even taken over some of the roles usually performed by real estate developers. In its unusual role, the Department of Environmental Affairs has the support of the five-member Planning Commission and the political backing of the City Council. One of the principal levers used by the City to guide the development is the building permit. All building permits must be approved by the Department of Environmental Affairs which freqently withholds its consent until plans are revised to conform to its specifications.

The City Government's active role in im-



A-1 Location of Cerritos

proving the physical environment of Cerritos includes stringent measures to control the problem of noise. City ordinances restrict noise emissions; the general plan and zoning laws control noise incompatible land uses; and building codes give detailed prescriptions for noise reducing construction techniques. The basic tool for achieving these ambitious goals in noise reduction is, once again, the city planning staff which provides technical and planning assistance as well as control and supervision.

The Role of the State Government The state of California assists in the control of noise incompatible land uses through two important statutory requirements. California requires local communities to adopt detailed general plans for development. In addition to such items as land use, housing, conservation, and open space, the plan is specifically required to contain a noise element. The noise element forces local communities to consider the problem of noise compatibility in planning land uses. There are many difficult obstacles to overcome in converting general or master plans into actual land uses. The State of California has taken a first step to encourage the implementation of general plans by requiring that local zoning maps be brought into conformance with the land use patterns adopted in the general plan. Once this occurs, zoning changes or variances cannot take place without previously revising the general plan.

The second major state contribution to encouraging noise compatible land use is the California Environmental Quality Act. This law requires a detailed Environmental Impact Report to be prepared for all major new construction projects, whether public or private. With a few minor exceptions, such as individual single-family homes or individual apartments of four dwelling units or less, the developer of any parcel of land must submit a detailed, documented analysis of any potential negative environmental impact. The Environmental Impact Report must be approved as adequate by local government authorities, a process which may require several revised submissions, and public hearings. With respect to noise, the EIR requires analysis of the impacts of the existing environment upon the project, the impact of the project upon the surrounding area, and the development of specific measures to minimize any negative impact.[1]

Discussions with California state and local officials indicate that the requirements of the Environmental Quality Act have helped educate local officials and real estate developers about the nature and magnitude of environmental impacts on the surrounding community. As a result, both local government and private entrepreneurs have become much more sophisticated in developing alternative plans to reduce environmental impacts. In addition, the EIR provides local communities with the information they need to estimate accurately the level of environmental degradation. In the case of noise there is now a much greater understanding of noise measurement techniques and the evaluation of the acceptability of noise levels, as well as sufficient data on individual sites to make informed judgments possible.

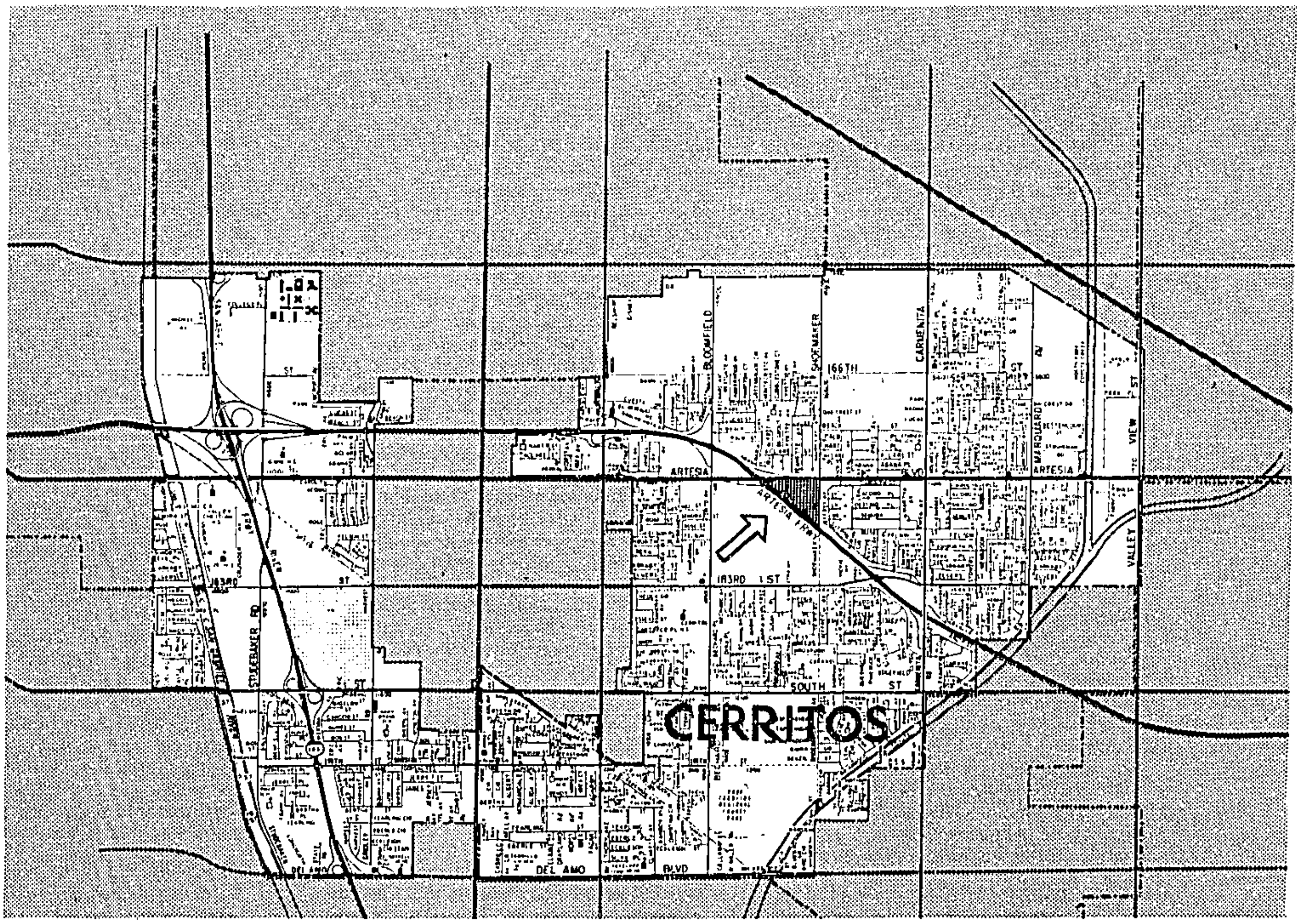
Noise Sources The principal noise sources in Cerritos are three major freeways: the San Gabriel Freeway (Interstate 605) in the western half of the city, the Artesia Freeway (Interstate 91) crossing the center of the city in an east-west direction, and the Santa Anna Freeway which is adjacent to the northeast corner of the city. These highways are heavily traveled by passenger cars and trucks and cause major noise impact along their borders. The land uses along these freeways are mixed, but include substantial amounts of residential development. (See Figure A-2).

Arterial streets in Cerritos are also heavily traveled and create another source of noise, although their impact is much less than that of the freeways. Neither Long Beach Airport seven miles away nor Los Angeles International Airport twenty-five miles away creates a severe noise impact. There are no stationary noise sources at the present time.

The City of Cerritos has established ambitious standards for dealing with the severe problems of highway noise. Ambient noise levels of 45 dBA within dwellings, and 60 dBA in outdoor residential areas, are standards advanced in the city's general plan.

The Study Site To illustrate some of the highway noise problems facing Cerritos, and to analyze some of the efforts being made by that community to solve them, it is useful to examine a specific site. A residential development currently under construction in the northeastern section of Cerritos provides a good example. Tract 29444 covers a roughly triangular

[1] State of California, *California Administrative Code*, Title 14, Div. 6, Chap. 3.
City of Cerritos, California, Department of Administration, *Environmental Impact Report Guidelines - Resolution*, 73-20 (April, 1973).



A-2 Map of Cerritos showing highways and major arterials and location of Study Site, Tract 29444.

Appendix A: Cerritos, Cal.

area of about 12 acres. It is bordered on the north by Artesia Boulevard, on the east by the proposed extension of Schoemaker Avenue, and on the southwest by the Artesia Freeway (California Route 91). (See Figure A-2) Like most of Cerritos, this area was once dairy farmland. It is now zoned for low density (2-5.5 units per acre) residential use, and a subdivision of 49 single-family homes is currently under construction on this site.

Noise from motor vehicles was one of the critical constraints in the planning of this subdivision. Traffic on well-traveled Artesia Boulevard creates a noise pollution problem, but the critical difficulty is presented by the Artesia Freeway which directly abuts the tract. Even the third border on the development site, while currently vacant and therefore not a noise source, is planned as a major city street to be constructed in the future. In the face of all these noise sources, developing this small tract of land to meet residential noise standards is a formidable task. The city of Cerritos has insisted on the use of a wide range of noise reduction techniques in the design and construction of these houses in order to meet the city's objectives of obtaining an ambient noise level of 60 dBA in open spaces relating to dwellings, and 45 dBA within dwellings. Before granting building permits, Cerritos' city planners carefully scrutinized building plans and insisted on specifying a variety of sound reducing design and construction features. Some of these changes are illustrated in the tract plan (see Figure A-3):

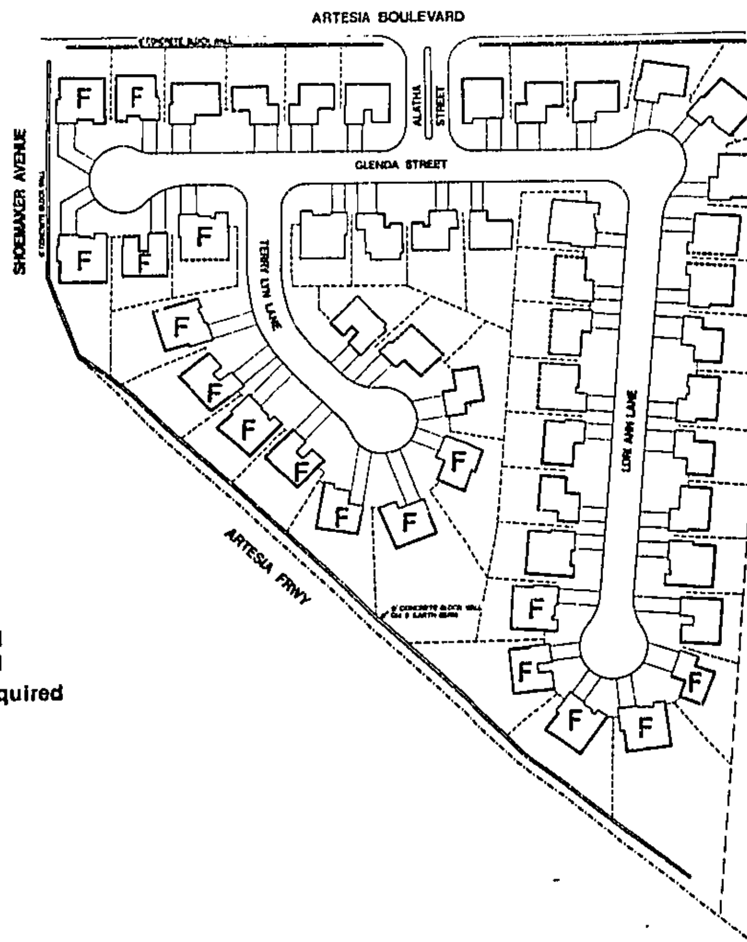
- A 9 foot high concrete block wall on top of an 8 foot earth berm provides a shield along the freeway side of the development.
- Six foot high concrete block walls are required on the Artesia Boulevard and Schoemaker Avenue borders of the tract. Landscaping and design variations are required to improve the aesthetic impact of these barriers.
- Sound insulating construction techniques are required for most of the exterior walls to meet either a 56 STC or 50 STC rating. The developer's proposed construction method for achieving these sound ratings, including double walls with staggered studs, had to be submitted for approval (see Figure A-4).
- For many of the homes, central air-conditioning was required as a sound insulation technique. For houses closer to the heavy traffic of the freeway, special charcoal filtering systems were specified tc reduce air pollution levels as well.
- Houses along the freeway were restricted to a single story to keep them within the sound shadow of the concrete block wall.
- One house with a potential noise problem along the proposed Schoemaker Avenue posed a future threat of excessive noise levels on the second story, and was therefore designed with double glazed windows.

Each of these techniques was worked out in negotiations between the city planning department and the developer. Three factors may be cited in the success of these negotiations in achieving satisfactory noise levels:

1) The legal authority to veto building plans which do not meet acoustical specifications, backed up through the political willingness to exercise this veto if necessary.
2) A sellers' market in single-family residential homes in Cerritos, which enables the developer to recoup the added construction costs.
3) A familiarity with noise reduction design and construction techniques and their impact by both developer and city government which results in an acoustically effective but economically practical solution.

Although the plans implemented for Tract 29444 have achieved their acoustical objectives, they do raise questions of economics and aesthetics. The cost of noise reducing construction and design adds a premium of about 10% to the price of these homes compared to similar residences built in less noise impacted areas. (This premium excludes the cost of air-conditioning and other improvements which are not solely noise related.) The aesthetic costs of noise reduction are much less quantifiable, and in fact are a matter of individual taste. The high concrete walls and reduced window space tend to create a closed-in environment which some might find cold and forbidding. Most people would agree that the high noise barriers on top of earth walls are not an ideal back-yard environment. The additional economic costs and aesthetic limitations must be traded off against the real benefits of a greatly improved noise environment. Considering the popularity of similar developments in Cerritos it is likely that Tract 29444 will be a popular success.

Action for Noise Reduction Cerritos, California's program for highway noise compatibility control utilizes a wide



— STC 56 Required
----- STC 50 Required
F Air Filtration Required

A-3 Plan of Tract 2944 showing noise reduction techniques.

variety of techniques. Three aspects of this approach stand out as most important in evaluating its applicability to other communities: strict legal controls, active municipal design review, and the implementation of noise reducing construction techniques.

Strict legal controls on noise in Cerritos result from a variety of state and local laws and regulations. Some of the most important mechanisms are the Environmental Impact Report required by state law and implemented by local government guidelines which result in planning for noise in the initial stages of project design; the general plan for future development which is backed-up by strict zoning ordinances; and a variety of local noise regulations aimed at the specific noise problem and adapted to local land use and construction patterns. Many of these guidelines could be adopted in other communities with minor modifications, if local and statewide political support are available. The most difficult aspect of the Cerritos environment to transfer is the political commitment on the part of public officials to solving noise problems.

Cerritos' approach to noise problems emphasizes the act of participation of city planners in all development activities to insure that environmental and aesthetics standards are being achieved. This active planning role, in which the city government sometimes appears to perform many of the functions of a private developer, is possible only because of the high level of skills of city planning officials and successful only because the demand for land in Cerritos is so intense that developers are constrained to cooperate with the city. While other communities may possess the skill to form this planning role, they may find it difficult to achieve the same high level of cooperation on the part of private developers. The role of the Cerritos city government in helping to educate developers and architects about noise reduction techniques can certainly be adapted to other communities.

Cerritos' implementation of noise reducing construction techniques provides important lessons for other communities. Significant levels of noise reduction have been achieved in residential developments without destroying their economic viability. Some of these techniques could be applied anywhere in the United States. Others, such as air conditioning, would raise questions of economic viability in other areas. The widespread use of concrete noise walls may be more difficult to transfer to other locations. In Cerritos, these walls are not out of place with the dominant Southern California architectural styles. In many other parts of the country, however, the lack of open space and the inward looking courtyard effect of the noise wall may be aesthetically unacceptable.

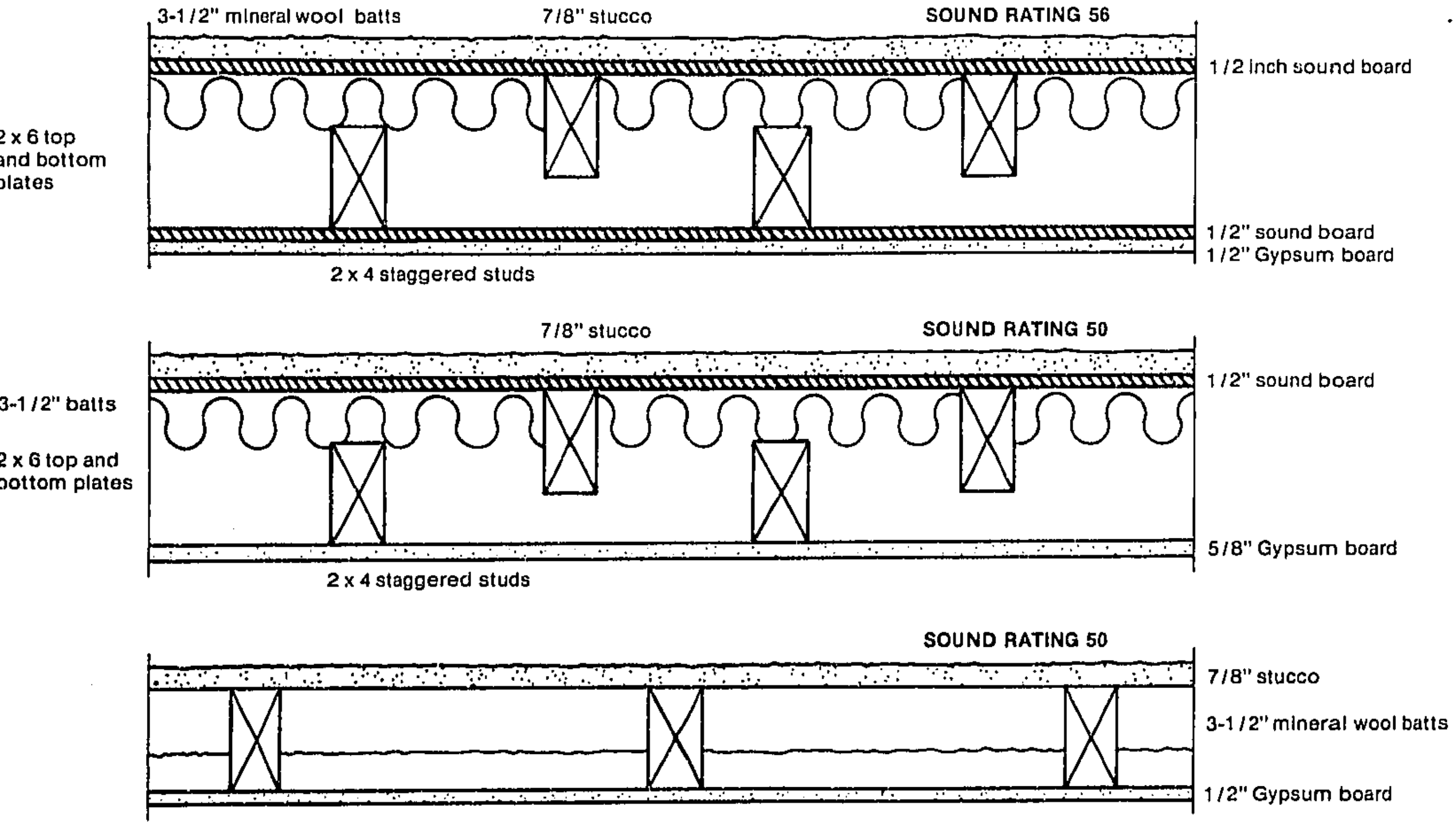
One important technique for noise impact reduction which has not been applied in Cerritos is the prohibition of noise-sensitive uses, particularly residences, in high-noise zones. The Cerritos general plan specifically rejects the option of placing industrial uses along the freeway borders, because it wishes to preserve continuity with existing residential developments adjacent to these areas. It has instead, chosen to isolate industrial uses in sections away from residential areas.[1] This decision emphasizes once again that noise considerations, even in the most environmentally conscious communities, are not the sole criteria for land use planning.

Case Study 2:
Somerville, Massachusetts

Somerville, Massachusetts, located 3 miles from downtown Boston, is an old urban residential community with a declining population. (See Figure A-5) Its residents, primarily middle income and consisting largely of elderly people and young transients, are only recently becoming concerned with highway noise due to the construction of Interstate 93 through the heart of a densely populated residential area. Until the recent citizen concern, the local government has done little to reduce noise impacts. The whole issue of noise pollution is relatively new, and, in any case, the city has been almost entirely built up for several decades, leaving little opportunity to change land uses to ones that are noise compatible. The City of Somerville has no noise control laws; the only significant noise standards are those set by the U.S. Department of Housing and Urban Development from which the city has sought funding.

Role of the Local Government At present there is a trend towards new housing construction in Somerville, largely due to the strong support of the Mayor. It is possible that, although Somerville has done little to regulate noise compatible development to date, concern for such

[1] City of Cerritos, California, *General Plan*, 1973, p. 11.04.



A-4 Construction plans for exterior walls

Appendix A: Somerville, Ma.

regulation will increase in the future because of the city's need for new federally assisted housing.

Role of Federal and State Government When Federal funding is required for construction of projects such as housing or schools, the projects must satisfy environmental impact requirements, which include noise criteria. With regard to highway noise, developers must show that noise levels are within levels which the Department of Housing and Urban Development considers to be compatible with the project. In the case of the Inner Belt Urban Renewal Project, traffic noise levels are presently too high for HUD's approval. Funds are being withheld until the developer can reduce the noise impact to compatible levels. This case study describes the administrative and physical techniques used by the City of Somerville to reduce noise impacts on the urban renewal site to compatible levels.

The City of Somerville also has frequent dealings with the State of Massachusetts. Somerville and the Massachusetts Department of Public Works have been involved in controversies over the location of state highways in Somerville. The Department of Public Works has the power to locate and relocate roadways. Two highways which have directly affected the project site under consideration are Interstate 695 and Interstate 93.

Somerville's housing stock is obsolete: 90.1% of its units, mostly wooden two-family houses, were built before 1939. Thus, Somerville has not attracted new residents who might profit from the city's proximity to Boston. In fact, since 1950, Somerville has experienced a 13% decline in population, and economic opportunities have been restricted by the lack of space for industry.

The only land available for redevelopment was recently changed from an industrial to a residential use. This site, known as the Inner Belt Urban Renewal Project, is the focus of the case study. It demonstrates, among other things, the effectiveness of an executive-legislative form of government in implementing change. The study site was originally zoned industrial because of plans to build a highway nearby. However, the highway plans were discontinued leaving the spot unmarketable for industry and yet too noisy for residential use because of heavy truck traffic on adjacent roads. The need for housing and the mayor's influence changed the site's future from industrial to residential. A federally funded low income housing project is planned, thus making the site subject to the Department of Housing and Urban Development's noise compatibility guidelines.

Noise Sources and Levels In recent years Somerville has been frequently confronted with the problems of highway location and highway noise. Because of the importance of wholesale and retail activities to the local economy, much trucking takes place giving several streets extremely high noise levels. Among these are Mystic Avenue, Prospect Street, and Alewife Brook Parkway. In addition, there is heavy truck traffic on the McGrath Highway and on I-93. A map showing the distribution of these noisy streets follows in Figure A-6.

Interstate 695, the "Inner Belt," was planned to link communities inside Route 128, and connect Interstate 93, approaching Boston from the North, with Interstate 95. It was designed as part of the 1948 Master Highway Plan for Metropolitan Boston. First the route, and then the rationale for the Inner Belt were questioned by the communities through which it was to have been built. In January 1969, Governor Sargent stopped work on it, and on Febrary 11, 1970 he declared a moratorium on all major highway projects inside Route 128 which were not yet under way. Unfortunately, Somerville and other communities had already made plans which depended on the construction of I-695. For example, the Inner Belt Urban Renewal Area was to be bordered by the Inner Belt, making it ideal for industrial development. But when the Inner Belt was cancelled, the site proved unmarketable for industrial uses. Furthermore, under the present heavy truck traffic conditions and consequent noise around the site, the site is also unsuitable for housing, and will not receive funding from the Department of Housing and Urban Development until noise impacts are reduced. The success of the present residential plan depends upon the relocation of Washington Street south of the project site and the special location of a proposed I-93 off-ramp near the site. Thus the future of the project depends upon the decisions of the Department of Public Works.

The Case Study Site The Inner Belt Urban Renewal Project is a 23 acre urban renewal block located in East Somerville. It is bordered on the north by Washington

A-5 Location of Somerville

Appendix A: Somerville, Ma.

Street, on the west by the McGrath Highway and on the south and east by the Boston and Maine Railroad. (Figure A-6) It is zoned for industrial use, but current plans include a mixture of residential, office, and commercial facilities. It was initially zoned industrial due to its proximity to the Boston and Maine railroad tracks and the proposed location of Interstate 695, the Inner beltway. In addition, an industrial park is located south of the project area.

Under present conditions the Somerville site is extremely noisy. It is the noise created by the heavy truck traffic on Washington Street which runs along the entire northern boundary of the site which is the most serious, as the amount of land fronting on McGrath Highway is small, and railroad service in the site area is infrequent. An additional noise problem is that presented by a projected Interstate 93 off-ramp which will be located near the project area, as well as the industrial park located south of the site.

According to the preliminary environmental impact report prepared for the Somerville Redevelopment Authority, there is no external location on the Inner Belt Urban Renewal site which falls unequivocally in HUD's "clearly acceptable" category.[1] Furthermore, the area within 110 feet of Washington Street would be "Discretionary—normally unacceptable"[2] for housing because of its exterior noise levels. The rest of the site falls in the category of "Discretionary—normally acceptable."[3] The present noise contours on the site are indicated in Figure A-7. The site plan employs two major techniques of noise reduction:

1) The major noise sources are all placed on one side of the site, the southern boundary. The most critical noise source, Washington Street, is relocated from the northern boundary of the site to the southern. In order to succeed in this part of the plan, the Somerville Redevelopment Authority has had to negotiate with the State Department of Public Works. It is not yet clear whether the Department of Public Works will relocate Washington Street, and thus the future of the project is uncertain. The proposed Interstate 93 off-ramp is located south of the site behind the "new" Washington Street. The Somerville Redevelopment Authority is presently negotiating with the State Department of Public Works about the location of the off-ramp. There are three alternative locations for this ramp, each of which affects the project site in varying degrees. Alternative C is the one preferred by the Somerville Planning Board. Figure A-8 illustrates the alternatives. The Industrial Park is presently located south of the site, behind "new" Washington Street, thus concentrating all three noise sources on one side of the site.

2) The housing units are placed close to the northern boundary of the site, as far as possible from the noise sources. They are buffered by open spaces, retail facilities, and a health clinic. (See Figure A-9)

If Washington Street were relocated south of the site, and Alternative "C" were chosen for the ramp location, the entire site would then be classified by HUD as "discretionary—normally acceptable,"[4] due to the proposed I-93 ramp. New Washington Street will have less truck traffic than is presently on Old Washington Street. Furthermore the reduction and possible removal of traffic from Old Washington Street will have the advantage of tying together the residential neighborhoods of East Somerville and the project area. And a relocated Washington Street would serve as a buffer between the project area and the Inner Belt Industrial Park. (See Figure A-10) Also the choice of Alternative "C" for the off-ramp would have the least noise impact on the site.

Another noise reduction method which is being considered by the Massachusetts Department of Public Works is to depress New Washington Street several feet below the site. This would also have the advantage of removing the visual impact of passing truck traffic from much of the site. If the road is depressed, the site plan envisions erecting a berm along the roadway to create a noise barrier equivalent to one story when one combines the height of the berm and the depth of the roadway. The cost of such a berm is felt to be quite small as the necessary earth would already be on the site.

Other Possible Solutions and Why They Were Not Applied Due to cost constraints, site planning has been the major means of noise reduction considered by the architect. Other alternatives such as barrier construction and soundproofing were eliminated because of their expense.

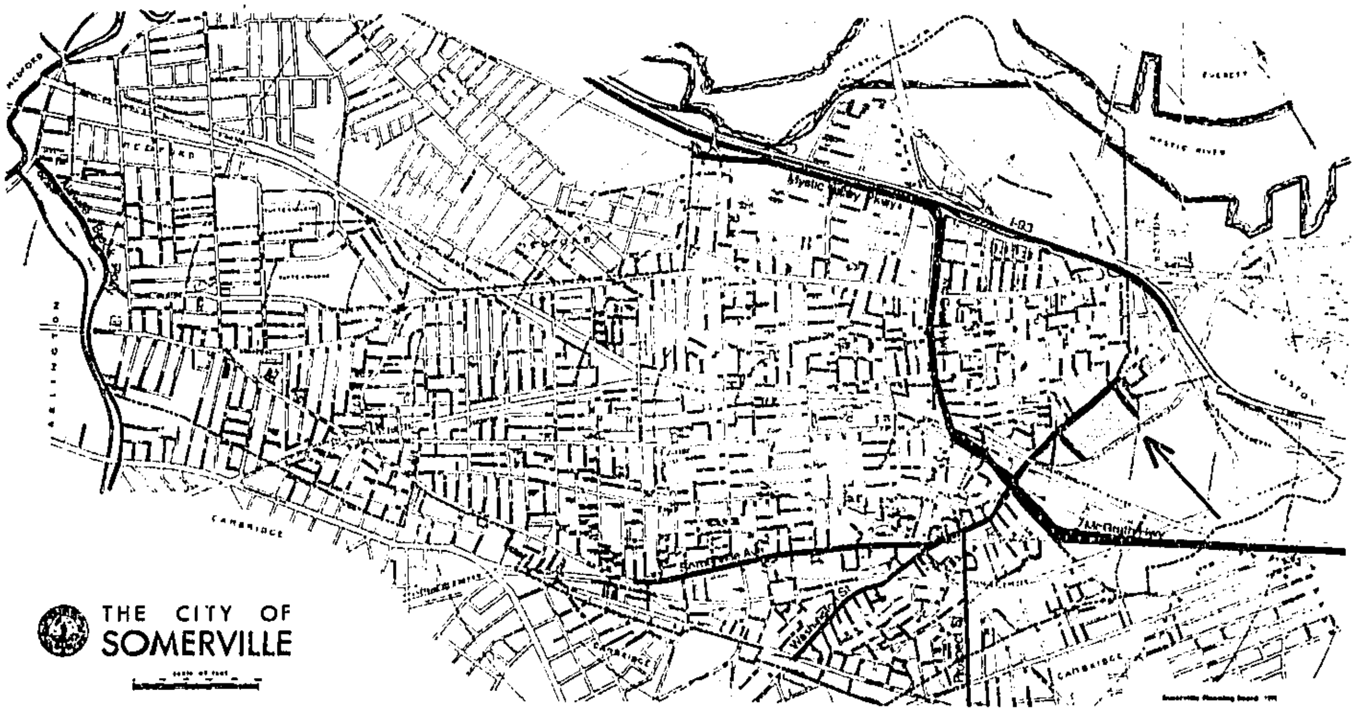
It would be possible to use stronger site planning techniques to minimize noise. Putting all of the non-residential facilities along New Washington Street would

[1] According to HUD's criteria, "acceptable" noise levels are those which do not exceed 45 dBA for more than 30 minutes per 24 hours. HUD, Departmental Circular 1390.2, *Noise Abatement and Control: Departmental Policy, Implementation Responsibilities, and Standards*, p. 8.

[2] This standard requires an L_{33} between 65 dB (A) and 75 dB (A). *Ibid.*, p. 8.

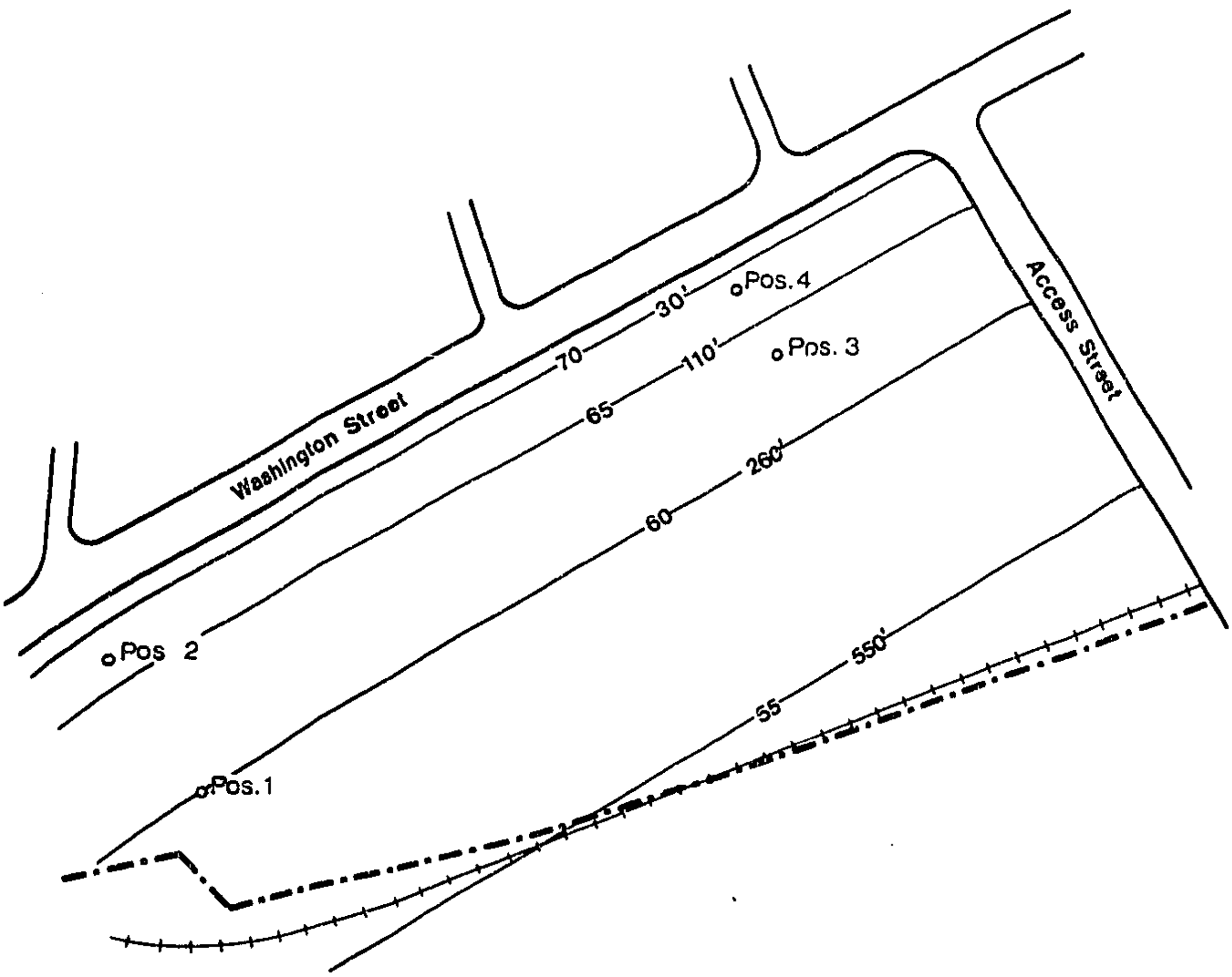
[3] This standard requires an L_{33} between 45 dB (A) and 65 dB (A), *Ibid.*, p. 8.

[4] It is assumed by the developer and the Somerville Planning Board that the noise levels from New Washington Street will be negligible. Therefore, no noise contours from New Washington Street are shown in figure A-10.

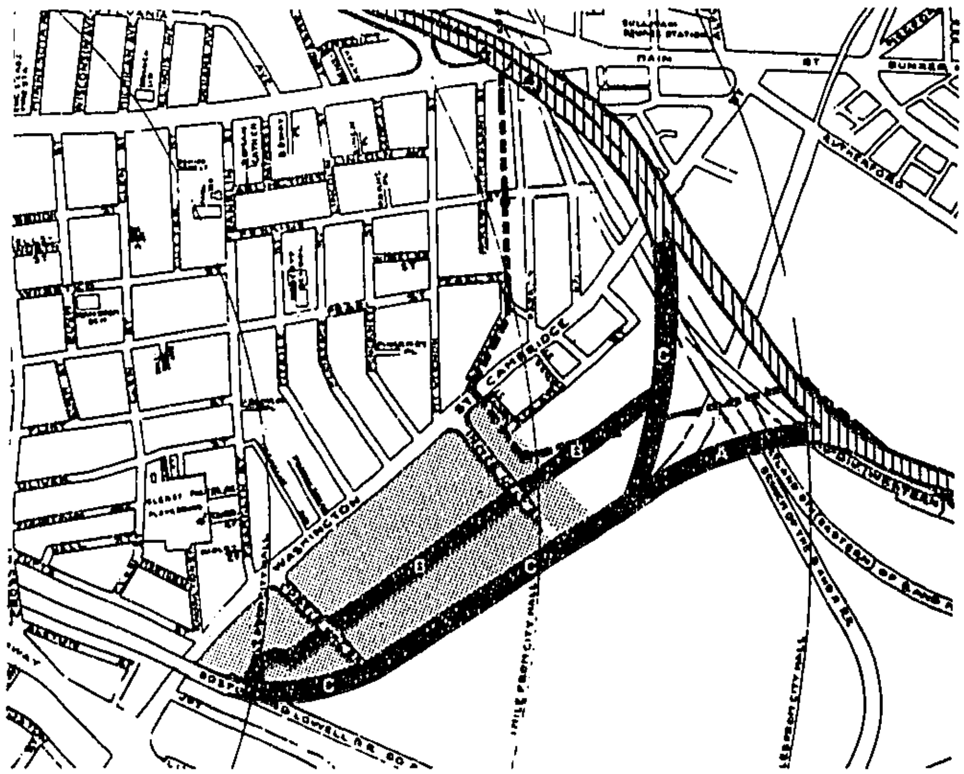


A-6 Map of Somerville showing study site, and highways and major arterials

Appendix A:
Somerville,
Ma.

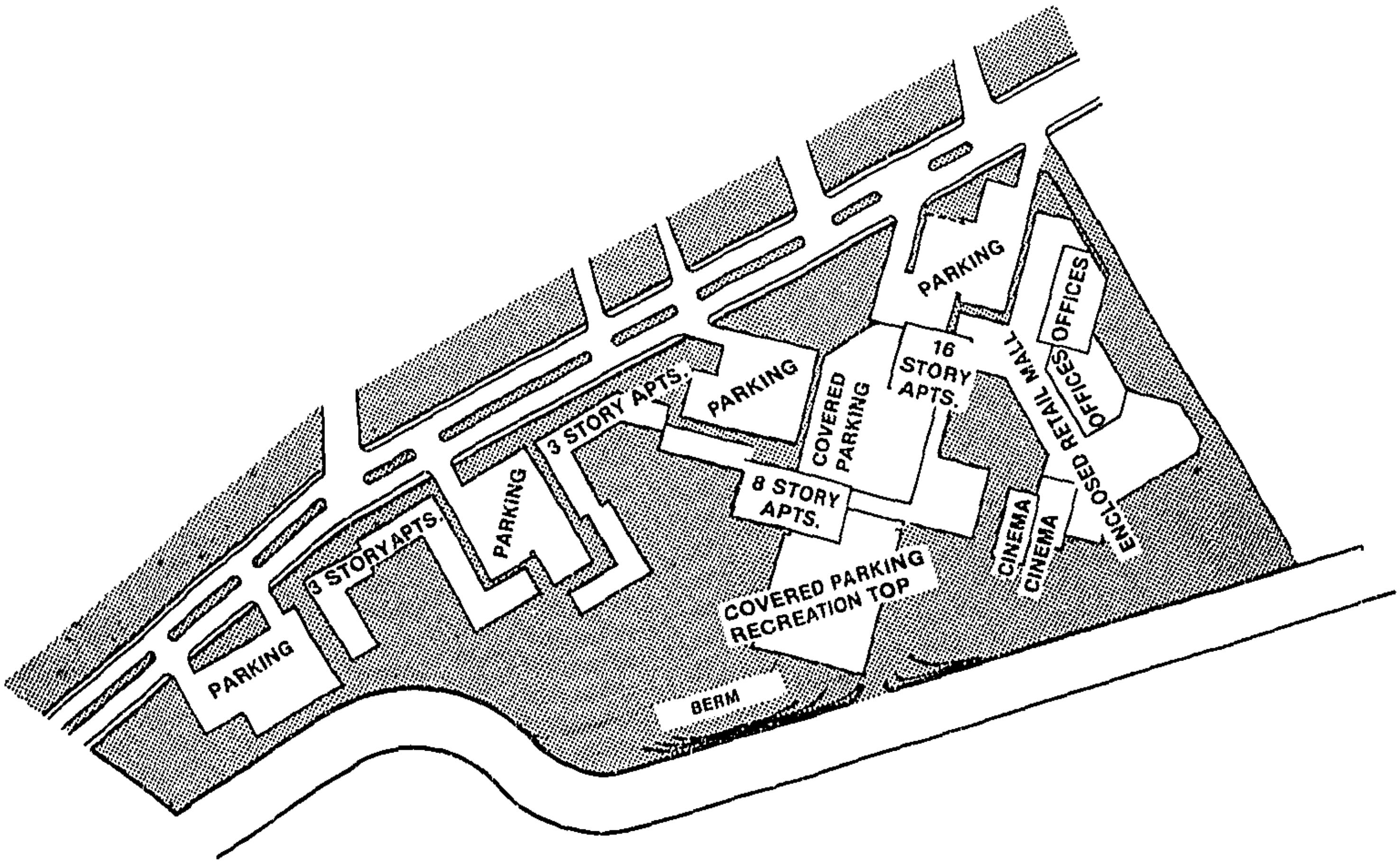


A-7 Present noise contours on Inner Belt Urban Renewal Project Site

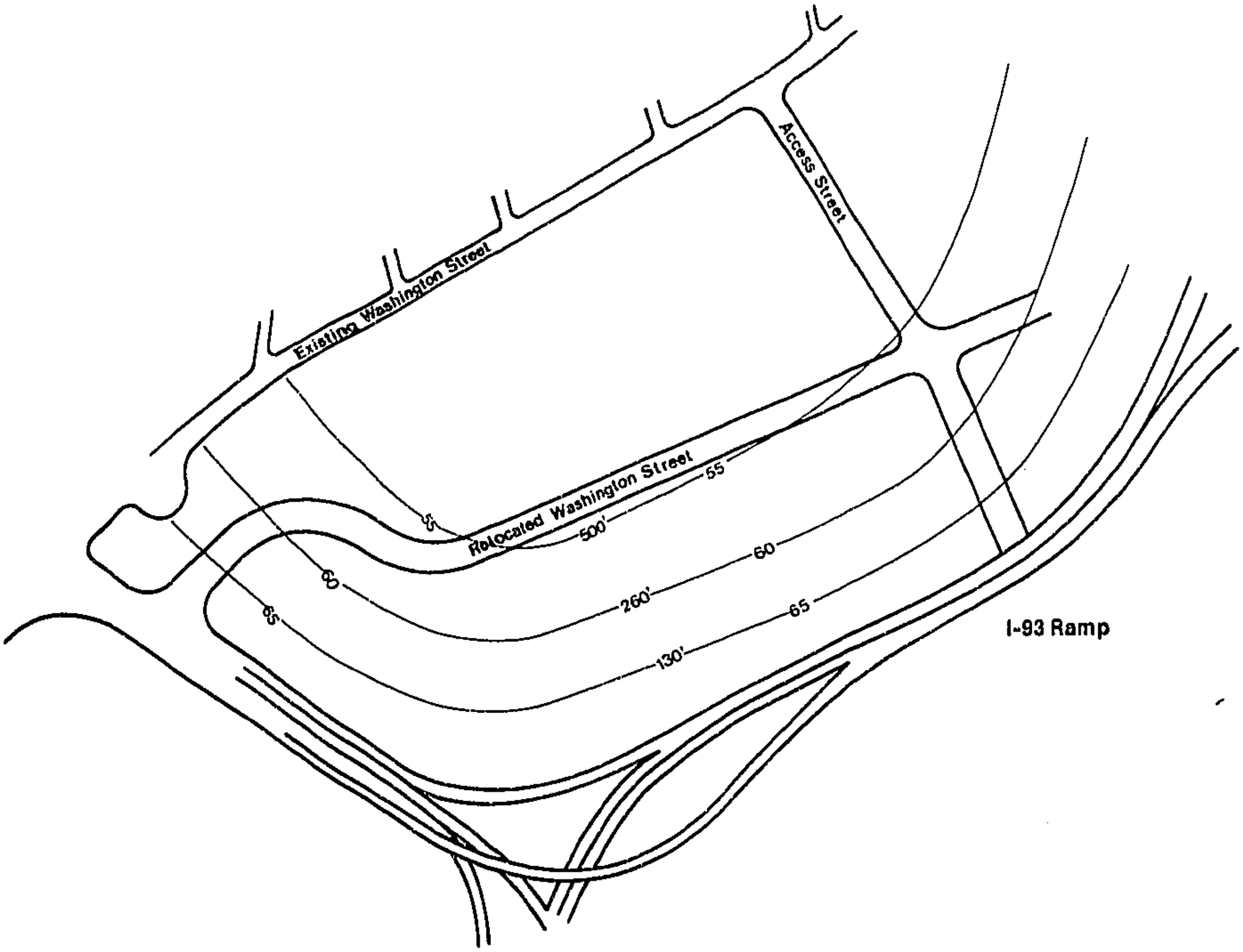


A-8 Alternative I-93 Ramp Routes (A, B, and C)

Appendix A:
Somerville,
Ma.



A-9 Site plan of Inner Belt Urban Renewal Project



A-10 Projected noise contours of Inner Belt Urban Renewal Site with relocated Washington Street create a more effective noise buffer for the housing. However, this solution has been rejected by the site planner because of access considerations for the residents of the East Somerville Neighborhood. Placing all of the retail and other facilities at the eastern end of the site makes a more attractive and accessible shopping area.

A technique of noise impact reduction which has been rejected in the Somerville case is the development of land in accordance with its compatible zoning classification; in this case, industrial. Development in accordance with a compatible use has proved impossible due to the site's unmarketability for industrial uses and strong political pressure for residential development.

Case Study 3:

Marshfield-Pembroke, Massachusetts

Marshfield and Pembroke are neighboring residential communities in rural southeastern Massachusetts. Because of highway access to both Boston and Cape Cod, the two communities have more than doubled their populations in the past decade. The residents are primarily middle income families. (See Figure A-11)

At present, the town governments are not especially concerned about highway noise. No regulation to control land use compatibility exists or is contemplated. However, if residential development proceeds at the present rate, the land along Route 3 may present a noise compatibility problem with which the two communities will have to deal.

The site chosen for consideration in this case study is a two-mile strip of primarily undeveloped land along Route 3. Because Route 3 runs along the borders of both towns at this point, part of the site belongs to Marshfield and part to Pembroke, involving both towns in the noise problem. The two towns took an initial step of zoning most of the land near the highway for industrial uses, but neither town has had much industrial development. If the need for residential development should arise, the use of this site may have to be rethought and residential development considered.

Both towns have town meeting forms of government. The legislative body is the Town Meeting, consisting of every registered voter in town. All town business, from approving the budget to zoning, is voted on by the Town Meeting. The benefits of this democratic form of government are inherent in the fact that anyone can have a voice in the town affairs if he attends the town meetings and votes. The disadvantages of this form of government are due to the fact that most townspeople do not attend the meeting unless they are particularly interested and/or affected by a particular article. In fact, it is often difficult to get the required five percent quorum at special town meetings concerning non-controversial matters. Thus, a town meeting can tend to become "packed" with those who have a special interest in a particular article and are therefore highly motivated to attend. It can accordingly become very difficult to pass, for example, a zoning change with the required ⅔ vote when it is opposed by a specially interested group.

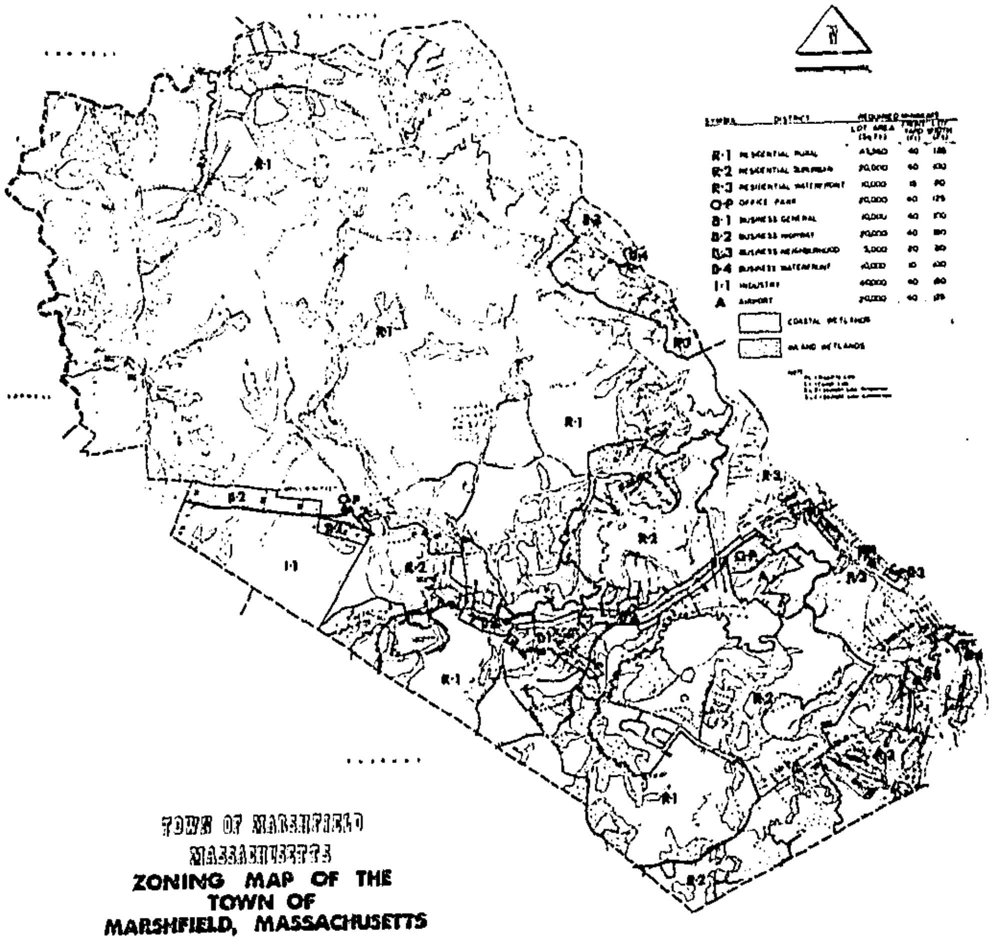
Marshfield and Pembroke each have a planning board consisting of five part-time citizens. The Planning Board is responsible for zoning, administering the subdivision control law, and long-range community planning. It is required to hold a public hearing on zoning changes and then to make its recommendations to the Town Meeting. That board members are part-time and not necessarily professional planners is a disadvantage inherent in most small town governments.

Both Marshfield and Pembroke have zoning bylaws which divide the towns into business, industrial, and residential districts. (See Figures A-12 and A-13) Development has been relatively light in both towns, with each being roughly 25% developed. Significant portions of the land in each town are classified as wetlands which severely restricts, and in some cases, prevents development. Most of the developed land is residential. Although both towns have been actively attempting to attract industry, much of the land zoned industrial remains vacant. Some commercial zones have been developed; however, this has resulted in an excess supply and there are a number of vacant stores and offices in these areas.

Most of the residential development has been single family lots, both because of the demand for this type of housing and the desire of the townspeople to prevent multi-family residential development. Marshfield's opposition to multi-family housing began in 1968 when it was voted legal at the Town Meeting. What resulted was a rapid and extensive development of

A-11 Location of Marshfield and Pembroke.

Appendix A:
Marshfield-
Pembroke,
Ma.



TOWN OF MARSHFIELD
MASSACHUSETTS
ZONING MAP OF THE TOWN OF MARSHFIELD, MASSACHUSETTS

A-12 Zoning Map of Marshfield, Massachusetts

A-13 Zoning Map of Pembroke,
Massachusetts

Appendix A: Marshfield-Pembroke, Ma.

multi-family dwellings along Route 139, which the townspeople found to be unattractive and disruptive to the small town atmosphere. By 1971, the town voted to prohibit any further multi-family residential development; and, with the present local attitude towards this type of development, it is unlikely that it will be allowed in the next 10-15 years. Pembroke's zoning permits multi-family residences in a small portion of town, but most of the land so zoned is actually unbuildable due to state and local wetlands restrictions.

Noise Sources The principal noise sources in the study are highway noise from Routes 3 and 139. Route 3 is a high speed, limited access highway with extensive automobile traffic and some trucks. Route 139 is a three-lane state road with numerous entry-ways. Considerable roadside development exists. A frequent source of local complaint is related to gravel trucks which travel west on Route 139 from gravel pits in Marshfield on their way to Boston on Route 3. The Route 139-3 Interchange is also a source of noise because of accelerating and decelerating vehicles. There are no nearby major industrial or railroad noise sources. The local airport in Marshfield is restricted to non-jet operations, and it constitutes only a trivial noise source.

The Study Site The study site is a two-mile strip of land along Route 3, which roughly follows the boundary of Marshfield and Pembroke. Route 139 intersects Route 3 midway along the site strip. (See Figure A-14)

The study site is mainly zoned industrial, except for the land along Route 139 and the interchange where it is commercial, and, in the extreme north, where it is residential. Development of the industrial zones in both towns has been very slow, with almost all of the land remaining vacant despite efforts to market it. There has been some construction of new homes in Marshfield in the site area, but this has been limited to one street with no homes within sight of the highway. Commercial development has been more extensive, with the land along Route 139 and the interchange more than 50% developed.

An interesting question raised by this case study is whether the industrially zoned land in either town can be developed as such in the forseeable future. If it can, the concept of zoning the land for compatible uses only will have proven viable in this case. If, however, it can not, pressure will eventually come from the landowners to rezone the land. Then, Marshfield and Pembroke will be faced with the task of finding another method to insure noise compatibility. At present, there is some evidence that an industrial use of the area will not be marketable. While industrial development has been extensive for the past few decades along Boston's Route 128 beltway, it has not made any significant progress along Route 3, despite efforts by the local industrial commissions to attract industry.

A commercial use of this area may also be unlikely. There is a major shopping plaza located five miles north of the site at a Route 3 exit. This, along with the current over-supply of retail space in Marshfield, casts doubt on the possibility of a shopping plaza at the case study site.

If, however, the residential growth of the two communities, and the surrounding area continues at its present rate, there may eventually be a demand for an industrial/research/office park or a shopping center in the site area.

While industrial development in the near future is not certain, residential development continues. In 1973, the consultant working on a master plan for the Marshfield Planning Board predicted that the town would reach 40,000 residents by 1990 despite downward changes in the birthrate and tighter zoning and subdivision laws in the town. At present, the town has room for roughly 25% more residential development.

Plans for Noise Reduction - Actions Being Taken

Zoning for industrial use has been the only action taken that insures noise compatibility; however, it should be emphasized that the issue of noise compatibility is one which simply has not been raised. This is primarily due to the fact that these two communities do not feel the threat of a noise compatibility problem. The area is sparsely populated and there is no real demand for residential development along the highway. In the case that some residential development does occur, the natural terrain and the original highway design combine to help considerably in the attenuation of highway noise transmitted to adjacent areas. Grade separation aids in the area north of

Route 139 where Route 3 is first depressed in a cut designed to bring it down towards the valley of the North River and then elevated as it crosses the valley. South of Route 139 the elevation of Route 3 approximates that of the surrounding topography with small cuts and fills as necessary to compensate for the uneven surroundings. In this area the land on both sides of the highway is heavily forested. Only if the land is rezoned residential and substantial development occurs will the noise become obvious.

Plans for Noise Reduction - Applicability of Other Actions:

Berms or Barriers The view along Route 3 as one drives into the case study area is most pleasant, changing from cranberry bogs to woodlands. Just beyond Route 139 the long incline to the valley of the North River affords a spectacular view of the tidal river meandering through the salt marsh and of the low hills beyond. Any attempt to construct berms or barriers which would affect these scenic views would be politically unacceptable.

In Marshfield, for example, there is a Watershed Association, an Historical Commission, a Conservation Commission, an Historical Districts Committee and a Beautification Committee, all of whom could be concerned with the scenic and historic river. Any article on the town meeting warrant to require berms or barriers faces certain opposition from at least one of these groups.

Buffer Strips If either town rezoned the industrial area to residential, a requirement for a buffer strip would be practical and easy to incorporate into the zoning bylaws. With 40,000 or 43,560 square foot minimum lot sizes, rear lot depths of over 200 feet are to be expected even without the provision for a buffer strip. Requiring that a portion of the rear yard be a buffer with appropriate plantings provides no additional hardship.

Both towns presently require buffers on industrial lots between industrial uses and residential uses. Marshfield also requires buffers between business and residential uses and around cluster developments. This provision could be extended to highways in the zoning bylaw.

Site Planning - Subdivision The terrain is sufficiently hilly to provide numerous low-noise pockets in the land near the highway. This, along with the large required lot size would make site plan layout to minimize noise incompatibility a very practical undertaking, if the presently zoned industrial land was rezoned residential. This is especially true for cluster subdivisions which are permitted in Marshfield.

There are several methods available in the existing laws of each town to incorporate acoustical site planning.

In Marshfield's cluster zoning, site plans must be approved by the Appeals Board, an appointed body which is responsible for granting special permits, zoning variances, and cluster plan approval. If acoustical guidelines were included in the cluster provision of the bylaw, they would be considered by the Appeals Board. The Board could then reject a cluster subdivision plan if the guidelines were not met.

For conventional subdivisions, the procedure is slightly more complex. Marshfield's zoning presently requires a certificate of occupancy which can't be issued unless all provisions of the zoning bylaw and of the building code have been met. Thus, the Town Meeting could vote to amend either the zoning bylaw or the building code to prohibit construction of a residence in areas where the ambient noise level exceeded a certain specified level. The legality of such an amendment, under state law, would be subject to the approval of the state Attorney General, and would be subject to subsequent challenge in the courts.

Pembroke would have to incorporate the occupancy permit itself into its zoning bylaw before taking such noise related action.

A modification to the rules and regulations of the Planning Board could require acoustical site planning either on a definitive basis (such as specifying a maximum noise level in dBA) or by requiring, as part of subdivision submittal, a statement of noise compatibility measures being taken. These, too, would be subject to court challenge.

Site Planning - Individual Lots Again, the uneven terrain and large required lot size make this method a practical possibility. Enforcement could follow the methods listed above, but would probably have to include some provision for exception where such site planning is impractical. Otherwise, the legality of such a regulation would be in doubt.

Appendix A: Marshfield-Pembroke, Ma.

Height Limitations A limitation of building height to a single story near the highway could be accomplished by use of a superimposed district. One problem with imposing height restrictions in this case is that it may be an unnecessarily stringent restriction. The large required lot size and the hilly terrain will in many cases make other measures such as limiting height unnecessary. Furthermore, such limitations might interfere with the panoramic view which would otherwise be available to homes near the North River. While special height restrictions might be incorporated into the zoning bylaw or building code of either town as one of a series of stated alternative choices available to the builder, the absolute requirement for such restricted height would be unrealistic and probably illegal.

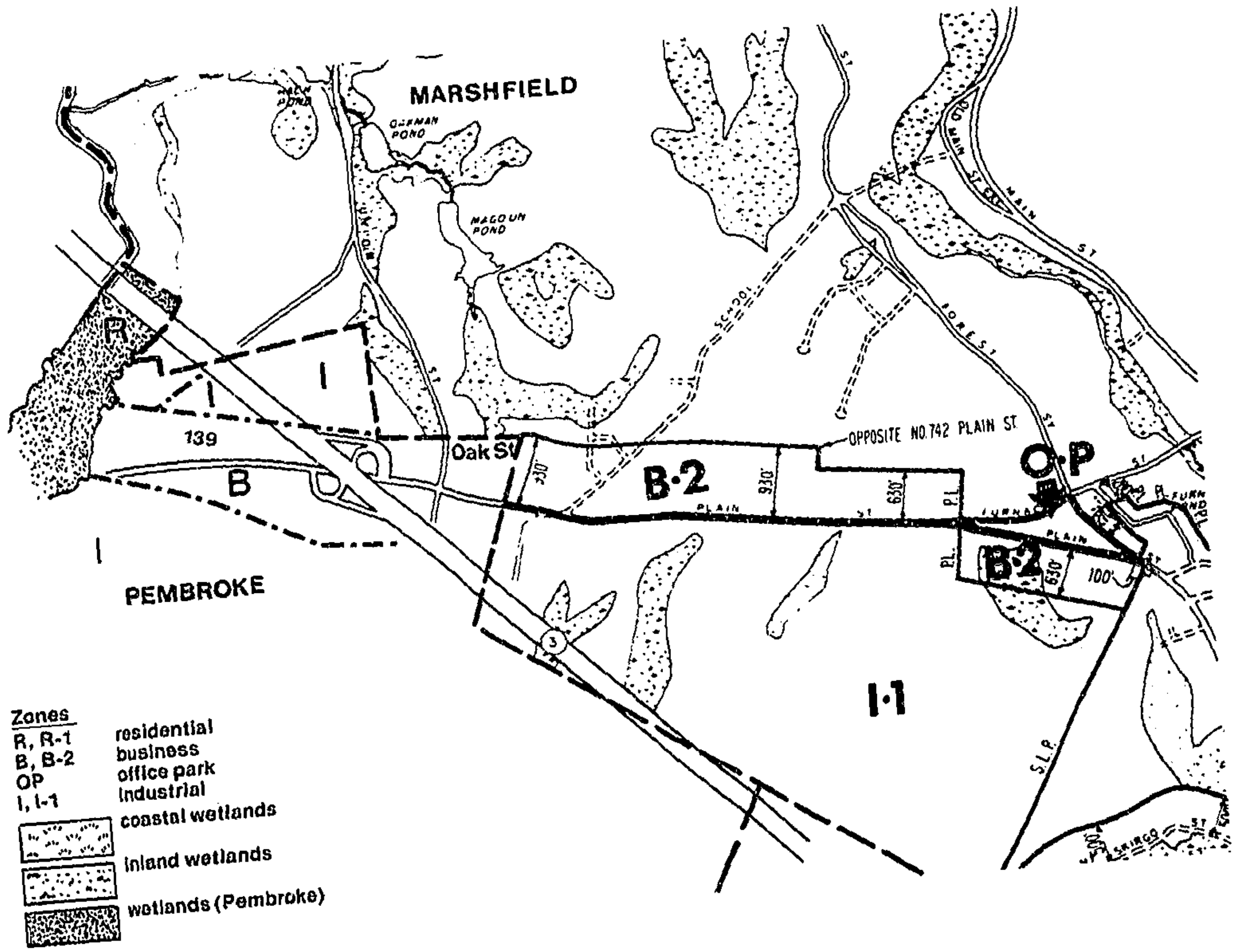
Acoustical Architectural Design Architectural building design in conjunction with site planning would be a practical method of utilizing the existing topography and vegetation to reduce noise impacts while still taking advantage of the scenic attributes of the area. Implementation of such a program of acoustical architectural design becomes, however, more a matter of incentive and eduation than enforcement.

One possible legal method of enforcement available to the two towns would be the inclusion of maximum permitted interior noise levels in the Board of Health's regulations, the Building Code, or the Planning Board's subdivision rules and regulations. Enforcement could be via the occupancy permit procedure which already exists in Marshfield's zoning bylaw, or by a similar procedure which could be voted by Pembroke's Town Meeting.

Design Services Neither town has a professional design staff with the ability and time to provide acoustical guidance to individual builders. It is unlikely that the Town Meeting would decide to fund such a municipal service.

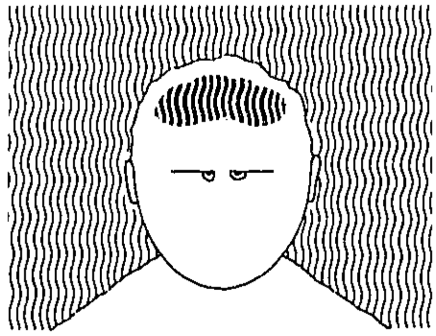
An Architectural Review Board could provide such a service. At present no such board exists in either town, and there has been little more than vague talk of founding one. However, each town has a large pool of potential members for such a board, and the towns could certainly benefit in many ways other than acoustical design if such boards were created. What is needed is the key person to serve as catalyst towards the founding of an Architectural Review Board.

Acoustical Construction The location of the study site is in an area of the country where temperatures rarely exceed 90 degrees and where proximity to the ocean and tidal marsh often results in cooling sea breezes. As such, air conditioning of residential homes is infrequent. Any building technique which calls for sealing windows and cooling with air-conditioning is therefore impractical.



A-14 Study Site

Appendix B: Noise Effects, Measures, Standards, and Predictors



This appendix contains brief discussions on the effects of noise on human life and economics, a definition of the noise measures and descriptors used in this manual, a review of certain Federal noise standards, and a listing of three recent noise level prediction techniques. The issues of noise costs, noise prediction and desirable noise levels are complex and controversial. These pages do not attempt a comprehensive analysis of these topics, nor do they advocate one particular standard or predictor. Rather, they are solely intended to provide an introductory background to aid in the use of this manual.

The Effects of Noise

The effects of noise on health are both physiological and psychological, though primarily psychological. Physiologically, excessive noise is capable of producing hearing loss, however it seems unlikely that many people have suffered from highway generated noise in this way.[1] Psychologically, the affects are more widespread:

- Noise can interfere with speech communications and the perception of other auditory signals
- Noise can disturb sleep and relaxation
- Noise can interfere with an individual's ability to perform complicated tasks.
- Noise can be a source of annoyance, it can influence mood, and can otherwise detract from the quality of life.[2]

As of yet, no one has been able to calculate the dollar cost of noise, but knowledgeable people think it is high.[3] The areas which highway noise affects economically are a) property values, b) impaired health, and c) lowered working efficiency. Property values have been the area of greatest concern because this is where financial impacts are most immediately felt and clearly distinguishable. Although studies have not provided conclusive evidence that highway noise reduces property values, there are strong indications that it does when the property use is incompatible with the highway, as in the case of many residential areas.[4] Other economic impacts which should be considered (although difficult to quantify), are those due to impaired health and lowered working efficiency.

Noise Measures and Descriptors

Sound is transmitted as rapid changes in air pressure which can be detected by our ears or by a sound meter. Acoustically, we do not usually measure air pressure changes in linear terms such as pounds per square inch or dynes per square centimeter. If we did, we would find ourselves using an astronomical range of numbers to describe the wide range of audible sounds. Therefore we compress

[1] W. Dixon Ward, "Effects of Noise on Hearing Thresholds," *Noise as a Public Health Hazard*, ASHA Reports 4 (The American Speech and Hearing Association, Washington, D.C., Feb. 1969), pp. 40-47.

Federal Highway Administration, Final Environmental Impact Statement Pursuant to Section 102 (2) (C), P.L. 91-100 - *Noise Standards and Procedures* (November 1972), pp. 183-186.

[2] The Administrator of the Environmental Protection Agency, *Report to the President and Congress on Noise*, 92nd Congress - 2nd Session, Document No. 92-93, (Washington, D.C.: Government Printing Office, 1972), p.xxii.

entire range of audible sounds into a arithmic scale which has the added antage of corresponding well to the nan ear's sensitivity to sound. The unit measurement is called the decibel).[5] The meaning of the dB scale can st be seen from a comparison of com- n sounds with their dB levels. (See ure A-16)

hould be remembered that logarithmic iles are not additive. That is, the com- ation of two 70 dB noise sources does result in 140 dB; rather, the result is proximately 73 dB.

150	Jet take off (at close range on the ground)
130	Machine gun, riveting machine
120	Thunderclap
117	jet plane (at passenger ramp)
107	Loud power mower
94	Pneumatic jackhammer
90	Sportscar, truck, shouted conversation
50-	
60	Normal conversation
50	Quiet street
40	Quiet room
0	Threshold of Audibility

A-16 Typical dB Readings of Common Sounds[1]

[1] Harold W. Bredin, "City Noise: Designers Can Restore Quiet, at a Price," *Product Engineering*, November 18, 1968, p. 29.

ironmental Protection Agency, *Economic Impact of Noise*, ishington, D.C., U.S. Govern- nt Printing Office, # TID 300.14, ember 31, 1971), pp. 39-45.

artment of California Highway rol, *Passenger Car Noise Survey*, ramento, January 1970.)

Robin M. Towne and Associates, Inc., *An Investigation of the Effect of Freeway Traffic Noise on Apartment Rents*, prepared for the Oregon State Highway Commission and the United States Department of Commerce, Bureau of Public Roads, October 1961.

5 The reference level for this scale is the zero dB pressure of 0.0002 dyn/cm^2.

ppendix B: oise easures

Because we are interested in human reaction to noise, it is important that a meter measures noise in the same way that humans perceive it. To the human ear, loudness is not only a function of sound intensity, but also of sound frequency. Higher frequency sounds tend to seem louder to people than lower frequency sounds. Therefore, sound level meters are often equipped with weighting networks which give more weight to higher freqency sounds. There are three different weighting networks, designated as A, B and C, which give varying degrees of weight to high frequency sounds. Highway generated noise is usually measured with the A-weighted network. The readings taken on the meter are recorded in A-weighted decibels (dBA).

In measuring noise which fluctuates, such as traffic noise, it is necessary to consider some average of noise level readings taken over time. In the case of highway noise measurement, it is important that this "average" correlates well with human annoyance to noise. To obtain a meaningful measure of traffic noise, readings can be taken periodically over a period of several hours, and a selected percentile level can be used. Three commonly used noise level descriptors are:

L_{10} - The noise level exceeded 10% of the time

L_{50} - The noise level exceeded 50% of the time

L_{90} - The noise level exceeded 90% of the time

The L_{10} noise level is an indicator of the noisiest portion of highway traffic, while L_{50} and L_{10} respectively represent the average and quietest portions. Because annoyance seems to be more a function of the loudest of the noisiest vehicles, e.g., trucks, the L_{10} descriptor correlates best with annoyance.

Highway Generated Noise Standards

Using the scales and measures described above, various studies have been done to determine noise levels which are compatible with existing land uses.[1] Based on these studies, various government agencies have established compatible noise levels for regulatory purposes. Of particular interest are the noise standards set by the U.S. Department of Transportation's Federal Highway Administration to regulate the design of highways passing through developed areas, and by the U.S. Department of Housing and Urban Development to regulate land use around existing and proposed highways.[2]

FHWA Standards

Presented here are the noise standards issued by the Federal Highway Administration for use by state and Federal highway agencies in the planning and design of highways:

[1] e.g., The Wilson Committee, *Noise - Final Report of the Committee on the Problem of Noise* (HMSO, London, 1963); Elizabeth Cuadra and Dale R. Beland, "Rationale for the Comprehensive Control of Urban Noise," paper presented at 16th annual meeting of the Institute of Environmental Science, "The Environmental Challenge of the Seventies," (Boston, Massachusetts, April, 1970) pp. 12-17; and Highway Research Board, NationalCooperative Highway Research Program Report 78, *Highway Noise Measurement, Simulation and Mixed Reaction*. National Academy of Sciences: National Academy of Engineering, 1969.

[2] In addition, the U.S. Environmental Protection Agency regulates vehicle noise emissions.

Design Noise Level/Land Use Relationships[3]

Land Use Category	Design Noise Level - L_{10}	Description of Land Use Category
A	60 dBA (Exterior	Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B	70 dBA (Exterior	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreation areas, playgrounds, active sports areas, and parks.
C	75 dBA (Exterior)	Developed lands, properties or activities not included in categories A and B above.
D	—	For requirements on undeveloped lands see paragraphs 5a(5) and (6), this PPM.
E	55 dBA (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums.

[3] U.S. Department of Transportation, Federal Highway Administration, *Policy and Procedure Memorandum 90-2, Noise Standards and Procedures* (February 8, 1973).

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ndards

These levels represent a compromise between what is desirable and what is acheivable; hence, local officials may want to strive for lower levels in controlling compatible land use development.[1]

HUD Noise Standards

In 1971, the Department of Housing and Urban Development adopted noise standards for use by builders of Federally-funded housing:[2]

HUD Noise Level Criteria

Exterior	
discretionary - normally acceptable	65 dBA - L_{33} (not to be exceeded more than 8 out of 24 hrs.)
clearly acceptable	45 dBA - L_2 (not to be exceeded more than 30 min. out of 24 hrs.)
Interior	
clearly acceptable	45 dBA - L_{33} (not to be exceeded more than 8 out of 24 hrs.)
	55 dBA - L_4 (not to be exceeded more than 1 out of 24 hrs.)
night:	45 dBA - L_6 (not to be exceeded more than 30 min. out of 8 hrs.)

[1] FHWA, *Final Environmental Impact Statement Pursuant to Section 102 (2) (C), P.L. 91-190, Noise Standards and Procedures* (FHWA EIS-72-020F, Washington, D.C., November, 1972) 16-17.

[2] US Department of Housing And Urban Development, *Department Circular 1390.2, Noise Abatement and Control: Departmental Policy, Implementation Responsibilities, and Standards* (Washington, D.C., August 4, 1972).

Prediction of Noise Levels

Determination of the noise level near an existing highway simply involves taking a series of readings over a sufficient time interval at appropriate locations near the highway.

Direct measurement is not possible, however, when noise levels near an uncompleted highway project are desired, when traffic patterns have not yet reached the ultimate levels, or when some nearby action such as construction of a barrier or removal of a forest, may affect the noise pattern. Furthermore, direct measurement may not be practical in large scale projects where data on thousands of points along many miles of highway is desired. In these cases, use of one of many noise prediction techniques is appropriate. The following are two techniques which are readily available for use:

Traffic Noise Prediction Model MOD 2
A computer program described in Report No. DOT-TSC-FHWA-72-1 available from National Technical Information Service Springfield, Virginia 22151

Highway Noise - A Design Guide for Highway Engineers
National Cooperative Highway Research Program Report 117 available from Highway Research Board National Academy of Sciences