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AUTHOR	Walsh, David P.
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ABSTRACT

A major survey of all schools built prior to 1933 was conducted after the enactment of the Field Act, which, in California, required specific school construction standards for earthquake safety. One aspect of this study, the acoustical environment of San Francisco Schools, is described in this speech. The document outlines the following procedures: (1) for the acoustical portion of the survey, a field survey was made to establish the existing condition at the facilities; (2) deficit documentation, which involved matching the existing conditions against the district standards by computer, was then completed; (3) unit costs for corrective work on all substandard areas were developed; and (4) cost benefit tables that matched the deficit documentation with the unit costs for corrective action were established. Portions of the forms used and computer printouts are included. (Figures 1 and 6 will reproduce poorly because of marginal legibility.) (Author/MLF)

RATING SYSTEM FOR EVALUATING THE ACOUSTICAL ENVIRONMENT OF EXISTING SCHOOL FACILITIES

by

David P. Walsh

Wilson, Ihrig & Associates, Inc.
~~2344 Sixth Street~~
~~Berkeley, California 94710~~
5605 OCEAN VIEW DRIVE
OAKLAND, CALIFORNIA 94618

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If we were to take a sampling of the recent literature dealing with educational facilities we would see such topics discussed as innovative architectural planning concepts, new school construction techniques and system components, new concepts of space planning, student orientation, etc. However, a much more serious problem faces school administrators in major cities who must contend with the constant upkeep of existing, often sub-standard, school facilities.

If we look at the situation from an historical standpoint, we can see how the problem has developed over the years. During the Depression years most urban school construction stopped and little construction occurred during the following war years. During the late 40's, 50's, and 60's the southern Black immigration into the cities was matched by the FHA-sponsored white emigration out of the cities, into the suburbs. The result was a negligible net change in the public school population.

Since, typically, new schools are built to meet increased enrollment most urban schools in major U.S. cities date back to just after the turn of the century. Due to this situation the school market is now expanding to meet the renovation needs of these antiquated inner-city buildings. This is occurring because renovation is more expedient than new construction, and because it is less expensive.

In most instances, however, school districts have not developed an effective, systematic approach to school renovation or plant repair and have no way of determining the extent of renovation required throughout the district. One approach towards organizing the numerous factors inherent in the physical upkeep of school facilities was developed for the San Francisco Unified School District [SFUSD]. This program, called the Computerized Facilities Inventory [CFI], was developed by Architect M. P. Berline* of San Francisco under a grant from the Educational Facilities Laboratory, Incorporated.

This program included a major survey of all schools built prior to 1933 when the Field Act, which in California required specific school construction standards for earthquake safety, was enacted.

Figure 1 shows the location of the schools surveyed in San Francisco. The total number of schools involved in the survey was 61 [49 elementary, 8 junior high, and 4 senior high schools], represneting a combined enrollment of approximately 50,000 students, or about half of the total enrollment of the School District.

As part of this study each teaching space was surveyed and data on its physical condition was collected in each of the following categories: Ventilation and Heating Systems, Lighting, Architectural, and Acoustics.

* Michel Paul Berline, Architect
School Renovation System, Inc.
60 Union Street
San Francisco, California 94111

In each of these categories the same approach for defining the problem was followed, as shown on Figure 2: STANDARDS were established, based on standard units of measure available in each area of concern; a STATEMENT OF THE EXISTING CONDITION OF THE FACILITIES was made [i.e., a field survey]; DEFICIT DOCUMENTATION was then completed which involved matching the existing conditions against the District standards by computer; DEVELOPMENT OF UNIT COSTS for corrective work on all sub-standard areas; and ESTABLISHMENT OF COST/BENEFIT TABLES which matched the deficit documentation with the unit costs for corrective action.

The STANDARDS used for the acoustical portion of the survey were developed from the three basic parameters of Architectural Acoustics: NOISE CONTROL, SOUND ISOLATION, and ROOM ACOUSTICS; and the standard units of measure that relate to them, such as; NC levels, Noise Reduction [NR] of various building constructions, Reverberation Time [RT] within spaces, etc.

However, the time and instrumentation associated with collecting this type of data for each teaching space would have been prohibitively expensive. For example, it would have cost in the range of $200 to $300 per classroom to obtain this data or about $11,000 for a typical elementary school.

More importantly, however, the degree of accuracy obtained in these types of objective measurements was not required and, in fact, could not have been used. The degree of accuracy which was required in this Survey was that which could specify corrective action for typical acoustical deficiencies. Therefore, as seen on Figure 3, the approach that was taken was to establish approximations of the standard acoustical units of measure which could then be used to subjectively evaluate the existing conditions in the field.

As a first step in developing the FIELD APPROXIMATIONS of acceptable levels for both background and intruding noises, the types of teaching spaces used in the School District were tabulated. Since there are a large number of different types of teaching spaces in the district their acceptable noise levels are related to the type of activity in each space. Figure 4 is a SPACE IDENTIFICATION TYPE chart which shows the types of teaching spaces in the School District and their acceptable background noise levels.

The next step was to prepare a Survey Form which we could take to the various schools and record data on sub-standard acoustical areas. This required taking the FIELD APPROXIMATIONS of our standard acoustical units of measure to identify the typical noise sources encountered in schools and relating them to the normal sound transmission paths found in school construction. An example of this is shown on Figure 5 for the major noise source in schools - playgrounds. We then combined these parameters with the SPACE IDENTIFICATION TYPES to allow for every possible combination of noise source, sound transmission path, and teaching space. This combination of parameters resulted in a Survey Form which is shown on Figure 6.

This chart is obviously much too cumbersome and confusing to use in the field survey. Therefore, a much simpler chart had to be developed. This was accomplished in the following manner. For both the NOISE CONTROL and SOUND ISOLATION sections the ambient noise level and the level of intruding noise within the space were to be subjectively rated on a scale from 1 to 4, relative to the type of activity within the space:

1. <u>NOISE LEVEL IS UNOBTRUSIVE FOR ALL FUNCTIONS</u>

   This represents the range of Sound Pressure Levels [SPL] normally found in Music Rooms, Practice Rooms, etc.

2. <u>NOISE LEVEL IS UNOBTRUSIVE FOR TEACHING FUNCTIONS</u>

   This represents the range of SPL's within a space which allows a high-degree of speech intelligibility at normal conversational voice levels.

3. <u>NOISE LEVEL IS HAMPERING TO TEACHING FUNCTIONS</u>

   This represents the range of SPL's within a space which makes it necessary to use a raised voice level in order to communicate intelligibily.

4. <u>NOISE LEVEL IS DISRUPTIVE TO TEACHING FUNCTIONS</u>

   This represents the range of SPL's within a space which makes it necessary to use a raised voice level at very close distances in order to communicate intelligibly.

Since the primary purpose of this survey was to determine areas where corrective action was required, teaching spaces that had subjectively QUIET or UNOBTRUSIVE noise levels were not recorded.

For the ROOM ACOUSTICS section the acoustical environment due to finish materials and space geometry was to be noted. The Reverberation Time within the space was to be rated in one of four ways:

THIS SPACE HAS A LOW REVERBERATION TIME SUITABLE FOR DRAMA, MUSIC PRACTICE, ETC.

THIS SPACE HAS AN ACCEPTABLE REVERBERATION TIME FOR TEACHING.

THIS SPACE PRODUCES AN ANNOYING DISTORTION OF SPEECH SOUNDS.

THIS SPACE IS TOO REVERBERANT FOR INTELLIGIBLE SPEECH.

Other acoustical phenomena within the space, such as FLUTTER, ECHO, and FOCUSING OF SOUND, and recommendations for the placement of sound absorptive materials to correct these shortcomings were also to be noted on the chart.

These field approximations resulted in the development of the chart shown on Figure 7,* which was used throughout the survey.

As an example of the survey procedure the acoustical deficiencies of a typical classroom are shown here:

- The top number indicates the computer designation of the school and the floor level.
- The room number is listed below. [Space is provided for additional room numbers since the ratings for several classrooms in a school may be identical.]

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* Note: The charts developed for the CFI Survey are copyrighted.

- Acoustical deficiencies of the 3 and 4 categories are indicated in the SOUND ISOLATION section. [Apparently this classroom is adjacent to a playground and the operable sash windows are inadequate to reduce the playground noise to an unobtrusive level. Similarly, the door to the corridor is acoustically inadequate.]
- Lastly, the ROOM ACOUSTICS rating and recommendation are shown.

The results of the Acoustical Survey, plus the results of all the other surveys, were recorded on punch cards for each teaching space and stored in the School District's accounting computers at the Board of Education Building.

Concurrent with the completion of the Survey, a list of UNIT PRICES FOR CORRECTIVE ACTION was developed in which the costs for all work necessary to correct the acoustical deficiencies recorded in the Survey were established. This cost information was also stored in the computers and is updated periodically to reflect labor and material cost changes.

Once the Survey was completed, coded, and fed into the computer, the cost of any or all corrective work was available to the appropriate personnel on the Board of Education. An example of the COST/BENEFIT information available from the computer for the acoustical corrective work in a particular school is shown on Figure 8.

From the Survey it was found that the primary acoustical deficiency common to the majority of spaces was the lack of acoustical isolation provided by the windows. This inadequate isolation is due to several factors. The windows are the old type of wood frame, operable sash windows which have warped considerably over the past 40 years. Gaps between the sash and the sill can be as much as 1/4" when the windows are completely closed and locked. Another important factor is that the type and patterns of vehicular traffic have changed significantly since these schools were built with a resulting increase in vehicular noise levels. Lastly, and most importantly, the school curriculum at the turn of the century when these schools were designed called for a common recess time for the entire school. Today classes rotate their recess times with the result that several classes use the playground continuously throughout the school day creating a day-long, high-level noise source.

In these schools the only available action for reducing the levels of disruptive exterior noise is to close the windows. Therefore our most important recommendation for remedial work was to improve the noise reduction provided by the windows. There were two degrees for this corrective work. The first was to eliminate the leakage paths and to provide airtight seals at the jamb and sill by means of resilient gasketing. The second, where higher exterior noise levels existed, such as from a playground, entailed permanently sealing the existing windows and applying a sheet of 1/4" Plexiglas to the exterior wood frame. Figure 9 shows the detail used for this corrective work.

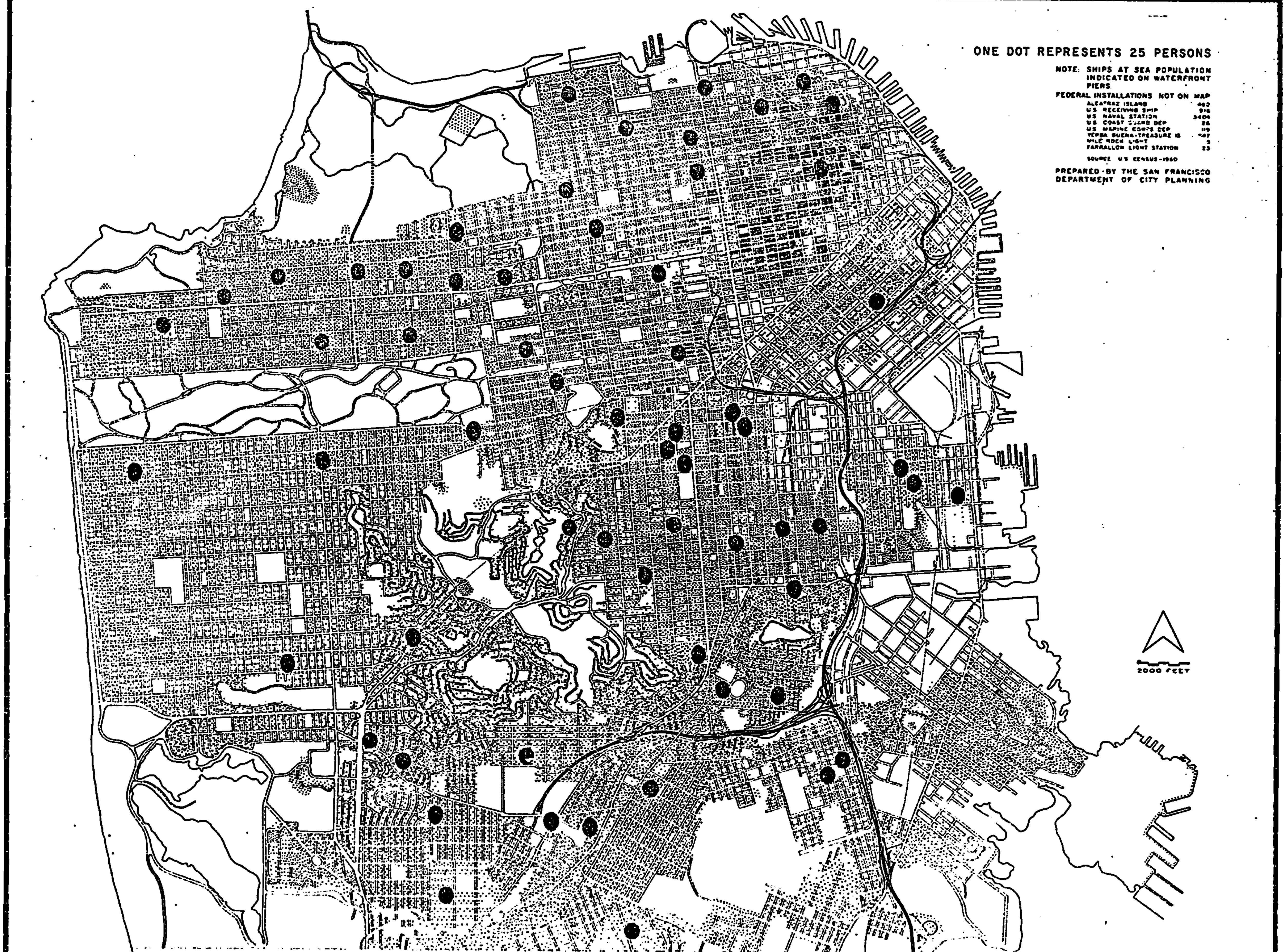
We were fortunate to have the opportunity of evaluating the improvement in noise reduction provided by this construction in one of the schools used in the Survey. This slide [Figure 10] is a photograph of the exterior of a typical classroom adjacent to a playground. The next slide [Figure 11] shows a close-up of one of the windows. Next is a slide [Figure 12] showing the double glazing construction in place. The cost of this installation was approximately $2.00 to $2.50 per square foot including labor and materials.

The major drawback to this type of detail is that the only source of fresh air for the classroom is sealed off. To compensate for this some form of forced air ventilation is required. As an outgrowth of the data collected in the Computerized Facilities Inventory, Architect Berline and his firm developed a modular, systems unit for school renovation which has the capability of providing such functions as forced air ventilation wherever necessary. An example of this approach is shown in the next two slides. The first slide [Figure 13] shows the interior of a typical classroom which has the standard, turn of the century finish treatments of linoleum flooring, plaster walls and ceilings, incandescent lighting, and the same wood frame, operable sash windows which were seen earlier. The next slide [Figure 14] shows the same classroom with the prototype of the School Renovation System installed, together with a new carpet and a fresh coat of paint. The system consists of an integral, "plug-in" suspension unit which contains: completely ducted unit ventilators, air supply and return diffusers, fluorescent fixtures, electrical power supply, lay-in acoustical ceiling panels, etc. To install one of these units in a classroom takes five working days and costs between $5.00 and $7.00 per square foot, plus service runs to the unit.

In summary, the major problem facing urban School Districts is that of improving the physical condition of their all-too-often antiquated school facilities. The most expedient way of upgrading these physical conditions is through school renovation rather than through new school construction, because it is faster and more economical.

As was discovered in the Computerized Facilities Inventory the one, significant problem existing in urban schools requiring corrective action is acoustics; that is, Noise Control, Sound Isolation, and Room Acoustics. From the data obtained in the Survey for the San Francisco Unified School District the computer cost analysis for corrective work shows that Acoustics Related problems alone run from 40% to 50% of the total cost figure.

The problem of upgrading existing school facilities is a very real and serious one, one which will not disappear by itself. A practical, systematic approach which will adequately define the problems of school renovation, provide realistic solutions, and present them in a usable format for school administrators is required. The procedures and techniques described here for the San Francisco Survey have, we feel, accomplished these goals.


ONE DOT REPRESENTS 25 PERSONS
NOTE: SHIPS AT SEA POPULATION INDICATED ON WATERFRONT PIERS
FEDERAL INSTALLATIONS NOT ON MAP
ALCATRAZ ISLAND
US RECEIVING SHIP
US NAVAL STATION 3404
MILE ROCK LIGHT 9
FARRALLON LIGHT STATION 23
SOURCE U S CENSUS-1960
PREPARED BY THE SAN FRANCISCO DEPARTMENT OF CITY PLANNING
2000 FEET

ESTABLISHMENT OF STANDARDS

STATEMENT OF THE EXISTING CONDITION OF THE FACILITIES

DEFICIT DOCUMENTATION

DEVELOPMENT OF UNIT COSTS

ESTABLISHMENT OF COST/BENEFIT TABLES

FIGURE 2: PROCEDURE FOR COMPUTERIZED FACILITIES INVENTORY

STANDARD ACOUSTICAL UNITS	FIELD APPROXIMATIONS
1. NOISE CONTROL SPL NC dBA PSIL	1. IDENTIFY NOISE SOURCES WITHIN SPACES
2. SOUND ISOLATION NR TL INR	2. IDENTIFY NOISE SOURCES OUTSIDE THE SPACE AND DETERMINE HOW THEY ARE TRANSMITTED TO THE SPACE (A) Airborne (B) Structure-borne
3. ROOM ACOUSTICS RT AI	3. EVALUATE THE QUALITY OF SOUND WITHIN THE SPACE AND DETERMINE THE CAUSITIVE FACTOR (A) Room Finish Treatment (B) Room Geometry

FIGURE 3: RELATIONSHIP BETWEEN STANDARD ACOUSTICAL UNITS OF MEASURE AND FIELD APPROXIMATIONS USED IN CFI SURVEY

FIGURE 4: SPACE IDENTIFICATION TYPES FOR SFUSD

A. Standard Classroom Spaces	Academic Classrooms Reading Rooms Individual Study Areas	NC 35-40
B. Specialized Classroom Spaces	1. General Science Classrooms Language Classrooms	NC 35-40
	2. Business Machines Typing Classrooms	NC 40-45
C. Large Group Instruction Spaces	1. Band Rooms Orchestra Rooms Choral Rooms Auditoriums Theatres	NC 25-30
	2. Multipurpose II Spaces	NC 35-40
D. Small Group Instruction Spaces	1. Seminar Rooms	NC 35-40
	2. Music Practice Rooms	NC 25-30
E. Academic Laboratories	Drafting Rooms Biology Labs Chemistry Labs Mathematics Labs Physics Labs	NC 35-40
F. Craft Laboratories	1. Arts and Crafts Dramatic Arts Homemaking	NC 35-40
	2. Auto Shop Electrical Shop Wood Shop Metal Shop Print Shop	NC 40-45
G. Activity Spaces	Gymnasiums Cafeterias Multipurpose I Spaces (Self Contained)	NC 40-45
H. Administrative Spaces	Offices Counseling Areas Library Catalog Control Faculty Work Rooms Faculty Lounge	NC 35-40

FIGURE 5: PORTION OF COMPUTER INPUT FOR EVALUATING PLAYGROUND NOISE

```
080  10  20  20  100  NOISE FROM PLAYGROUNDS IS BELOW AMBIENT
080  10  20  20  400  NOISE FROM PLAYGROUNDS IS UNOBTRUSIVE FOR CLASSROOM FUNCTIONS
080  10  20  20  600  NOISE FROM PLAYGROUNDS IS UNOBTRUSIVE FOR SHOP FUNCTIONS
080  10  20  20  900  NOISE FROM PLAYGROUNDS IS DISRUPTIVE TO TEACHING FUNCTIONS
080  10  20  20  910  SOUND TRANSMISSION IS THRU GLASS
080  10  20  20  920  SOUND TRANSMISSION IS THRU OPERABLE SASH
080  10  20  20  930  SOUND TRANSMISSION IS THRU MECHANICAL SYSTEM
080  10  20  20  932  SOUND TRANSMISSION IS THRU MECH. VENT TO OUTSIDE
080  10  20  20  933  SOUND TRANSMISSION IS THRU GRAVITY VENT TO OUTSIDE
080  10  20  20  934  SOUND TRANSMISSION IS THRU MECH. VENT TO ADJACENT SPACE
080  10  20  20  935  SOUND TRANSMISSION IS THRU GRAVITY VENT TO ADJACENT SPACE
080  10  20  20  936  SOUND TRANSMISSION IS THRU GRAVITY SUPPLY FROM OUTSIDE
080  10  20  20  937  SOUND TRANSMISSION IS THRU MECHANICAL SUPPLY FROM OUTSIDE
080  10  20  20  938  SOUND TRANSMISSION IS THRU  GRAVITY   SUPPLY FROM ADJACENT SPACE
080  10  20  20  939  SOUND TRANSMISSION IS THRU MECHANICAL SUPPLY FROM ADJACENT SPACE
080  10  20  20  940  SOUND TRANSMISSION IS THRU CEILING
080  10  20  20  950  SOUND TRANSMISSION IS THRU FLOOR
080  10  20  20  960  SOUND TRANSMISSION IS THRU WALLS TO ADJACENT SPACE
080  10  20  20  970  SOUND TRANSMISSION IS THRU TO CORRIDOR
080  10  20  20  972  SOUND TRANSMISSION IS THRU DOOR TO CORRIDOOR
080  10  20  20  975  SOUND TRANSMISSION IS THRU WALL TO CORRIDOR
080  10  20  20  978  SOUND TRANSMISSION IS THRU GLAZING TO CORRIDOR
080  10  20  20  980  SOUND TRANSMISSION IS THRU OPENINGS TO ADJACENT SPACE
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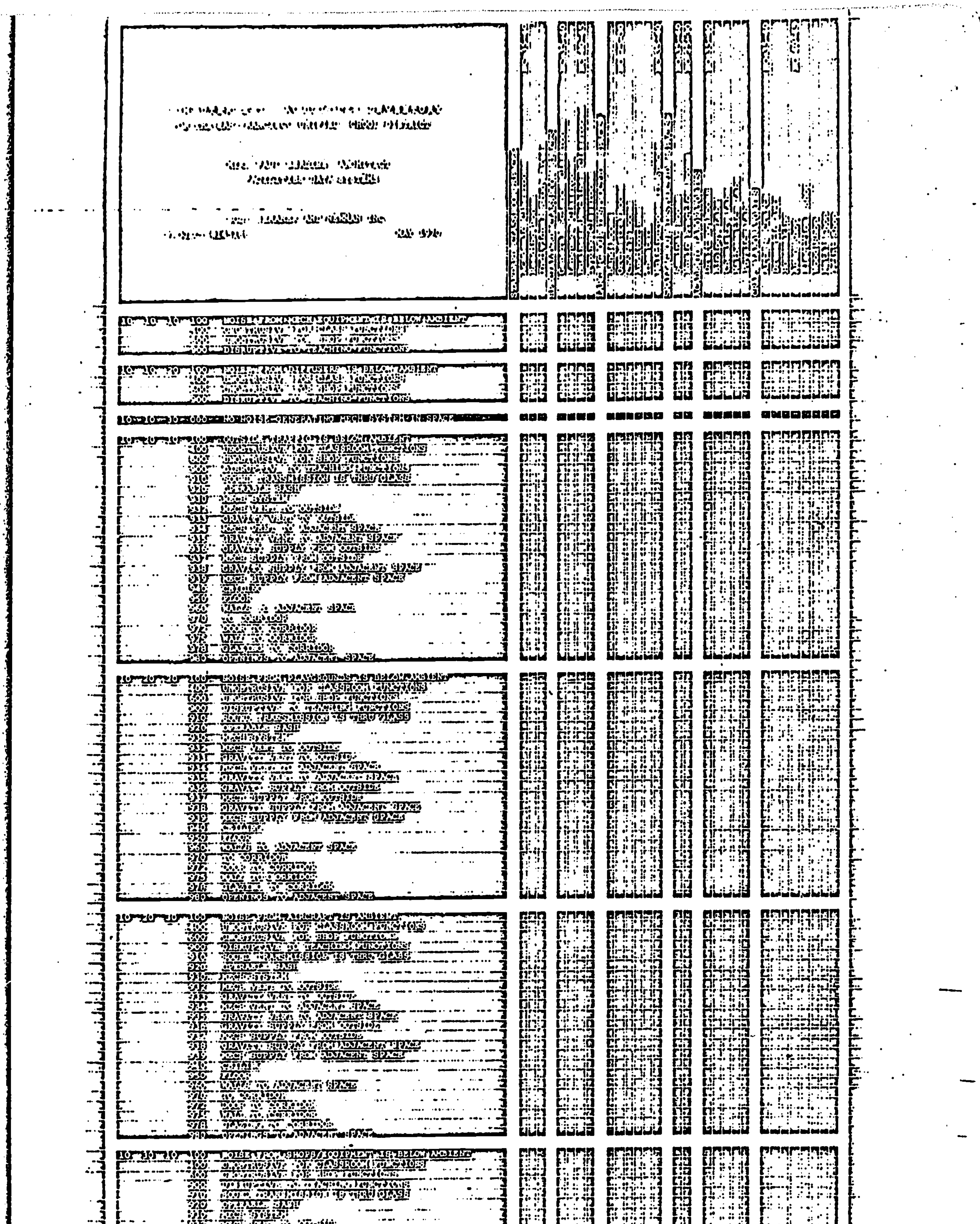

FIGURE 6: PORTION OF PRELIMINARY ACOUSTICAL SURVEY FORM

[Note]: This Form continues for 6 more sections

FIGURE 7: CFI SURVEY FORM

SCHOOL	Sherman Elementary	NUMBER	0 2 3 3 8 2 2 0 FLOOR
INSPECTOR	DPW	DATE	8 Sept 70

ROOM NUMBERS	204							

NOISE LEVEL IN SPACE IS VERY QUIET 080 000 100 001	[ ]	NOISE LEVEL IN SPACE IS OK FOR TEACHING 080 000 100 002	[ ]

					QUANTITY
STRUCTURE BORNE NOISE	CEILING TRANSMITS IMPACT NOISE	080 200 100 00[ ]	[ ]		
	WALL TRANSMITS IMPACT NOISE	080 200 200 00[ ]	[ ]	sq.ft.	
	WATER-HAMMER IN HEATING SYSTEM	080 200 300 00[ ]	[ ]		
	OTHER PLUMBING NOISE	080 200 350 00[ ]	[ ]		
	EQUIP. TRANS. VIB. TO OTHER SPACE	080 200 400 00[ ]	[ ]	quantity	
INSIDE NOISE	MECHANICAL EQUIPMENT IN SPACE	080 300 100 00[ ]	[ ]	quantity	
	DIFFUSERS IN SPACE	080 300 200 00[ ]	[ ]	quantity	

NOISE FROM:

TRAFFIC 10	PLAYGROUNDS 20	AIRCRAFT 30	ADJACENT SHOPS/EQUIP 40	NORMAL SPEECH 50	RAISED VOICES 60	AMPLIFIED SOUND 70	LIVE MUSIC 80	NOISE FROM ADJ. CORR 90	TRANSMITTED THROUGH	ENTER '3'or'4'	QUANTITY
	4								GLASS	080 4[_ _] 000 10[ ]	
	4								OPERABLE SASH	080 4[_ _] 000 20[ ]	
									DUCTS quantity	080 4[_ _] 000 30[ ]	
									CEILING	080 4[_ _] 000 40[ ]	
									FLOORS	080 4[_ _] 000 50[ ]	
									WALL AREA sq.ft.	080 4[_ _] 000 60[ ]	
									MISC. OPENINGS	080 4[_ _] 000 70[ ]	
								3	DOORS quantity	080 4[_ _] 000 80[ ]	2

ERISTICS			
	LOW REVERBERATION TIME GOOD FOR DRAMA MUSIC ETC.	[ ]	080 500 100 001
	ACCEPTABLE REVERBERATION TIME FOR TEACHING	[ ]	080 500 100 002
	AN ANNOYING DISTORTION OF SPEECH SOUNDS	[ ]	080 500 100 003
	TOO MUCH REVERBERATION TIME FOR INTE. SPEECH	[X]	080 500 100 004
	FLUTTER ECHO	[ ]	080 500 200 003
	ANNOYING ECHO	[ ]	080 500 200 004
	ANNOYING FOCUSSING OF SOUND	[ ]	080 500 300 003
	SOUND ABSORBING CEILING TREATMENT REQUIRED	[X]	080 500 900 100

SPACE ID	TYPE OF CORRECTIVE ACTION REQUIRED	COST FOR CORRECTIVE ACTION SPECIFIED
02339610080	ABSORB SOUND AT CEILING	$ 144.00
02339610113	ABSORB SOUND AT CEILING	$ 286.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 2,288.00
02339610113A	ABSORB SOUND AT CEILING	$ 97.50
	BLOCK SOUND THROUGH DOORS	$ 200.00
02339610190	ABSORB SOUND AT CEILING	$ 192.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 1,536.00
0233962B006	ABSORB SOUND AT CEILING	$ 372.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 2,976.00
	BLOCK SOUND THROUGH DOORS	$ 100.00
0233962B007	ABSORB SOUND AT CEILING	$ 384.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,072.00
	BLOCK SOUND THROUGH DOORS	$ 100.00
0233962B008	ABSORB SOUND AT CEILING	$ 384.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,072.00
	BLOCK SOUND THROUGH DOORS	$ 200.00
0233962B009	ABSORB SOUND AT CEILING	$ 384.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,072.00
	BLOCK SOUND THROUGH DOORS	$ 100.00
0233962B294	ABSORB SOUND AT CEILING	$ 408.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,264.00
02339620015	ABSORB SOUND AT CEILING	$ 416.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,328.00
02339620016	ABSORB SOUND AT CEILING	$ 416.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,328.00
02339620017	ABSORB SOUND AT CEILING	$ 416.00
	BLOCK SOUND THROUGH OPERABLE SASH	$ 3,328.00
	BLOCK SOUND THROUGH DOORS	$ 200.00
02339620018	ABSORB SOUND AT CEILING	$ 416.00

FIGURE 9: SKETCH DETAIL OF DOUBLE GLAZED WINDOWS