Rentals. Sources were asked how a typical household would be furnished. Responses included both hard- and soft-surface furniture.

The source at Grantree Furniture Rentals in Seattle, Washington supplied information for a house with more rooms than the 5-room unit being considered here. The inventory of hard and soft furniture suggested by this firm appears in Table E.3.11. Also shown in this table is the suggested inventory by Aaron Rents Furniture in Bellevue, Washington.

A single inventory of hard-surface furniture for a 5-room house can be distilled from these two lists. Ignoring the family room and the third bedroom included in the Grantree list, there is reasonable agreement from the two sources. A representative inventory of hard-surface furniture for the average household is presented in Table E.3.12.

The third and final group of hard-surface furnishings is plumbing fixtures. The average household is estimated to have a kitchen and one-and-a-half baths. The associated list of plumbing fixtures is: one double sink, two bathroom sinks, one bathroom cabinet, two toilets, and one shower-bath.

The next building contents category is soft-surface furnishings. A representative inventory of the items in this group can be constructed from the information obtained from the furniture rental companies described earlier. This inventory is shown in Table E.3.13.

In addition, windows in the living room, dining room, master bedroom, and second bedroom are assumed to have curtains. Curtains are estimated to cover 75% of the total glass area in the house. Due to pleating and vertical overlap, curtain area is assumed to be twice the area of the associated window. Therefore,

$$\begin{aligned} \text{curtain area} &= 2 \bullet 0.75 \bullet \text{window area} \\ &= 2 \bullet 0.75 \bullet c' \bullet h \bullet \text{PRA} \\ &= 2 \bullet 0.75 \bullet 0.09 \bullet 1.46 \bullet 136.8 \\ &= 27.0 \text{ sq meters} \end{aligned}$$

The factors c', h and PRA are discussed above and their values provided in Table E.3.5.

The third group of building contents is electronic equipment, which includes items such as televisions, radios, stereos, videocassette recorders, and personal computers. The primary source of information for this building contents category is a 1986 publication titled "Consumer Electronics U.S. Sales." The most useful of the statistics in this publication is Table 36, "Estimated Household Penetration by Product." This table shows how many households have specific items of consumer electronics. Table E.3.14 presents this information.

TABLE E.3.11. Suggested Inventories of Hard- and Soft-Surface Furniture for Representative Households, 1983

Grantree Furniture Rentals

Living room
- 1 sofa
- 2 wing back chairs
- 1 cocktail table
- 3 lamps
- 2 end tables

Family room
- 1 recliner
- 1 desk
- 2 lamps
- 1 love seat
- 1 book case

Kitchen-dining room
- 4-8 vinyl covered wood or metal chairs
- 1 table
- 1 china cabinet
- 1 other cabinet

Master bedroom
- 1 triple dresser
- 2 end tables
- 1 queen size bed
- 1 bookcase
- 1 chair
- 2 lamps

Second bedroom
- 1 double bed
- 1 night stand
- 1 lamp

Third bedroom
- 2 twin beds
- 1 night stand
- 1 lamp

Other
- possibly some patio or other outdoor furniture

Aaron Rents Furniture

Living room
- 1 love seat
- 1 cocktail table
- 2 lamps
- 2 end tables
- 1 bookshelf

Dining room
- 1 table, wood
- 4 chairs, wood and fabric

Master bedroom
- 1 dresser and mirror
- 2 night stands
- 1 queen size bed
- 2 lamps

Second bedroom
- 1 night stand
- 1 twin bed
- 1 lamp
- 1 chest or desk and chair

TABLE E.3.12. Representative Inventory of Hard-Surface Furniture for an Average Household

Living room	Master bedroom
1 cocktail table	1 triple dresser and mirror
2 end tables	1 queen sized bed frame and headboard
1 bookshelf	2 night stands
3 lamp bases	2 lamp bases
Dining room	**Second bedroom**
1 table, wood	1 night stand
1 cabinet	1 double bed frame and headboard
Other	1 dresser
4 hard-surface chairs	1 lamp base

As with the household appliance listing (Table E.3.9), this list is interpreted to mean that the average household possesses 0.92 color television sets, 0.60 black and white television sets, 0.37 videocassette recorders, 0.16 home computers, and so forth.

The last building contents category is paper products. This includes items such as documents, books and files. Not included are other paper products such as packaging materials.

According to a source at the American Paper Institute, Inc., publisher of the annual Statistics of Paper, Paperboard, and Woodpulp, there is information on the annual production of different types of paper products, but none on the paper products inventory in homes or businesses. The estimate of the paper products in homes is therefore based on the paper-related hard-surface furnishings items. These include a book case, a desk, and cabinet space. We assume the book case measures about two meters high by

TABLE E.3.13. Representative Inventory of Soft-Surface Furniture for an Average Household

Living room	Master bedroom
1 sofa	1 queen sized box spring
2 wing back chairs (or 1 love seat)	1 queen sized mattress
3 lamp shades	2 lamp shades
Dining room	**Second bedroom**
6 chairs	1 double sized box spring
	1 double sized mattress
	1 lamp shade

TABLE E.3.14. Percent of Households with Specified Electronic Equipment as of September 1986

Item	Percent of Households
All television	98
Color TV	92
Color TV with MTS[1]	4
Stereo-Adaptable Color TV	7
LCD Color TV[2]	1
Monochrome TV	60
Projection TV	3
VCR	37
Camcorders	2
Prerecorded videocassettes	33
Home computers	16
Audio systems	88
Compact	52
Component	40
Compact disc players	5
Telephone answering devices	13
Cordless telephones	15
Home radios	98

1 Color TV with built-in stereo capability.
2 Color TV with liquid crystal display.

Source: Electronics Industries Association, Consumer Electronics Group, "Consumer Electronics U.S. Sales," Table 36, "Estimated Household Penetration by Product", October 1986.

one meter wide with six shelves. If five of the shelves are used for books and other paper items, there are 5 shelf-meters of these. In addition, it is estimated that paper items in the desk, in the cabinet space, and elsewhere are equal to two standard file drawers of paper.

The last surfaces to be considered are exterior, horizontal surfaces other than roofs; namely, lawns and other paved asphalt and concrete areas. As discussed earlier, these surfaces are treated as a residual, after removing the area taken up by structures within single-family residential land use areas.

A guide for determining the share of residential land covered by lawn areas lies in several studies on rain water runoff prepared for various locations. In analyzing the amount, rate and pollution of runoff, these studies generally estimate the percentage of land cover that is "impervious". Impervious cover includes houses, sidewalks, roads, parking lots and other surfaces that prevent rainfall from penetrating into the soil. The principal

surface not included in this group is lawn. Thus, we can assume that, after some adjustments to the data, any residential surface that is not impervious is lawn.

The United States Geological Survey provided relevant sections of several of these runoff studies, each of which deals with several drainage areas within a specific city or urban area. None of the studies identify the percentage of impervious cover for all residential areas in the United States. Further, the locales for these investigations were not selected with any intent to be representative of any particular land use type. This means that these data can only give an indication of the range and variability of factors **d**, **e** and **f**, which correspond to the relative respective amounts of other paved asphalt, other paved concrete, and lawn area.

Table E.3.15 presents data from these reports that are relevant for estimating lawn cov r in residential areas. Note that the drainage areas in the runoff reports a not strictly residential according to the designations used in this work. In particular, impervious areas in the runoff reports include road surfaces, and some reports note portions of the drainage area that are commercial, industrial, or other land use type.

The Pompano Beach, Florida, site characteristics provide sufficient information to make a rough estimate of how much the given impervious percentage should be adjusted to remove road surface area. Assuming a street width of 7.6 meters (25 feet), which appears reasonable from the aerial photo in the report, then each lot, including its share of the street, measures about 28.2 meters by 30.5 meters, making a total of 860 sq meters per lot. Since 43.9% is designated impervious, that is equivalent to about 377 sq meters. Of this area, the street comprises an area of about 3.8 meters by 24.4 meters, an area of 92.7 sq meters. Thus, the impervious nonstreet area per parcel is 284.3 sq meters, or 33% of the nonstreet residential area. Another way of looking at this is that about 10% of the land (or 25% of the reported impervious area) is road pavement. Therefore, we adjust our estimate of impervious cover for road surfaces by subtracting 10% from the figure given.

In addition, some site descriptions include information on the amount of vacant land and other characteristics. Assuming that open land, parks, public land, conservational land, agricultural land, and so forth are all pervious surfaces, the pervious-impervious estimate for residential areas can be further improved. The fifth column of Table E.3.15 shows the impervious area percentage after taking into account the adjustment for road surface and this last adjustment for vacant land. However, no adjustment is made for industrial and commercial areas since their surface composition (pervious or impervious) is not known. By subtracting these adjusted impervious area figures from 100, an estimate of lawn area is obtained. These estimates are listed in the last column of Table E.3.15. The figures show that there is considerable variability in surface makeup of residential property, with estimates of lawn area ranging from a low of 25% to a high of 92.4%.

Table E.3.15 Selected Data from Runoff Reports

Source	Site	Site Characteristics		Impervious Area (%)	Adjusted Impervious Area (%)	Estimated Lawn Area (%)
"Effects of Storm Runoff on Water Quality in the Mill Creek Drainage Basin, Willingboro, New Jersey"	W1, W2, W4, W5, W9	Single-family residential	= 56.25%	24.70	25.0	75.0
		Multi-family residential	= 0.00%			
		Commercial	= 0.50%			
		Industrial	= 12.10%			
		Public, conservational, recreational	= 31.15%			
"Quantity and Quality of Urban Runoff from the Denver Metropolitan Area, Colorado"	Littleton	Single-family residential	= 75%			
		Parks and open space	= 25%	25	23.1	76.9
	Lakewood	Multi-family residential	= 30%	40	75.0	25.0
		Commercial	= 20%			
		Undeveloped	= 50%			
	Denver	Mixed single- multi-family residence	= 37%	65	65.5	34.5
		Multi-family	= 37%			
		Commercial	= 20%			
		Parks	= 6%			
"Urban Storm-Water-Quality Data Portland, Oregon, and Vicinity"	Fanno Creek	Single-family residential	= 76%	32	28.2	71.8
		Multi-family residential	= 6%			
		Commercial	= 6%			
		Rural	= 12%			
	Willamette R. tributary in Oak Grove	Single-family residential	= 73%	36	34.7	65.3
		Multi-family residential	= 4%			
		Commercial	= 8%			
		Rural	= 15%			

Table E.3.15 Selected Data from Runoff Reports (Cont.)

Source	Site	Site Characteristics						Impervious Area (%)	Adjusted Impervious Area (%)	Estimated Lawn Area (%)
	Tyron Creek	Single-family residential = 72% Multi-family residential = 10% Commercial = 5% Rural = 13%						32	28.6	71.4
		A	B	C	D	E	F *			
"Storm Runoff As Related to Urbanization in the Portland, Oregon-Vancouver, Washington Area"	Vancouver sewer outfall	25	0	13	36	21	5	49	60.0	40.0
	Beaverton Creek	25	3	51	4	13	4	23	21.0	79.0
	Fanno Creek	13	0	75	6	6	0	32	28.6	71.4
	Singer Creek	18	0	77	4	1	0	28	25.0	75.0
	Willamette River Tributary (Oak Grove)	14	0	74	4	8	0	36	34.2	65.8
	Tyron Creek Tributary	12	0	72	11	5	0	32	28.2	71.8
	NE Hancock-Flint sewer	2	0	0	91	5	2	43	37.5	62.5

Table E.3.15 Selected Data from Runoff Reports (Cont.)

Source	Site	Site Characteristics A	B	C	D	E	F*	Impervious Area (%)	Adjusted Impervious Area (%)	Estimated Lawn Area (%)
	N Albina-Kilpatrick sewer	6	0	1	75	18	0	44	40.5	59.5
	N Vancouver-OWR&N sewer	2	0	0	81	17	0	46	40.9	59.1
"Characteristics of Four Urbanized Basins in South Florida"	Pompano Beach, Broward Co., FL	Land use: single-family residential Average lot size: 80' x 100' Average house size: 40' x 60'						43.9	32.9	67.1
	Kings Creek Apts., So. Miami, FL	Land use: apartments						70.7	53.0	47.0
"Bellevue Urban Runoff Project and Bellevue Street Sweeping Demonstration Project"	Surrey Downs	Single-family homes and a senior high school						35.0	26.3	73.7
	Lake Hills	Single-family homes and church						43.1	32.3	67.7

Table E.3.15 Selected Data from Runoff Reports (Cont.)

Source	Site	Site Characteristics	Impervious Area (%)	Adjusted Impervious Area (%)	Estimated Lawn Area (%)
"Quality of Runoff from Small Watersheds in the Twin Cities Metropolitan Area, Minnesota--Hydrologic Data for 1980	80th St. storm sewer	Fully developed medium-density residential	16.0	7.5	92.4
	Estates Drive	Medium- to high-density single-family residential	29.0	21.8	78.2
	Highway 100	High-density single-family with intersection commercial	35.0	26.3	73.7
	Valley View Road	Medium-density single- and multi-family	11.0	8.3	91.7

*A = Parks, forests, vacant.
B = Agricultural.
C = Light to normal residential.
D = Dense residential.
E = Apartments and commercial.
F = Downtown and industrial.

TABLE E.3.16. Percentage of Residential Land in Roofs, Lawns and Other Concrete

Surface	Percent
Roof	22.3
Other concrete	9.6
Lawn	68.1

Additional information was provided by the City of Bellevue, Washington, Storm and Surface Water Utility Department, in the form of a large aerial photograph of a residential area with a corresponding map of properties and structures. A random sample of surfaces was taken from the photograph. The photographic quality is such that it is impossible to distinguish asphalt from concrete. Therefore, driveways and other paved surfaces were assumed to be concrete. In general, the neighborhood in the photograph appears to be a fairly new subdivision with larger than average lots and homes. The proportion of lot coverage by the house is probably less than average for urban residential areas.

After excluding observations that happened to land on nonresidential areas such as roads, the results are presented in Table E.3.16, and the factor estimates are summarized in Table E.3.17; these estimates are based on all the foregoing information and on the assumption that 80% of nonroad pavement is concrete.

As a final note, it should be mentioned that a potential source for data specific to a particular locale may be the local property tax assessment records. These records typically include such information as lot size, structure size, number of floors, number of rooms, construction material, driveway dimensions, and so forth. Unfortunately, this type of information is not normally available in machine-readable format, which would allow one to readily characterize a representative structure.

Multi-Family Residential Areas. In this section we develop the various factors for multi-family residential areas. In some cases we assign the value developed for single-family housing units, or the value developed (below) for commercial structures, depending on the particular factor.

A prototype multi-family commercial structure was developed from some published building characteristics. The Residential Energy Consumption Survey: Housing Characteristics, 1982 (1984) (cited in Statistical Abstract of the United States 1986, Table 1318) reports that the average floor area of a multi-family household in a building with 5 or more units is 73.9 sq meters (795 sq ft). Also cited in the Statistical Abstract of the United States 1986 (Table 1308; taken from Current Housing Reports, series H-150-83, Annual Housing Survey, part A) are data suggesting that the average multi-family structure contains about 6 housing units. For the prototype structure, we assume a building containing six identical units, with three units lying end-to-end on each of two floors. Floor plans of a single unit and of the multi-family structure are shown in Figure E.3. An area equal to 10% of the indoor

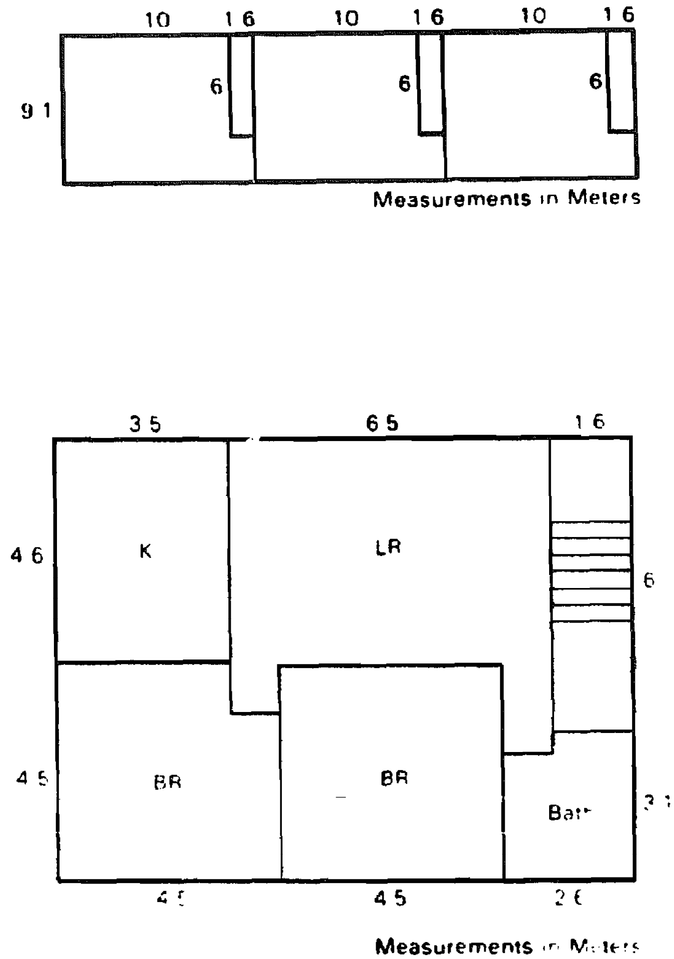

FIGURE E.3. Floor Plan of a Multi-Family Residential Structure

TABLE E.3.17. Summary of Factors for Horizontal, Exterior Residential Surfaces

Factor	Definition	Value
d	Ratio of other asphalt area to residential land area	0.01
e	Ratio of other concrete area to residential land area	0.04
f	Ratio of other paved area to lawn area	0.14

living space of a multi-family unit is added to the multi-family structure to account for common areas such as outside hallways, elevators, stairways, and so forth.

To obtain estimates of the factors, we first calculate the exterior surfaces for the multi-family structure; we then divide these figures by 6 to obtain a value per multi-family unit. Interior wall areas are then computed based on the floor plan of a single unit. The specific calculations are described below.

The overall outside dimensions of the multi-family structure are 9.1 x 33.2 meter. The projected roof area is, therefore, 303.8 sq meters. Dividing this by the number of units per floor, we obtain

$$\text{Projected roof area} = 303.8 / 3 = 101.2 \text{ sq m}$$

To compute the actual roof area, we assume that half of the roofs have the same characteristics ascribed to roofs of single-family dwellings, while the other half are flat with no overhangs. The specific characteristics of the former are: the ridge of the roof runs over the 33.2 meter dimension, the roof has a slope of 30° with overhangs of one meter on the long side and .67 meter on the short side. Then the area of the roof itself is:

$$\text{Roof area} = [2 \bullet (16.6 + 1) / \cos 30^o] \bullet [2 \bullet (4.55 + 0.67)]$$

$$= 424.3 \text{ sq meters}$$

The area of a flat roof will equal the area of the projected roof area over one floor, or 303.8 sq meters. The average roof area for all multi-family structures is therefore (424.3 + 321) / 2 = 372.7 sq meters. Factor **b'**, the actual roof area for a single unit is one-sixth of this, or 62.1 sq meters.

Since all of the multi-family units are assumed to lie on one floor, factor **k**, the ratio of nonbasement floor area to projected roof area, is 1.0.

Given the exterior building dimensions of 9.1 x 33.2 meters, the building perimeter is 604.2 meters. Assuming a wall height of 3 meters per story, the average exterior wall height is 3 x 2 = 6 meters. The total exterior wall area is, therefore, 6 x 604.2 = 3625.4 sq meters. Factor **h**, the ratio of exterior wall area to projected roof area for a single unit, becomes

$$h = 3625.4 / (303.8 \bullet 6) = 1.99$$

Finally, we assume that 45% of exterior walls are brick (factor **i**), 45% are painted wood (factor j), and 10% are concrete (factor **d'**), with 7% of exterior wall area comprised of glass (factor **c'**).

To estimate **v**, the ratio of interior wall area to projected roof area, we assume the 5-room floor plan shown in Figure E.3. The interior walls for each unit extend over 62.2 lineal meters. With an average wall height of 2.4 meters, the interior wall area is estimated at 2.4 x 62.2 = 149.3 sq meters. Therefore,

$$v = 256.8 / 101.2 = 2.54$$

We assume that 70% of multi-family structures have basements, and that these basements extend over 90% of the projected roof area; i.e., factors **l** and **m** are 0.7 and 0.9, respectively. A reasonable dimension for the basement, given the floor plan, is 9.1 x 29.9 meters. Assuming that the basement is divided into four rooms with a wall height of 3 meters, we obtain an interior wall area of 156.0 x 3 = 468.0 sq meters. For a multi-family unit, the factor **w**, the ratio of basement wall area to projected roof area is

$$w = 397.8 / (6 \bullet 101.2) = 0.77$$

This completes the estimates of the structural surface areas and factors. In disaggregating the surfaces according to the type of surface covering, we assume that multi-family dwellings have the same relationships for nonbasement floors and interior walls as do single-family dwellings. Thus, the fraction of floor surfaces that is linoleum (**n**) is 0.20, the wood factor (**o**) is 0.25, and 0.55 is the carpet factor (**p**). Similarly, all nonbasement interior walls are assumed to be painted wood or plaster, so factor **x** has a value of 1.00.

Multi-family structures are assumed to have the same basement wall covering and floor covering characteristics as commercial buildings, which are addressed in the next section. At this point, we simply note that factor **r**, the fraction of basement floor area that is linoleum is 0.20, and factor **u**, the fraction that is concrete, is 0.80. Similarly, factor **z**, the fraction of basement wall area that is painted wood or plaster is 0.20, and factor **a'**, the fraction that is concrete, is 0.80.

Next we turn to building contents. As indicated earlier, the factors relating to the four building contents categories are assumed to be constant irrespective of the size of the housing unit, as measured by floor area. A minor discrepancy arises because within the soft-surface furnishings category, curtains depend upon window area rather than on floor area, and the relationship between window area and floor area is different for single- and multi-family structures. However, because it is small, this discrepancy is ignored in the calculations. Factors **b** and **c**, the respective ratios of asphalt road and concrete road to multi-family land use area, are assumed to

be the same as for commercial buildings, which are developed in the next section. These values are:

$$b = 0.20$$

and

$$c = 0.13$$

Factors **d** and **e**, the respective ratios of other asphalt and other concrete areas to multi-family land use area are assumed to be the same as for single-family residential areas; namely,

$$d = 0.01$$

and

$$e = 0.04$$

Finally, a reasonable value for **f**, the ratio of other asphalt and concrete areas to lawn area is taken to be 0.50.

<u>Commercial Areas</u>. This section describes how the various factors for commercial areas are estimated. The first to be estimated are those relating to horizontal, exterior surfaces. Then, factors specifying the dimensions of the representative commercial structure are developed. Next, the factors dealing with the proportion of specific material used for floor covering material are developed. Finally, factors relating to building contents are estimated.

The lack of data for commercial land use areas is even more acute than for residential areas. This is compounded by an even greater variability in land use practices on commercial property compared with those on residential property. A simple example of this variability is illustrated by the fact that areas designated commercial include high-density downtown business areas, small arterial and neighborhood commercial areas, and large suburban shopping centers.

Exterior horizontal surfaces in commercial land use areas include roofs, asphalt parking areas and concrete parking areas. The various runoff reports described in Section E.3.2.2.2 do not help to identify these surfaces, since they are all categorized as "impervious".

The City of Bellevue, Washington supplied an aerial photograph and an accompanying map of a commercial area. However, this area is distinctly a low-density shopping center and was not felt to be representative of commercial areas in general. The photograph did, however, give a guide as to the lower range for a, the ratio of projected roof area to commercial land

area. Rough estimates place projected roof area at no more than 50% of surface area. The low seems to be about 20% of land area. Average roof cover, then, would be expected to lie somewhere between 50% for low-building-density, suburban shopping center areas and 90% or more for high-building-density, downtown business areas. We take 70% to be representative.

Commercial areas include parking areas. While multi-level parking garages are generally constructed in concrete, street level parking surfaces are predominantly asphalt. Because street level parking lots comprise a larger share of parking surfaces, we estimate b, the ratio of asphalt parking area to commercial land area, to be 0.20. Factor c, representing the ratio of concrete parking area to commercial land area is estimated at 0.13. The horizontal, exterior commercial surfaces add to more than unity because of multi-level concrete parking garages.

Next to be considered are the dimensions of the representative commercial structure. Fortunately, some useful data relevant to this question are available. Of particular interest is Nonresidential Buildings Energy Consumption Survey: Building Characteristics by the U.S. Department of Energy. Table 3A in that publication provides information on numbers of commercial buildings by area and function. That information is reproduced here in Table E.3.18. These figures can be used to derive an estimate of the average floor area of commercial buildings by computing the weighted average floor area of all commercial buildings. To do this, the midpoint of the given size intervals is used except for the two end intervals. For these, values of 69.7 sq meters (750 sq feet) and 10,219 sq meters (110,000 sq feet) are used. The calculations yield an average commercial building size of 1,005 sq meters. In addition to the overall average commercial building size, average building size for each separate function is also calculated (see Table E.3.19). These figures are used in developing the factor estimates relating to materials used for floor cover.

TABLE E.3.18. Mean Square Footage of Commercial Buildings by Function

Building Function	Mean Square Footage
All Commercial Buildings	10,820
Assembly	11,060
Auto sales and service	5,260
Education	32,060
Food sales	5,600
Health care	23,530
Lodging	16,520
Office	10,870
Residential	8,940
Retail/services	7,130
Other	11,660
Vacant	8,920

Table E.3.19 Commercial Building Size Distribution, by Function

Function	Total	Total Square Footage: 1,000 or less	1,001-5,000	5,001-10,000	10,000-25,000	25,001-50,000	50,001-100,000	Over 100,000
Total	3995	655	1672	745	551	207	101	65
Assembly	418	44	156	131	79	25	8	5
Auto sales and service	401	92	197	78	28	5	1	1
Education	161	10	33	21	31	30	24	13
Food sales	366	70	207	51	31	5	2	1
Health care	44	4	15	9	6	2	4	4
Lodging	101	10	33	22	16	13	4	3
Office	600	89	259	115	86	27	13	12
Residential	347	41	177	45	64	11	6	2
Retail/services	714	123	292	152	95	31	14	7
Warehouse and storage	430	79	169	59	64	33	17	10
Other	237	58	76	38	39	16	5	5
Vacant	147	37	69	24	12	9	2	2

Note: Data may not sum to totals due to rounding.
Source: U.S. Department of Energy, Nonresidential Buildings Energy Consumption Survey: Building Characteristics, March 1981, Table 3A, p. 13.

To obtain the gross exterior dimensions it is next necessary to estimate the number of floors in the representative commercial structure. Table 4A in the DOE publication cited above supplies information useful for this purpose. Figures from that table are presented here in Table E.3.20. The number of floors in the representative commercial building is computed as a weighted average of all types of commercial buildings. This is a straightforward use of the top row of Table E.3.20, except that for the last group, the number of floors is assumed to be 5.5. The result is an average of 1.8 floors per building. Thus, **k**, the ratio of floor area to roof area, is 1.80.

Dividing the total floor space by the number of floors gives 557.4 sq meters. This represents average roof area and average floor area per floor. Approximate dimensions for such a building is assumed to be 16.8 x 33.5 meters. The exterior wall area is estimated by multiplying wall height per floor (say, 3.7 meters) by the average number of floors (1.8) by the total building perimeter (100.6 meters). This yields 670 sq meters. The ratio of exterior wall area to projected roof area is therefore

$$h = 670 / 557.4 = 1.20$$

Factor **c'**, the ratio of glass area to external wall area is assumed to be 0.06. Also, because all commercial building roofs are assumed to be flat, actual roof area is equal to projected roof area; i.e., factor **b'** is 1.00.

TABLE E.3.20. Number of Commercial Buildings by Number of Floors and Function (Numbers in Thousands)

Function	Total	1 Floor	2 Floors	3 Floors	More than 3 Floors
Total	3995	2322	912	483	279
Assembly	448	195	169	68	16
Auto sales and service	401	326	68	8	0
Education	161	86	41	22	13
Food sales	366	256	74	28	9
Health care	44	16	16	6	6
Lodging	101	44	28	13	16
Office	600	300	151	88	62
Residential	347	55	84	120	87
Retail/services	714	476	141	71	27
Warehouse and storage	430	310	74	30	15
Other	237	163	35	21	18
Vacant	146	96	33	7	10

Note: Data may not sum to totals due to rounding.
Source: U.S. Department of Energy, Nonresidential Buildings Energy Consumption Survey: Building Characteristics, March 1981, Table 4A, p. 16.

Estimation of the percentage of commercial buildings with basements do not have the benefit of direct evidence. A rough approach is to determine a weighted average of buildings with basements by estimating the percentage of each commercial building function likely to have basements. In this procedure, 15% of both assembly and automotive sales/service are estimated to have basements. Twenty percent of education, 10% of food sales, and 90% of health-care structures are presumed to have basements. The corresponding figures for other commercial buildings are: lodging, 10%; office, 80%; residential, 70%; retail/services, 50%; and warehouse and storage, 10%. This procedure is felt to be an improvement over a single direct estimate of the fraction of commercial buildings with basements because it reflects the distribution of building functions. This weighted average calculation process disregards the "other" and "vacant" categories. The result is that factor 1 is 0.40.

Given that a building has a basement, we estimate the size of the basement relative to projected roof area (**m**) at 0.90. Basements are presumed to be divided into four large rooms. With a height of 3.0 meters, basement wall area is about 429 sq meters, making **w**, the ratio of basement wall area to projected roof area, equal to 1.30.

Interior wall area varies greatly from structure to structure. For example, buildings used for assembly, sales, and warehousing purposes tend to have a few relatively large rooms. On the other hand, lodging buildings and most offices tend to have the floor segmented into many rooms of smaller size. In order to estimate **v**, a hypothetical 16.8 meter by 33.5 meter floor plan is divided into a number of large and small rooms. These rooms include one large one measuring 16.8 by 16.8 meters and several others of various smaller sizes. This yields a total room perimeter of 225.6 meters per floor. With 1.8 floors per building and an average interior wall height of 3.0 meters, total interior wall area is 1237 sq meters. Thus, the ratio of interior wall area to projected roof area is

$$v = 1237 / 557.4 = 2.22$$

Next to be considered are the materials with which the building walls and floors are constructed. Exterior walls are assumed to be all concrete (factor **d'**). Interior walls are assumed to be all painted wood or plaster (factor **x**). Twenty percent of basement walls are assumed to be painted wood or plaster (factor **z**), and the rest concrete (factor **a'**).

The factors for floor covering material are developed in Table E.3.21. It is possible to estimate reasonable percentages for different floor covering materials for commercial buildings when the building function is specified. These separate estimates are then multiplied by the aggregate floor area for buildings of that function. This yields the area for different floor covering materials by building function. The total concrete, linoleum, and carpeted floor area is calculated, and these totals are then divided by total floor area to yield the following factor estimates: **q** = 0.22; **n** = 0.54; and **p** = 0.24. Twenty percent of basement floors are assumed

Table E.3.21 **Number of Commercial Buildings by Total Square Footage and Function (numbers in thousands)**

Building Function	Number of Buildings	Mean Square Footage	Estimated Floor Covering Percent: Concrete	Estimated Floor Covering Percent: Linoleum	Estimated Floor Covering Percent: Carpet	Floor Covering Area: Concrete	Floor Covering Area: Linoleum	Floor Covering Area: Carpet
Assembly	448	11,060	80	20	--	3,963,904	15,855,616	--
Auto sales/serv.	401	5,260	65	35	--	1,371,019	733,241	--
Education	161	32,060	10	80	10	516,166	4,129,328	516,166
Food sales	366	5,600	--	100	--	--	2,049,600	--
Health care	44	23,530	--	90	10	--	931,788	103,532
Lodging	101	16,520	--	5	95	--	83,426	1,585,094
Office	600	10,870	--	15	85	--	978,300	5,543,700
Residential	347	8,940	--	10	90	--	310,218	2,791,962
Retail/services	714	7,130	--	60	40	--	3,054,492	2,036,328
Warehouse, storage	430	13,350	100	--	--	5,740,500	--	--
Total	3,612	(a)				11,591,589	28,131,009	12,576,782
Factor						0.22	0.54	0.24

(a) Total square footage is 52,299,380.

to be covered with linoleum (factor r), and the remaining 80% are concrete (factor u). There are two possible approaches to estimating the relative number of hard-surface furnishings units, soft-surface furnishings units, electronic equipment units, and paper products units per sq meter of floor area in commercial as compared to residential structures. The most direct method is to estimate the commercial to residential contents ratios directly. Alternatively, the representative inventories of each of the contents categories could be estimated for commercial structures, and then the effort to decontaminate this inventory could be estimated. Besides being simpler, the first approach avoids the problems that arise as a result of inconsistent information from different sources. This first approach is adopted here.

According to the source at Cleaning Consultant Services in Seattle, Washington, most of the procedures for decontamination of building contents are similar to fire restoration cleaning, especially as pertains to clean up from smoke damage. Organizations dealing with this type of work are the basic source of information.

The source at the Institute of Fire Restoration (a branch of the Association of Specialists in Cleaning), in Falls Church, Virginia, was able to supply estimates of the relative amount of the different kinds of building contents. The information from this source is based on office buildings as representative of commercial structures in general. Emphasizing the variance in building contents and the conjectural nature of any such generalizations, this source said that there were about 200% more hard-surface furnishings items (in terms of cleaning effort) per unit of floor area in commercial businesses than in residences. An obvious reason for this greater density of hard-surface items is that businesses may be more motivated to use space intensively. Also a specific area can be reserved for a specific function permitting the supporting contents items to be concentrated in that area.

This preceding information is confirmed in a general manner by a representative of Servpro South/West Seattle in Seattle, Washington who said that there was more "clutter" in commercial establishments and more open space in residences. This source added, however, that items in commercial buildings are generally designed so that cleaning is easier than cleaning of items in residences.

This estimate of 200% more hard-surface items per unit of floor space in commercial buildings means that there are equivalently three times as many hard-surface items per unit of floor area in commercial businesses as residences. Therefore, factor e' can be calculated as follows:

$$e' = 3 \cdot 6.34 = 19.02 \text{ units/1000 sq m}$$

For reference purposes an outline of the specific inventory of hard-surface furnishings in a representative commercial structure is enumerated. The inherent oversimplification is recognized in view of the fact that commercial buildings house such varied functions as hospitals, automobile sales and service, offices and schools. In addition, there is very little

information on commercial building inventories, regardless of the building's function. For these reasons, we assume that contents inventories of office buildings can be taken as representative of those for all commercial structures. It should be added that what is important here is not the actual mix of items in the inventory but the resulting cleaning time, cleaning method and cost per unit of floor area. In other words, the assumption is that decontaminating, say, the hard-surface furnishings in 1,000 sq meters of floor area in an office building is representative of the cleaning time, cleaning method and cost to decontaminate the hard-surface furnishings in 1,000 sq meters of floor area of commercial structures in general.

Lending support to the use of office building contents inventories as representative of the whole group of commercial buildings is information contained in Table E.3.19. It can be seen that office buildings are the second most numerous subcategory. Moreover, in terms of aggregate floor area they comprise the largest subcategory.

Information regarding office building contents comes from SeaFirst Bank in Seattle, Washington, the IBM Corporation in Seattle, Washington, and Cleaning Consultant Services also in Seattle, Washington. A general discussion of this information is presented before giving estimates of the specific contents inventories.

A representative in the SeaFirst Properties Department said that the standard work station in a high-rise office building occupies about 13.9 sq meters per person. A work station consists of a wood or metal desk, a credenza, an executive chair, and one or two side chairs. All chairs are fabric covered or fabric with high density plastic backs. Each work station is separated by portable partitions or, as the source called them, "panels". These are either wood or metal framed. They are sound and fire retardant. About 90% are fabric covered. The rest are glass. There is no set number of these partitions per work station because many work stations abut walls or share partitions.

This source was not able to indicate the number of employees or work stations per unit of floor area. Also, the source did not have direct information on common or communal areas such as aisles, lobbies, conference rooms, filing areas, etc. Additional information is derived directly from a SeaFirst office floor plan for one floor in their main office building. Besides showing the arrangement of rooms, this shows the location of desks, tables, chairs, and so forth.

The source in the Properties Department said that the area of each floor in the main office building was 1,300 sq meters, but measurements from the floor plan yielded an estimate of approximately 2,050. Probably, the difference lies in how the areas are counted. The smaller area quite possibly represents usable space, which would exclude stairwells, elevator shafts, elevator lobbies, ventilating shafts, rest rooms, and staff kitchen areas. Measurements from the floor plan are shown in Table E.3.22.

Subtracting the total of these areas leaves about 1353 sq meters, which is close to the floor area figure given by the source. This seems to confirm

that the floor area figure given by the source was the usable area, i.e., that available for work stations.

Another SeaFirst source estimated that the average number of employees per floor is about 1C0, but in some cases the number can reach as high as i75. The count for the floor represented by the floor plan is 117. These figures imply that the usable floor area on a per-work station or per-employee basis is somewhat less than 13.9 sq meters.

When advised that the average commercial establishment had about 1000 sq meters of floor space, the representative of IBM Corporation indicated he could provide some information fairly easily because each floor in his office is about that size. For 1000 sq meters he estimated that in his office there are about 50 work stations, each about 9.3 sq meters, eight offices each about 13 sq meters, and four secretarial stations each about 13 sq meters. The secretarial stations are larger than the standard work stations because they have extra file space. Each employee has a computer terminal. There are several printers per floor for output as well as two large copiers plus one small convenience copier. Each person has a desk which contains 0.5 file

TABLE E.3.22. Area Measurements from Commercial Building Floor Plan

Use	Area (sq m)
Stairwells and ventilating shafts	29.1
Elevator shafts	84.8
Elevator lobby	31.2
Restrooms	43.5
Staff kitchen	11.1
Electrical & ventilation core	36.2
Service elevator & elev. lobby area	5.0
Conference areas (7)	98.8
Janitorial storage	5.9
Major aisles	351.3
Total	696.9

drawers, plus each person has 4.5 additional lateral drawers of file space. Each floor also has a couple of work rooms measuring 3 x 3.7 meters, a mail room, a copier room, and a study. The 1000 sq meters include aisles, staff room, but not restrooms and not "common space." The source at Cleaning Consultant Services said that office space is usually equal to 13.9 sq meters per employee plus 10% to 15% for common areas. It is somewhat unclear, however, how inclusive is his definition of common areas. For example, it is not clear if stairwells, restrooms, store rooms, elevator lobbies, and so forth are included. According to this source, there are about 1.5 four-drawer file cabinets per employee. The source added that space is used more intensely in businesses than in homes, offices having 20% to 30% more items per unit of floor space than homes. On the other hand, items in offices are generally designed to be cleaned more easily than items in homes.

From this information it is possible to estimate an inventory of hard-surface furnishings. The primary hard-surface items are desks, tables, file cabinets, credenzas, bookshelves. For the SeaFirst floor with a total area of about 2050 sq meters and about 110 to 120 employees, the inventory of hard-surface items can approximated as follows. For 110 work stations and five offices we estimate there are about 115 desks, 115 tables, 115 credenzas, and 50 half-height bookshelves. Based on three partitions per work station of which 10% are hard surfaced, there are 33 hard-surface partitions out of a total of 330. For the seven conference areas and for other areas such as copier rooms, we estimate another 15 tables.

The number of file cabinets is harder to estimate. The floor plan is difficult to use for this purpose because it is difficult to tell tables from file cabinets. Also, the floor shown has more file storage space than most other areas of the bank. Recalling that the IBM source estimated 4.5 file drawers per employee and the Cleaning Consultant Services source estimated six drawers, we take five file drawers or 1.25 file cabinets per employee as representative. On the 2050 sq meter floor with 115 employees this comes to 144 file cabinets.

The source at the Institute of Fire Restoration estimated that commercial businesses have considerably more soft-surface furnishings than do residences, largely due to the widespread use of fabric covered partitions separating work stations. According to this source there is an average of four such partitions per work station. Based on this, commercial buildings are estimated to have three times as much soft-surface items per unit of floor space as do residences. With three times the soft-surface items per square meter,

$$f' = 3 \cdot 6.34 = 19.02 \text{ units/1000 sq m}$$

The source at the Institute of Fire Restoration estimated the density of electronic equipment on the assumption that each work station has a computer terminal. On this basis, commercial property is estimated to have five times as much electronic equipment per sq meter of floor space as do residences. Since it is felt that a computer terminal for every work station is somewhat

more than average, factor g' is calculated on the assumption that commercial property has four times as much electronic equipment per sq meter. Therefore,

$$g' = 4 \cdot 6.34 = 25.36 \text{ units/1000 sq m}$$

There is, according to the source at the Institute of Fire Restoration, five times as much paper per sq meter of floor area in a commercial building as compared with a single-family residence. This implies that

$$h' = 5 \cdot 6.34 = 31.70 \text{ units/1000 sq m}$$

Industrial Areas. As in the preceding section, the first factors to be estimated are those having to do with horizontal exterior surfaces. Following that, factors that characterize a representative industrial structure are derived. Next, those apportioning surfaces among specific materials, such as floor area to wood, carpet, concrete, or linoleum material are estimated. Finally the factors giving the units per sq meter of the four building contents categories are estimated.

The horizontal, exterior surfaces in industrial areas consist of roof, asphalt and concrete parking areas, and lawn surfaces. As with residential areas, a starting point could be the runoff studies summarized in Table E.3.15. These studies provide information on the percentage of particular drainage areas that are covered with impervious surfaces such as buildings or pavement. The remaining pervious area corresponds to the only pervious surface, lawn. Unfortunately, only two of the many drainage areas covered by these studies were characterized by a significantly high proportion of land in industrial use. In "Quality of Runoff From Small Watersheds in the Twin Cities Metropolitan Area, Minnesota - Hydrologic Data for 1980," the Sandburg Road site was described as a light industrial park with partly curbed or guttered streets. The area includes a school and a major industry parking lot. In this area, 5.8% of the land was designated as agricultural or idle, 9.6% as low- density homes, and 84.6% as commercial-industrial. The impervious area was listed as 70.0%. If this figure is adjusted by subtracting the agricultural portion from the 30% pervious area, we get 74.3% of the area as being impervious. In other words, 25.7% of the area is pervious lawn.

In "Storm Runoff As Related to Urbanization in the Portland, Oregon Vancouver, Washington Area," the SE 9th-Madison site is listed as being 19% downtown and industrial. In this drainage area, 39% is denoted impervious. The remaining 61% is therefore lawn.

Another source of information is a large aerial photograph of an industrial area supplied by the Storm and Surface Water Utility Department of the City of Bellevue, Washington. As was done with the aerial photograph of a Bellevue residential area, the surfaces at randomly selected points were

noted in order to establish an estimate of the relative distribution of exterior horizontal surfaces. However, unlike the residential area photograph in which essentially all of the photograph was of the one land use type, the industrial area photograph included a large proportion of undeveloped land. The sampling area was therefore restricted to the north side of Bellevue-Redmond Road. Within the remaining area there remained some undeveloped parcels. These too were excluded from the sample. The tonal quality of the photograph made it impossible to distinguish between concrete, asphalt, and vacant, except by inference from the use of, and objects on, the surface. In general, it was felt that little or no concrete was used in that area. In instances where the sample point landed on a vehicle or material in storage on the property, such as lumber, that fact was noted and the surface was recorded as either vacant or asphalt pavement. Also, as with the residential photo, public roads were eliminated from the sample because concrete and asphalt roads are a separate land use category. The results of the sampling process appear in Table E.3.23.

The foregoing information on horizontal, exterior surfaces is summarized in Table E.3.24. From these data we estimate the roof factor (a) at 0.27. The data for asphalt and concrete road surfaces are not as clear. The sum of the roof percentage, plus the two pavement percentages in the first three sources, are 74.3%, 39.0%, and 72.6%, respectively, with an average of 62.0%. If we weight the 39.0% figure less than the other two in the averaging process--because it seems the most likely figure to be an outlier--a figure of 65.0% is obtained, which seems reasonable. Subtracting 27.0% for roof area leaves 38.0% for the total of asphalt and concrete areas designated as parking areas. The breakdown between these materials is unclear, though it is felt that asphalt will be used more for roads and parking lots while concrete will be used more often for other functions. In general, it is felt that in total, the asphalt area will be about twice that of concrete. Thus, the asphalt factor (b) is estimated at 0.25 and the concrete factor (c) at 0.13.

Accompanying the photograph is a map indicating for several parcels property lines, building outline, and property areas. This map provides enough information so that the building size can be determined by measurement. Thus, roof area as a proportion of lot area can be calculated. These calculations yield roof area as a percentage of land area, ranging from a low of 15.2% to a high of 55.0%. The average of the properties measured is 29.3%.

The foregoing estimates constrain the vacant land and lawn factors to sum to 0.35. We estimate lawn area (f) at 2.0% of industrial areas and vacant land (g) at 33.0%. These factors are summarized in Table E.3.25.

The next step is to estimate the dimensions of the representative industrial structure. For this purpose the U.S. Department of Energy publication Nonresidential Buildings Energy Consumption Survey: Building Characteristics is very helpful. Table 3A provides information on building area. These data are reproduced in Table E.3.26. An average building size is calculated using the same weighted average process described for commercial buildings, yielding a result of 2081 sq meters.

TABLE E.3.23. Sampling Results for Distribution of Industrial Surfaces

Surface	Percent
Asphalt or concrete road	47.9
Vacant	26.0
Roof	24.7
Lawn	1.4

Table 4A of the DOE publication lists the number of buildings having one, two, three, or more than three floors. Again, a weighted averaging process as for commercial buildings is used to find the average number of floors at 1.6. This is the value taken for factor k. Dividing total floor area by the number of floors gives an average 1300 sq meters per floor. This figure is also used as the estimate for roof area.

We assume building length and width of 50.3 by 25.9 meters with height of 6.1 meters per floor. With 1.6 floors, this makes the exterior building wall area equal to 1487 sq meters. The factor relating exterior wall area to projected roof area is, therefore:

$$h = 1487 / 1300 = 1.14$$

Of the external wall area, 2% is assumed to be glass; i.e., factor c' is 0.02.

The factor for interior wall area is estimated by designing a hypothetical floor plan for a 50.3 x 25.9 meter industrial building, as shown in Figure E.4. The interior walls in this structure serve to set off a small portion of the main floor area for office space, while leaving most of the interior open and unobstructed. The additional interior wall added by the office is 18 linear meters. This gives a total of 18 + 152.4 = 170.4 linear meters of interior wall per floor. Assuming an average interior wall height of 5.5 meters, the factor relating interior wall area to projected roof area (v) is

$$v = 1.6 \bullet 5.5 \bullet 170.4 / 1300 = 1.15$$

TABLE E.3.24. Summary of Data on Horizontal Exterior Surfaces in Industrial Land Use Areas

	Surface				
Source	Roof	Asphalt Road	Concrete Road	Vacant	Lawn
Runoff Study #1		74.3%		25.75	
Runoff Study #2		39.0%		61.0%	
Aerial Photo	24.7%		47.9%	26.0%	1.4%
Map	29.3%		70.7%		

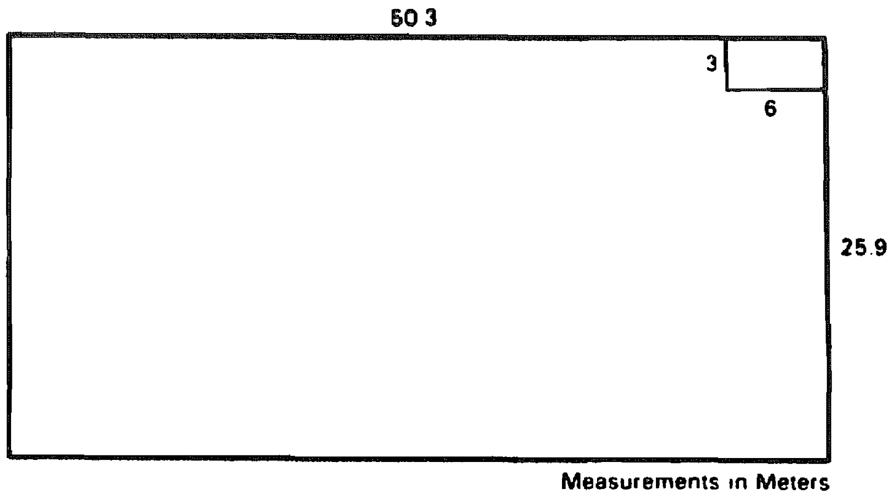

FIGURE E.3. Floor Plan of an Industrial Structure

TABLE E.3.25. Distribution of Exterior, Horizontal Industrial Areas

Factor	Surface	Estimated Value
a	roof	0.27
b	asphalt road	0.25
c	concrete road	0.13
f	lawn	0.02
g	vacant	0.33

TABLE E.3.26. Numbers of Industrial Buildings by Total Square Footage (in Thousands)

Total	1,000 sq. ft or Less	1,001-5,000 sq. ft.	5,001-10,000 sq. ft.	10,001-25,000 sq. ft.	25,001-50,000 sq. ft.	50,001-100,000 sq. ft.	Over 100,000 sq. ft.
243	22	58	55	45	30	20	13

It is assumed that industrial structures have flat roofs, so that factor b' is 1.0; they are also assumed not to have basements.

Exterior walls and interior walls along the perimeter of the building are assumed to be of concrete construction. The remaining interior walls are assumed to be painted wood or plaster. Based on the interior wall dimensions described above, x, the fraction of interior wall area that is painted wood or plaster, is 0.45, and y, the factor for concrete walls, is 0.55. Factor d', the factor for exterior concrete walls, is 1.00; i.e., all exterior walls are assumed to be concrete.

A representative of the Wood and Synthetic Flooring Institute said that there are no data on industrial floor materials. However, he indicated that concrete is the material in greatest usage with a synthetic resilient flooring the second most common. Carpet is used in some of the office space. We estimate the factor for concrete floor (**q**) at 0.80, and 0.15 and 0.05 for linoleum (**n**) and carpet (**p**), respectively.

Next, we turn to the estimation of factors relating to building contents. Factors **e'**, **f'**, **g'**, and **h'** give, respectively, the number of hard-surface furnishings units, soft-surface furnishings units, electronic equipment units, and paper products units per 1000 sq meters of industrial floor space. The primary source of information for the estimation of these factors is a representative of the Institute of Fire Restoration.

According to this source, there is a wide variance in the density of hard-surface items in industrial buildings. Some buildings require considerable open space in which to move, store, or work on items. Other industrial establishments have machinery packed closely together, resulting in a high level of hard-surface items per unit area. In general, this source felt that there were more hard-surface items in an industrial structure than in a residence, but not quite as much as in a commercial building. Therefore, the estimated building contents factor is 2.5. With 2.5 times as much hard-surface items per unit area, factor **e'** can be calculated as follows:

$$e' = 2.5 \bullet 6.34 = 15.85 \text{ units/1000 sq m}$$

This source said that there are essentially no soft-surface furnishings in an industrial building. Therefore, the factor **f'** equals zero. The estimated building contents factor for electronic equipment, according to the same source, is 2.0. Factor **g'** is calculated as follows:

$$g' = 2.0 \bullet 6.34 = 12.68 \text{ units/1000 sq m}$$

The last building contents category is paper products. According to the source at the Institute of Fire Restoration, there is essentially no paper in industrial buildings. This implies that **h'** is zero. However, it is felt that this value does not adequately reflect an office as part of an industrial property. Such an office would have paper as do commercial offices. For this reason the estimate of the building contents factor is raised somewhat to 0.2. Factor **h'** is therefore

$$h' = 0.2 \bullet 6.34 = 1.27 \text{ units/1000 sq m}$$

This concludes the derivation of estimates for all of the factors in Table E.3.5.

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