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A PRELIMINARY EVALUATION OF CRISIS-RELOCATION FALLOUT-SHELTER OPTIONS.

VOLUME 2. DETAILED ANALYSIS

by

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OVERVIEW AND STUDY PARTICIPANTS

This, the second volume of a two-volume report prepared for the Federal Emergency Management Agency (FEMA), presents a preliminary, detailed evaluation of various shelter options for use if the President orders crisis relocation of the U.S. urban population because of strong expectation of a nuclear war. The availability of livable shelter space at 40 ft^2 per person (congregate-care space) by state is evaluated. Options are evaluated for construction of fallout shelters allowing 10 ft^2 per person -- such shelters are designed to provide 100% survival at projected levels of radioactive fallout.

The authors find that the FEMA concept of upgrading existing buildings to act as fallout shelters can, in principle, provide adequate shelter throughout most of the U.S. Exceptions are noted and remedies proposed. The authors also find that, in terms of upgrading existing buildings to fallout shelter status, great benefits are possible by turning away from a standard national approach and adopting a more site-specific approach. Existing FEMA research provides a solid foundation for successful crisis relocation planning, but the program can be refined by making suitable modifications in its locational, engineering, and institutionally specific elements.

Volume 1 of this study presents our preliminary findings in summary form. The current volume amplifies the findings in detail. The report is based on research conducted by the following Argonne National Laboratory participants in the project:

Danilo J. Santini, planner/architect, Ph.D.
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A PRELIMINARY EVALUATION OF CRISIS RELOCATION FALLOUT SHELTER OPTIONS

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1 BACKGROUND

In this section the context of our preliminary evaluation is described, the history of nuclear civil protection (NCP) reviewed, and the evolution of crisis relocation planning (CRP) discussed. The conceptual development of upgrading buildings and constructing new expedient shelters as ways of eliminating the shelter deficit for populations evacuating the cities is explained. The National Shelter Survey (NSS) and CRP survey are discussed and used to estimate the amount of shelter space of various types that could be provided for Americans relocated to rural and small-town "host" areas, away from most major U.S. cities. It is found that the expedient shelter concept is far less important than the upgrading concept as a way of providing shelter for the U.S. population. It is argued that a national CRP program relying primarily on upgrading is entirely feasible; at the same time, special cases peculiar to certain states, regions, and key industrial areas, including agriculture, make it necessary to consider other shelter options. Most of these other shelter options are also expected to prove superior, for particular applications, to the expedient shelter option.

1.1 NUCLEAR CIVIL PROTECTION — PROTECTION IN PLACE AND THE NATIONAL SHELTER SURVEY

Crisis relocation planning is one of two elements in the nuclear civil protection program. The other NCP element involves the protection of people in place, at or near their places of residence. In-place protection was developed in the early 1960s. Since 1961, the National Shelter Survey (NSS) has identified more than 240 million fallout shelter spaces that provide a relatively high level of protection from fallout. These spaces have a fallout protection factor (PF) of 40 or more, which would reduce radiation exposure to less than 1/40 of that experienced by a theoretically unprotected individual.*

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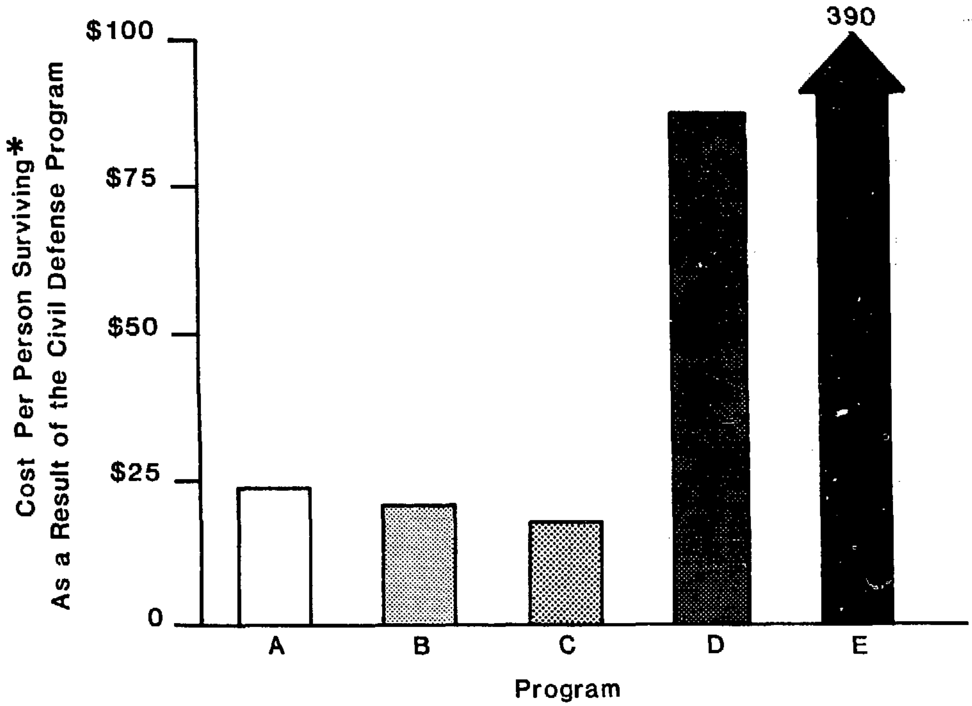
*A theoretically "unprotected" individual is defined in CRP research as one who stands on a smooth, infinite, flat plane contaminated uniformly throughout. In reality, features such as hills, adjacent buildings, ground roughness and fallout particle degradation (incorporation into the soil) all act to lower the true outside exposure of an individual below that of the theoretically unprotected individual.

Protection is equivalent to the inverse of the PF value — i.e., PF 40 reduces radiation to 1/40 of its unprotected level. In addition to the high-quality fallout shelters containing the 240 million spaces, other shelters offering less radiation protection have also been identified. These other shelters have PF ratings of 10 to 39.[1] Including all shelters with a PF of 10 or more, there are almost 400 million spaces across the country that would provide a substantial reduction of exposure to radiation from fallout. Considering that the U.S. population in 1980 was 227 million, this number of spaces seems to be more than enough to protect the population from fallout, especially when it is recognized that many people could rapidly build acceptable fallout shelters in their home basements. However, home shelters do not provide good protection against the blast of nuclear weapons. Also, while many NSS spaces do provide some inherent protection from nuclear blast, these tend to be concentrated in high-rise office buildings found in central business districts of cities, i.e., in or near likely nuclear target areas. Therefore, while an apparent surplus of NSS spaces exists, many of the spaces are not where the public can easily make use of them. Consequently, great numbers of NSS shelter spaces would be useful in nuclear war only when they are not in or near a targeted area. In a war confined to military targets, however, these same shelter spaces would be extremely valuable.

1.2 CRISIS RELOCATION PLANNING AND THE CRP SURVEY

NCP planning must recognize the possibility of a war involving both industrial and residential targets. Research conducted by the Federal Emergency Management Agency (FEMA), the Defense Civil Preparedness Agency (DCPA), and their predecessor agencies evaluated ways to protect the U.S. population from a combination industrial-residential attack. Figures 1.1 and 1.2 illustrate the basic findings of that research, as presented in Ref. 2. Three general civil defense approaches were evaluated in this research: (1) use of NSS shelters already identified, (2) relocation of populations away from areas likely to be attacked, and (3) construction of blast shelters for protection in place. The complete absence of civil defense preparedness was also evaluated in that study. Altogether, five civil defense alternatives were evaluated, as shown in Figs. 1.1 and 1.2. These five are actually variations on the relocation and protection-in-place approaches. Briefly summarized, the results reported in Ref. 2 indicated that the use of existing shelters is the least costly approach, while the use of blast shelters provides people with the greatest chance of survival. However, when one combines the criteria of cost and population survival, it is found that the most cost-effective alternative is a crisis relocation program that would move populations from areas of high risk to rural and small-town "host" areas. Very few of these host areas are likely to be subjected to fire and blast effects in the event of a nuclear attack. Program C in Figs. 1.1 and 1.2 represents the relocation alternative.



Program Description	Cost (1979 $, in millions)
A. Current funding, no CRP	540
B. Best use of present shelter, no CRP	825
C. Relocation to rural and small-town fallout shelters,using crisis relocation planning	1825
D. Less extensive relocation: 15-psi blast protection in host areas	11935
E. Extensive in-place blast protection	63025

Fig. 1.1 Cost-Effectiveness of Alternative NCP Programs Evaluated in 1978

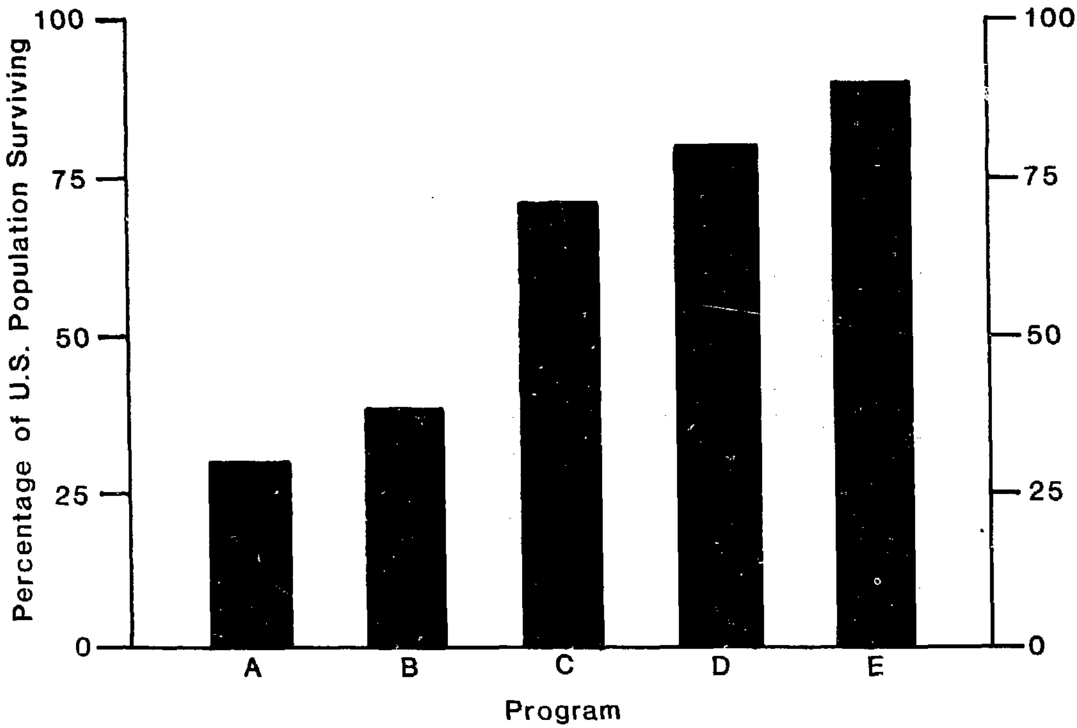


Fig. 1.2 Expected Survival Rates as a Result of Alternative NCP Programs Evaluated in 1978 (see also Fig. 1.1 legend)

1.2.1 The CRP Survey and Upgrading

Because of its cost-effectiveness, FEMA has been developing crisis relocation as the primary element in NCP planning. The CRP concept is fairly young in the history of NCP. It was recognized very quickly that the NSS fallout shelter spaces previously identified in rural areas would not be adequate to shelter a large fraction of the relocated U.S. population. Consequently, two approaches were developed in order to make up the shelter deficit in host areas: the upgrading of existing buildings to shelter status and the construction of new expedient shelters.[3,4] In the upgrading concept, earth is placed on the roof of a building and is built up against the outside of its walls in order to place added mass between the fallout and the building occupants.

One difficulty in this approach is the problem of assuring, through upgrading, structural adequacy of the building to accept earth loads sufficient to provide the desired PF. In some areas, the building would have to be able to accept both earth loads and low-level blast loads (less than 2.0 psi). Blast pressures as low as 0.6 psi can cause walls and roofs of some unreinforced buildings to collapse.

It was recognized by DCPA and FEMA, however, that implementation of the upgrading concept would require availability of a sufficient number of upgradable buildings. Consequently, it was decided that a new survey should be undertaken to supplement the NSS survey.

This new survey is intended to answer two questions. First, can adequate space be found in host areas simply to house the relocated population while buildings are being upgraded for use as fallout shelters? (This space is called congregate-care space and is estimated on the basis of 40 ft^2 per person.) Second, can upgradable buildings in sufficient quantity be found to shelter the relocated population? The new survey, called the crisis relocation planning survey, was about 68% complete at the end of this study (end of fiscal year 1982 — Sept. 30, 1982).[5,6,7] For each building capable of providing shelter for 10 or more people, the CRP survey provides information on the characteristics of the building necessary to estimate how much earth must be moved in the upgrading process. It also provides data on the presence of heating systems, medical facilities, pharmaceutical facilities, water sources, dining facilities, toilet facilities, and beds. However, structural characteristics of the building itself are not evaluated in this survey. Consequently, there is no way of knowing how much earth and blast load can be sustained by an individual building labeled as upgradable without a resurvey.[1] (If the structure of a building cannot be readily inspected, then there will be a great deal of uncertainty with respect to methods of structural modification. If the building is old, there may also be uncertainty about the structure's present strength. The expectation of weak roof structures prevents buildings from being classed as upgradable.)

Nevertheless, the CRP survey does provide a benchmark from which the feasibility of the upgrading concept may be evaluated. It also gives a good estimate of the congregate-care space available. The survey has already shown that congregate-care space at 40 ft^2 per person is not adequate in the northeastern U.S. and in California. In these areas, some alternative to the standard method of providing congregate care must be applied. One such alternative is to allow less than 40 ft^2 per person.

1.2.2 The Expedient Shelter as an Alternative to Upgrading

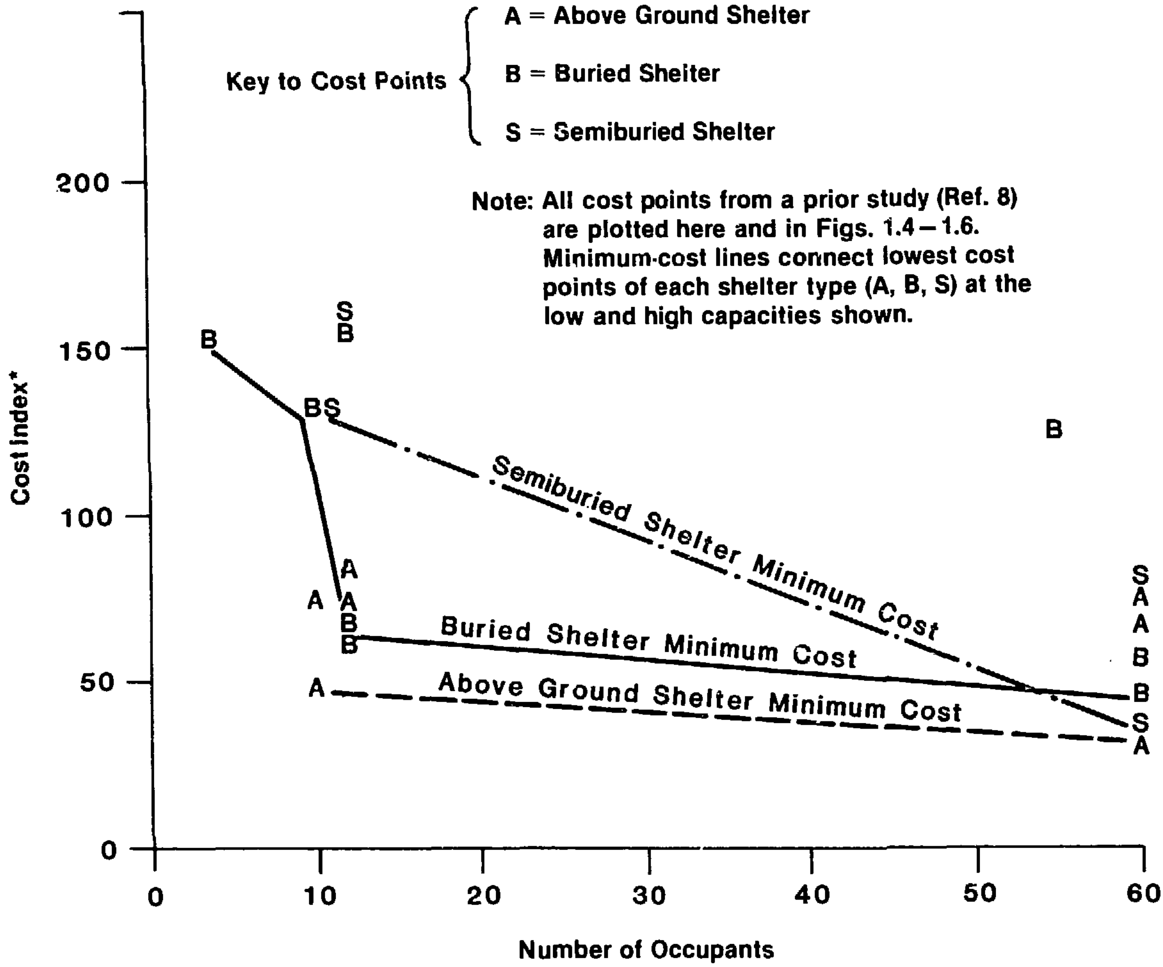
At the time the CRP survey was designed, there was undoubtedly some uncertainty concerning the eventual adequacy of upgrading as a sheltering alternative. In the absence of crisis relocation plans for upgrading, DCPA suggested that expedient shelters could be constructed.[4,8,9] Such shelters are relatively small, being designed for families or small groups. While NSS fallout shelters across the nation would average more than 400 occupants each,[7] expedient shelters are designed for 2-60 people.[4,8,9] Expedient shelters are built outside, with whatever materials are available; they may involve digging a hole and covering it over, or building a wooden structure above ground and covering it with earth. Air circulation, when provided for, is to be provided manually with a hand-built device called a punkah pump.

The feasibility of the expedient shelter concept has been demonstrated to the extent that expedient shelters have been built from instructions provided to people of average intelligence and have been occupied on a test basis for a period of a few days. They have not been test-occupied for a two-week period, however, and that is the period assumed to be necessary in a nuclear attack. A cost-effectiveness evaluation[8] indicated that larger expedient shelters were generally less costly per space and that above-ground shelters were either less costly than underground shelters (depending on soil characteristics and excavation methods), or equally inexpensive. Moreover, it was found that upgrading existing buildings is less expensive than constructing expedient shelters (see Figs. 1.3-1.7).

1.2.3 The Preconstructed Single-Purpose Shelter as an Alternative to Upgrading

The most costly form of shelter studied thus far by FEMA is the underground blast shelter.[2] It has been ruled out (see Fig. 1.1) as a national option because Congress (i.e., the American people) has not been willing to pay its high cost. An underground fallout shelter can be somewhat less expensive than a blast shelter, since it does not have to stand up to blast effects. However, construction of such a shelter would still require ventilation and the use of durable, waterproof materials because it has to "stand ready" for an indeterminant length of time. Material costs per unit of space in such a shelter greatly exceed the similar costs of an upgraded shelter and are also greater than those of an expedient shelter. Preconstructed public shelters are also very costly to the government because they must be built and paid for *before* a crisis warranting their construction occurs. The "expected" cost of the preconstructed shelters is far in excess of upgraded or expedient shelters because the probability of nuclear war is relatively low and the costs of expedient shelter and upgrading are actually not likely to be incurred. (The note on p. 8 of Vol. 1 contains a sample calculation of the extra costs of preconstructed single-purpose shelters.)

While this study did not actually estimate costs for any preconstructed single-purpose shelters, it did examine a rapidly erectable expedient buried plywood shelter for 256 people as well as burial of a house trailer. These shelters would be sufficient for protection from fallout immediately after their construction, but they would not stand up well to underground conditions over a period of years. For the shelters to be made permanent, substantial additional costs would be necessary. A number of reasons (exclusive function, necessity of being built, cost of being made permanent) plainly indicate that preconstructed single-purpose shelters constitute the highest-cost option evaluated; we therefore considered it unnecessary to go through a ritual exercise of estimating their exact unit costs.



*Values expressed in this index represent $ units per shelter space, based on assumed values of certain elements of construction cost. The index thus provides a consistent means of comparing costs of different kinds of shelters.

Fig. 1.3 Representative and Minimum Costs of Expedient Shelters by Capacity — Light Soil, Mechanically Excavated

1.2.4 The Preconstructed Multi-Purpose Shelter as an Alternative to Upgrading

The NSS inventory includes existing buildings which, in addition to their normal function, can also act as fallout shelters in the event of a crisis. These shelters are preconstructed, in effect, but their cost as shelter is far below that of buildings designed as shelters only. They are fallout shelters only incidentally. In order to make even better use of new buildings as shelters, FEMA and DCPA have developed the concept of slanting.

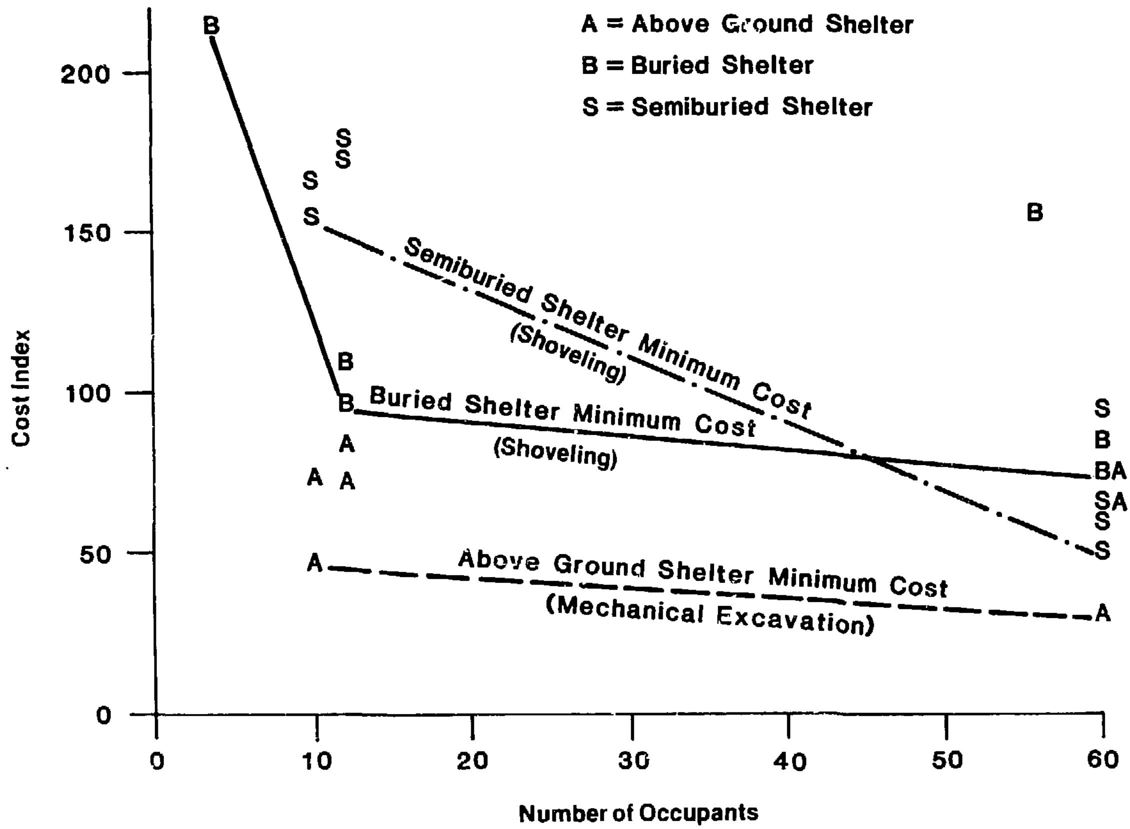


Fig. 1.4 Representative and Minimum Costs of Expedient Shelters by Capacity — Light Soil, Shoveled or Mechanically Excavated (Fig. 1.3 explains cost index and cost points)

In this concept, minor design modifications are adopted in order to increase the square footage of a building that can serve as shelter space. This concept is inherently different from that of shelter construction or improvement during a crisis. It is discussed in detail in Sec. 1.5.

1.2.5 Other Alternatives to Upgrading

While FEMA's prior published research has emphasized the four alternatives mentioned above (identification of existing buildings that can serve as shelters, identification of existing buildings that can be upgraded to shelter status, construction of expedient shelters, and construction of new single-purpose shelters prior to a crisis), there are numerous other alternatives that have been considered and rejected by FEMA -- or considered but given relatively less emphasis than the four emphasized alternatives. The use of homes as shelters for evacuees has been considered in previous FEMA research but was ruled out in this study. (The use of homes by host-area residents, however, is still a possibility.) The NSS survey includes mines, tunnels,

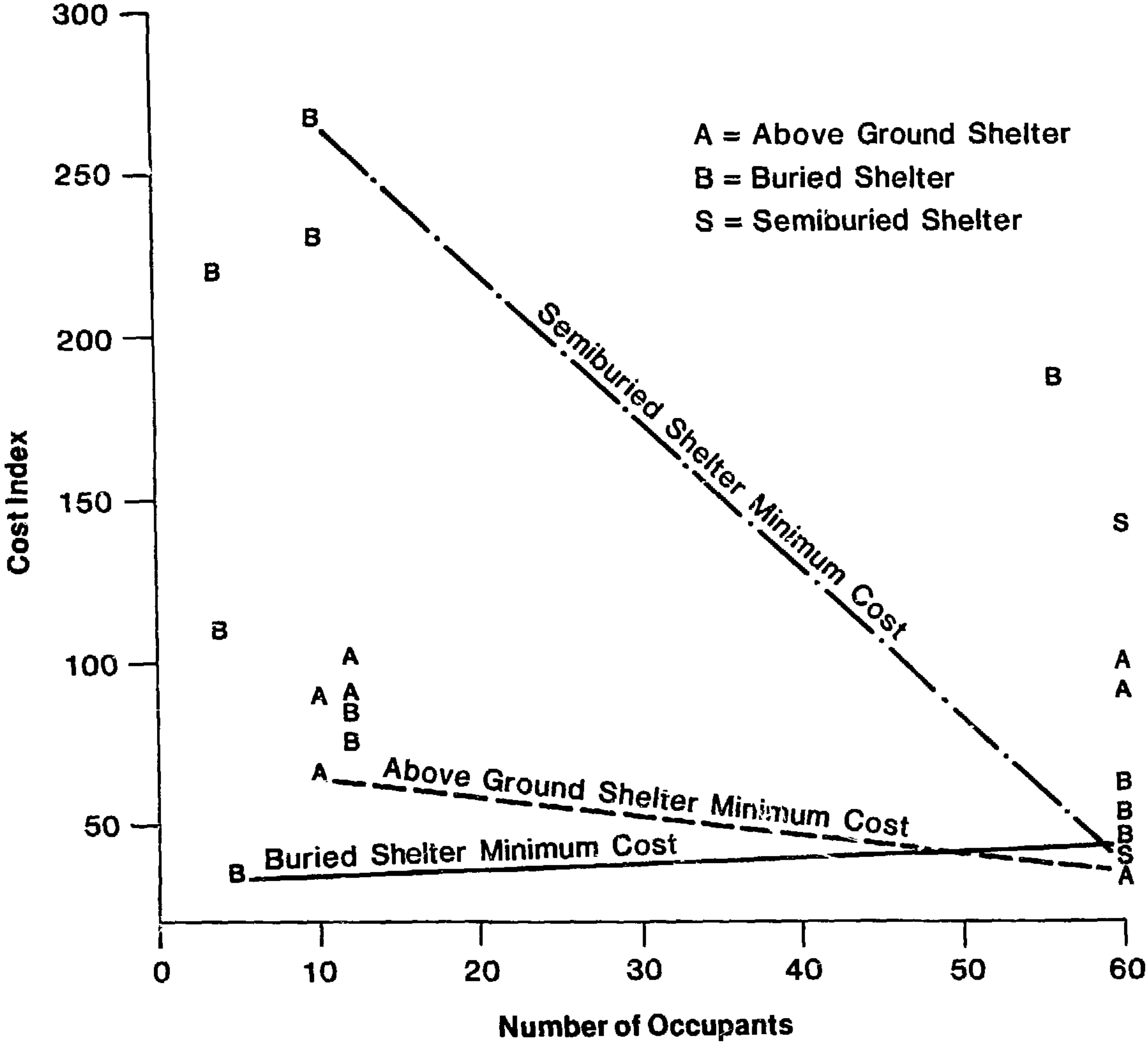


Fig. 1.5 Representative and Minimum Costs of Expedient Shelters by Capacity — Heavy Soil, Mechanically Excavated (Fig. 1.3 explains cost index and cost points)

and caves, and this study also includes use of such facilities. Mine-shelter cost estimates by FEMA were also included in this analysis.

Barn shelters were examined in this study for two reasons. First, such shelters might provide the agricultural sector with extra labor necessary to prepare farms for fallout protection. Second, in some areas of the country, all other in-building shelter options might be exhausted and barns might be the only nonresidential buildings available. The study found that the upgrading of sturdy, enclosed livestock barns would not be necessary in most of the states where such barns were abundant (compare Figs. 1.8 and 1.10). The only clear exception to this finding was the state of Pennsylvania.

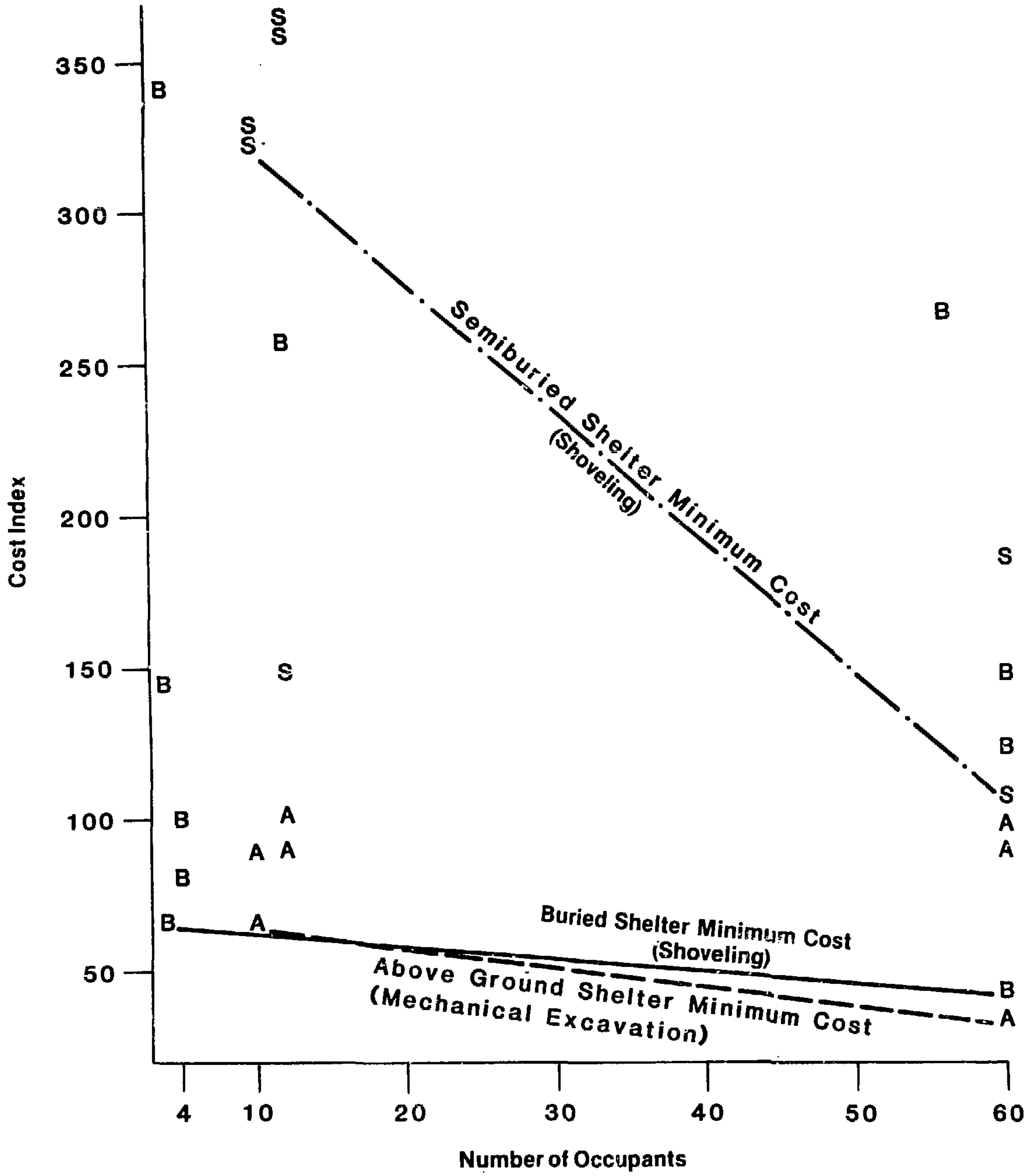


Fig. 1.6 Representative and Minimum Costs of Expedient Shelters by Capacity — Heavy Soil, Shoveled or Mechanically Excavated (Fig. 1.3 explains cost index and cost points)

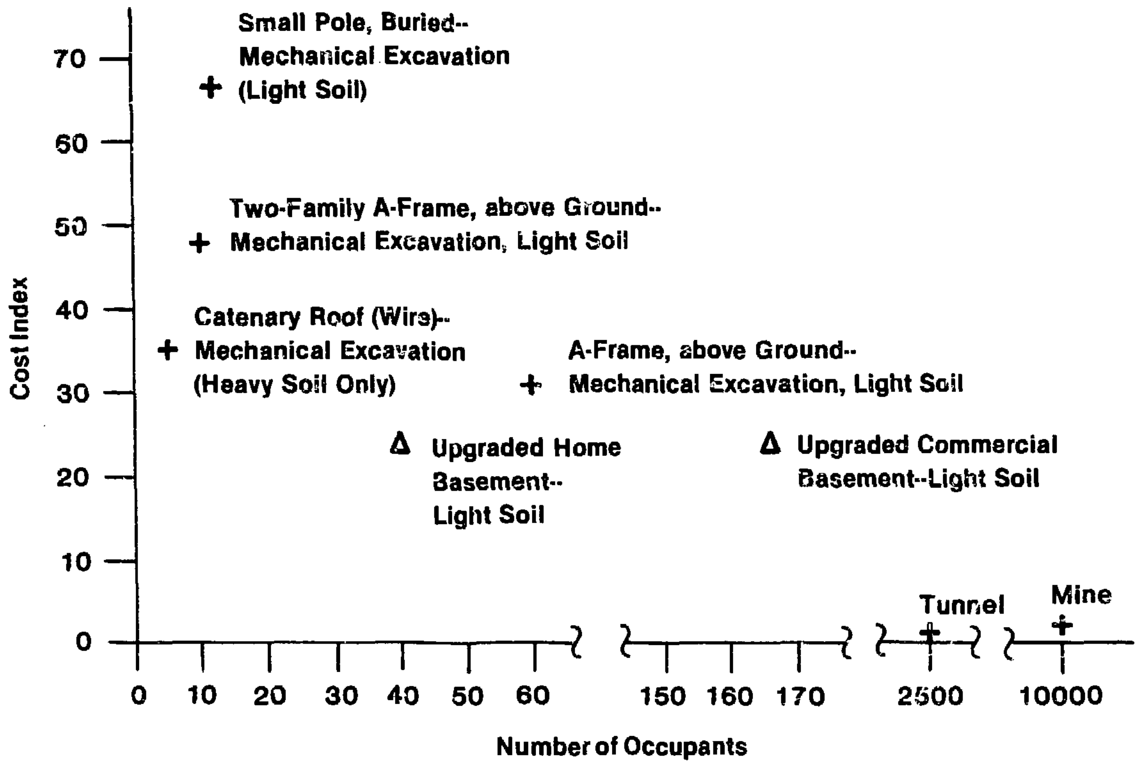


Fig. 1.7 Minimum Costs of Shelter Alternatives by Capacity (Fig. 1.3 explains cost index)

Surprisingly, we also found that the most promising special-case use of barns might be in Maine and Delaware, where an extremely large number of enclosed poultry barns with lofts is located (Fig. 1.9). It was discovered that modern poultry-raising methods require a carefully controlled environment for the poultry. Modern poultry barns are therefore heated and cooled in order to maintain ideal growing conditions. Since Maine and Delaware are both near states with severe upgradable shelter deficits (Fig. 1.10), it may be desirable to investigate the possibility of upgrading enclosed, climate-controlled poultry barns for use as fallout shelters. (The potentially negative aspect of an unpleasant odor in such barns is discussed in the note on p. 9 of Vol. 1.) On the whole, there proved to be little need to consider adding barns to the CRP shelter inventory in most states.

Another shelter option that received consideration was the use of boats. In this option, people would move offshore and away from blast areas in boats. Since fallout sinks in water, the major problem would be from fallout deposited on the boat. In areas of very heavy fallout, exposure during fallout deposition could be a problem. The problem could be addressed by regular washing. Boats could be organized into flotillas with several capabilities (e.g., providing medical care, radiological monitoring, and

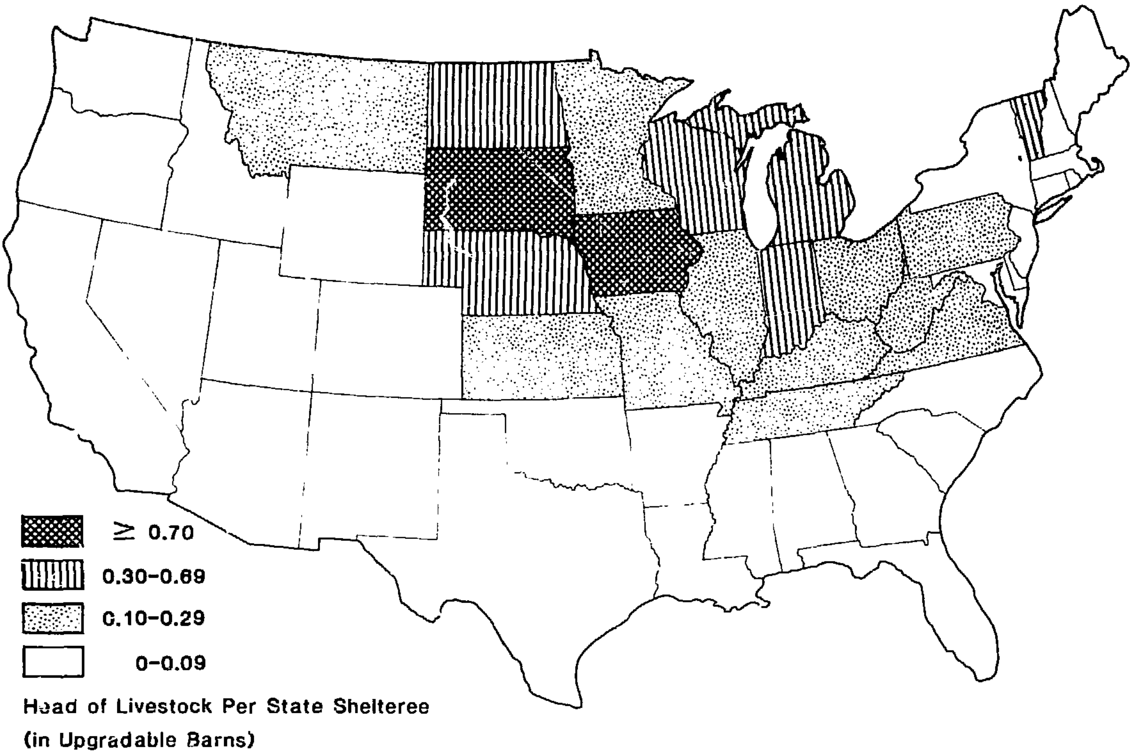


Fig. 1.8 Relative Abundance of Suitable Animal-Barn Shelter Spaces, by State

supplying water and food) built into larger vessels in the flotilla. It was roughly estimated that as many as four million people (four persons each on an estimated one million boats) could be sheltered by such a method *in those areas where upgradable shelter is inadequate*, and that a national total of about 18 million boat spaces could be available along the U.S. ocean coastlines. Although the analysis of this option is superficial, these rough estimates do indicate that the planned use of boats as shelters might warrant further consideration in a few states. If expedient shelters were not used, the use of barns and the boat option would both be alternatives that could provide needed supplemental shelters in FEMA's northeastern and southwestern ocean coastal regions (see Figs. 1.8-1.11).

The barn option could theoretically handle a total of 37.5 million people. However, in those parts of the country where supplemental shelters are most needed, about three million animal-barn shelter spaces and seven million poultry-barn shelter spaces would be available. (The calculation is based on one shelteree per animal space and one shelteree per 10 head of poultry, and it also assumes that both people and animals could be sheltered in animal barns.) These numbers are put into perspective by our estimate that a total of 193 million shelter spaces will be needed in host areas in order to evacuate 80% of those living in U.S. metropolitan areas.

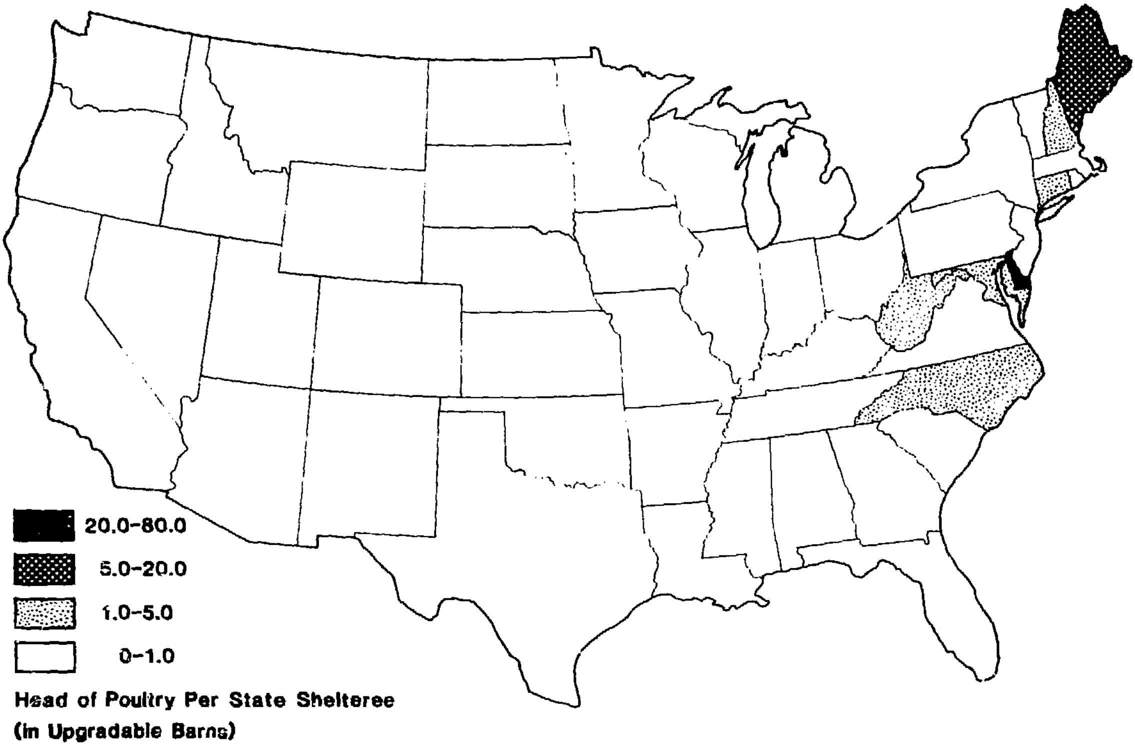


Fig. 1.9 Relative Abundance of Suitable Poultry-Barn Shelter Spaces, by State

Many ideas, when evaluated on their technical merits, appear to represent good shelter options. However, when evaluated in terms of national applicability, most options fall by the wayside simply because there are not enough qualifying shelter spaces. Since FEMA, a national agency, has to devote limited resources to the solution of the host-area shelter deficit problem, it is best to devote greatest attention to those options that present the greatest potential payoff — i.e., the greatest amount of shelter space produced for every research and development dollar spent. The exceptions to this economic rule justifiably arise out of the political arena. For those areas of the country in which the best national shelter option is inadequate, alternative shelter options must be made available. Because the areas of the country where shelter is least adequate are also the most populous areas of the country, the potential political pressure from them can be substantial.

As the reader will see, the results of the research reported here do not provide us with an answer to the question of best options for those areas where the total number of shelters and upgradable buildings is inadequate. However, the results do provide us with evidence that upgrading clearly has the potential to serve a substantial majority of national shelter needs under crisis relocation planning.

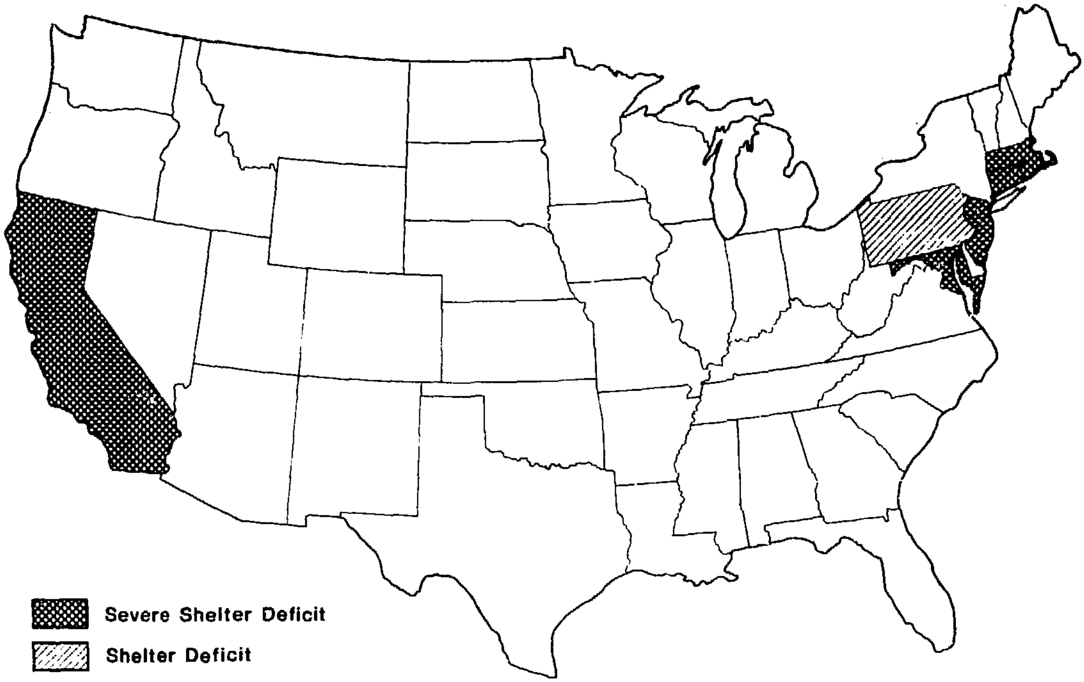


Fig. 1.10 Upgradable Shelter Deficits, by State

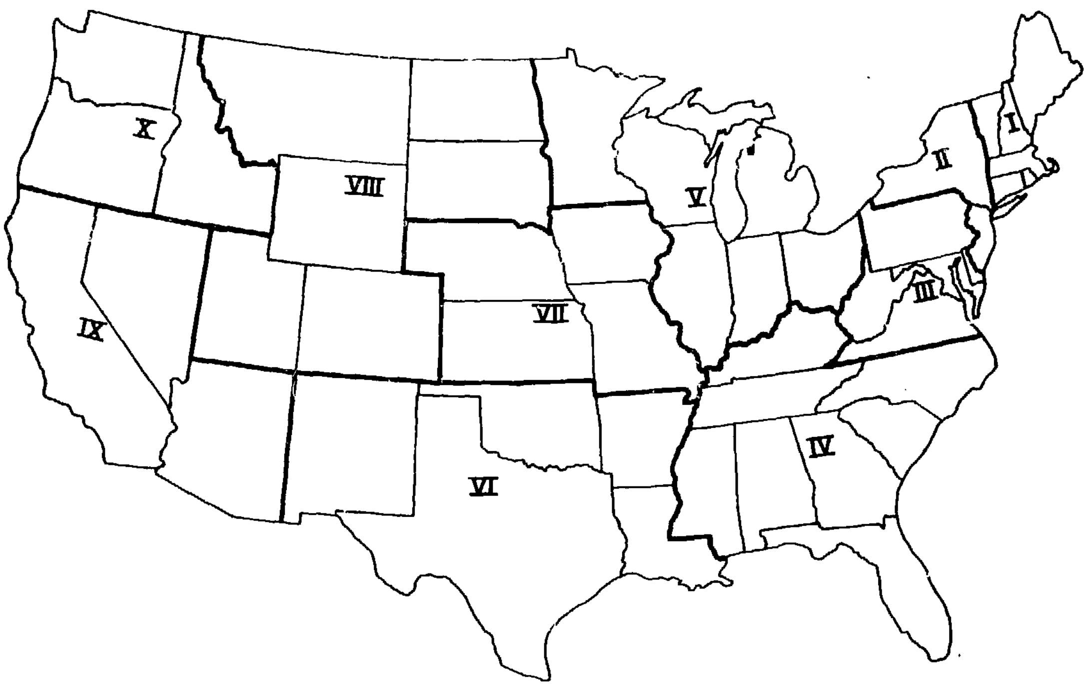


Fig. 1.11 FEMA Regions

1.2.6 Costs

Estimated costs per square foot of shelter space provided vary widely depending on the type of shelter, upgrade requirements, and other factors. Since many types of shelter configurations have been put forth over many years, it is extremely difficult to find a common denominator in which costs per shelter can be compared. One common element in shelter options is the bill of materials. To compare the various Argonne National Laboratory expedient and modular shelter options and other FEMA shelter options, all of the alternatives examined were broken down into material requirements and multiplied by current material prices. The resultant cost was then divided by the number of square feet of shelter space provided to arrive at the cost per square foot of shelter space provided. Table 1.1 summarizes these costs.

By itself, the cost of materials per square foot of shelter space provided does not supply enough information to rank the shelter options -- because skilled labor, equipment, identification, and planning costs are not included. There is also a wide disparity among reports on these costs and definitions, making it still harder to compare shelter alternatives. In order to account for skilled labor, equipment, and other costs, we have devised a cost-ranking system. Using cost data provided to FEMA for various FEMA options as a base,[8] we determined the relative cost differentials between cost components (materials, skilled labor, etc.) by dividing each cost component by material costs. This provides a factor that is multiplied by material costs per square foot of space provided -- and in this way we obtain the relative cost per square foot of space for that component. For example, FEMA's small nonresidential upgrade option has a material cost per square foot of $0.10 (in current prices); skilled labor cost divided by the cost of materials (1974 $) equals 3.10. The $0.10 is multiplied by 3.10 to obtain a relative cost for skilled labor of $0.31 per square foot. This process was completed for all costs. Column five of Table 1.1 presents total costs for each option. The 1980 FEMA work[8] cites 48 different shelter upgrades or expedient options. ANL has selected six of those options for comparison with six ANL options discussed later in the text.

Table 1.1 shows the ranking of the options (12 options, 10 ranks). The mine option (FEMA #4) is the least costly. Unfortunately, there are not enough mines to shelter a significant portion of evacuees. The table shows that expedient shelters in basements of existing nonresidential structures is the next least costly option. The FEMA #2 and and ANL #2 options are $0.80 and $1.50, respectively, per shelter space (10 ft^2/person). The ANL modular upgrading system (ANL #5) ranks in the middle of the options. It is lower in cost than its logical "competitors" -- the FEMA above-ground upgrades (#1 and #3). The options that require burying an expedient shelter (ANL #4 and FEMA #5) show the next lowest costs -- approximately $2.4 and $3.6 per shelter space provided. Trailer or preengineered modular shelters appear to be the most costly option, with FEMA #6 and ANL #5 ranking ninth and tenth, respectively.

Table 1.1 Relative Costs per Shelter Space Provided by Several Shelter Options[a] ($/Space)

Option (ID #)[a]	Cost of Materials	Cost of Skilled Labor[b]	Identifying & Planning[c]	Total Cost[d]	Rank
ANL					
Indoor expedient (#1)	3.6	0	0	3.6	#8
Indoor expedient (#2)	1.5	0	0	1.5	#3
Outdoor expedient (#3)	2.4	0	0	2.4	#5
Outdoor expedient (#4)	2.4	0	0	2.4	#5
Buried H (#5)	5.0	3.5	0	8.5	#10
MUS (#6)	1.0	0.7	0	1.7	#4
FEMA					
Upgrade (#1)	0.1	3.1	0.04	3.2	#6
Upgrade (#2)	0.1	0.7	0.03	0.5	#2
Upgrade (#3)	0.1	3.4	0.02	3.5	#7
Mine (#4)	0.02	0.02	0.01	0.05	#1
Pole expedient (#5)	2.2	1.3	0	3.5	#7
Buried trailer (#6)	3.0	2.1	0	5.1	#9

[a]See legend, next page, for shelter-option descriptions -- options are identified in legend by ID# in table.

[b]Unskilled labor is assumed to be abundant and donated. Its cost here is therefore zero.

[c]Identification and planning costs are those costs associated with identifying of building and location characteristics to allow advance planning for the shelter type.

[d]Totals dollars per space do not necessarily indicate what would be paid in a crisis. Costs here are useful as a means of aggregating the difficulties in obtaining scarce materials to construct shelter spaces. These should be thought of as average national costs. Local costs could differ appreciably, depending on availability of various materials and/or skilled labor. As specified, the shelter options also vary greatly in their ability to withstand blast effects.

Table 1.1 (Cont'd)

ANL Options

Expedient #1	Indoor family (4-person) basement shelter using lean-to against basement wall. Purchased sandbag cover. No ventilation, lighting, or latrine, but available in building.
#2	Same as above using locally collected earth cover. No ventilation, lighting, or latrine, but available in building.
#3	Outdoor family (4-person) A-frame on the ground surface -- earth cover. No ventilation, lighting, or latrine.
#4	Outdoor family (4-person) A-frame partially buried -- earth cover. No ventilation, lighting, or latrine.
#5	Buried box-frame, plywood-based, H-shaped shelter with separate lighting, ventilation, and latrine facilities included -- 256-person occupancy.
Upgrade #6	Modular upgrading system (MUS). Indoor expedient shelter in which a roof 5-6 ft high is built inside. Earth cover inside, on new interior roof. Earth against outside walls. Ventilation, lighting, and latrine not included but may already be provided by the building. PVK, punkah-pump ventilation possible.

FEMA Options (Ref. 8)

Upgrade #1	Above-ground upgrade of a small nonresidential building. Lighting, ventilation, and latrines as available in the building. PVK, punkah ventilation possible.
#2	Basement upgrade of small nonresidential building. Other conditions as above.
#3	Above-ground upgrade of a private home. Other conditions as for FEMA #1.
#4	Upgrade of a drift entry mine. Lighting and ventilation are primary costs.
Expedient #5	A small, buried expedient shelter constructed of poles and using a punkah pump for ventilation. No lighting or latrine -- 60-person occupancy.
#6	A buried trailer with independently powered lighting and ventilation possible; latrine facility also possible.

1.3 EVIDENCE OF THE ADEQUACY OF UPGRADING AS A CONCEPT

This and prior FEMA research show that the major advantage of expedient shelters is their low labor cost. In our cost-estimating procedures, we have assumed that the average person will be willing and eager to provide low-skilled labor at no cost for construction of a personal or family shelter. Expedient shelters are designed to be built by persons of average intelligence, and this simplicity constitutes an advantage for them. Counterbalancing this positive feature of expedient shelters are numerous disadvantages, not the least of which is a doubt that the majority of individuals could and would successfully build and use the expedient shelters that have been designed to date.[10] Furthermore, relative to other shelter options, expedient shelters require the most materials and tools -- substantially more, for example, than upgraded shelters require. This is easily understood. Most expedient shelters require the construction of new walls and a roof for the sheltered group. Upgrading makes use of existing walls and roofs, thus drastically lowering the amount of materials needed. Because upgraded buildings will generally be able to shelter many more occupants per shelter than newly constructed expedient shelters, they will use far less wall area per shelter occupant than the expedient shelters. Less wall area reduces the amount of earth and wall-reinforcing materials that must be used per space, contributing to the lower material needs of upgrades compared to expedient shelters (Table 1.1).

The least-cost, most easily constructed shelters examined in this study were underground shelters. The space cost per occupant of mines and caves was the lowest (Table 1.1). Such spaces are included in the NSS and were included in our estimates of available shelter. However, mines and caves represent only a small fraction of the total necessary shelter space. Other "underground" shelters are basement shelters. The entire basements of nonresidential buildings can be upgraded, and this approach constitutes the least expensive upgrading method. The next lowest-cost expedient shelter was the family lean-to against a basement wall. This type of shelter might be preferred by some host-areas families, those that choose not to leave their homes, but it would not effectively use the full space available in a basement. A program of upgrading whole basements would use far less material than one consisting of many more basement basement lean-tos, but it would require more skilled labor.

To estimate the kinds of shelter space likely to be used under the present NSS and CRP programs, the following order-of-use and protection-factor assumptions were used: NSS PF 40+ shelter spaces would be filled first; second, NSS PF 10-39 spaces would be upgraded and filled; third, upgraded CRP basements would be filled; and last, above-ground CRP upgrades would be filled. Under these assumptions, 30 million NSS PF 40+ spaces, 34 million NSS

PF 10-39 upgraded spaces, 40 million upgraded CRP basement spaces,* and 89 million above-ground CRP upgrades would be used to house 193 million shelterees in host areas (see Fig. 1.12). These totals ignore problems in getting people to shelter spaces and ignore state and regional variation in space availability (see Fig. 1.13 for an indication of variability in basement space availability and Table 1.2 for general statistics on state variability). For successful movement of people to shelter spaces, some shelterees would have to pass through two or more states to get to an upgraded CRP space. While all basement spaces are used under these assumptions, only 27% of the theoretically possible above-ground CRP upgradable spaces would be used. If standard above-ground upgrading methods are made available for building types that

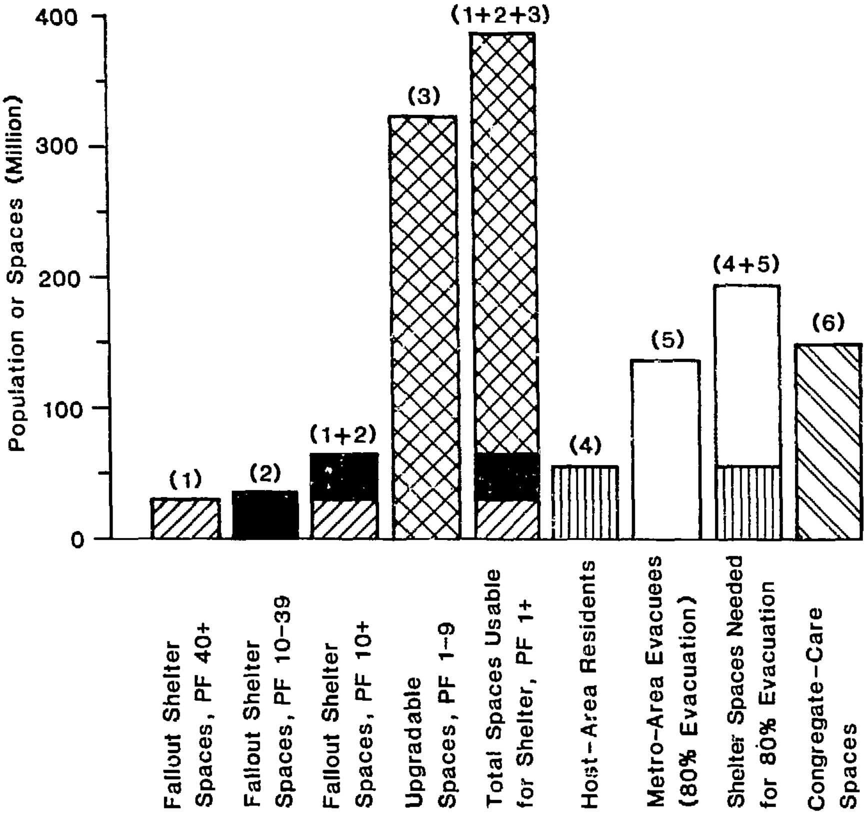


Fig. 1.12 Estimates of Host-Area Shelter Capabilities and Needs: Total U.S.

*A reasonable fraction of these basement spaces might not actually be upgradable because of water-seepage problems. Many areas of the country depend on electrically driven sump pumps to keep basements dry. After a nuclear attack many such basements would flood without back-up power.

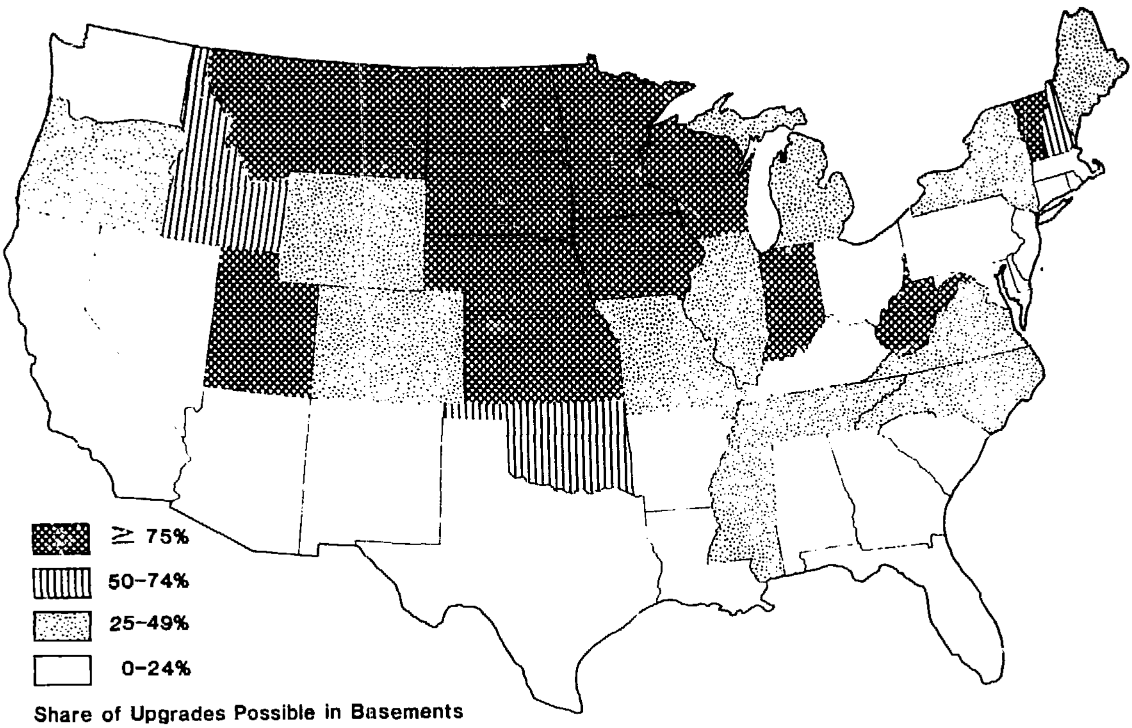


Fig. 1.13 Availability of Basements for Upgrading, by State

represent, say, 60% of the buildings listed as potentially upgradable, then most areas of the U.S. could easily implement upgrading and still be selective. Further, in those areas of the country where all buildings *must* be upgraded, the modular upgrading system (MUS) could, in principle, be used wherever unique problems or uncertainty about structural integrity existed.

In terms of our cost ranking method (Table 1.1), the modular upgrading system proposed in this research ranks between a basement upgrade and an above-ground upgrade using previously developed methods. Its material needs are greater than those of other upgrading methods but less than those of expedient shelters. The MUS requires more skilled labor than does a system based on expedient shelters but less than other upgrading methods. It could be used in any upgrading situation. Where materials are scarce, the MUS would be less desirable than previously developed upgrading methods, but where structural engineers are scarce and materials abundant, its standardized design would enhance a shelter's safety.

The most costly of shelter options examined in this study are those that require a new (though inexpensive) building to be constructed and placed underground. These shelters would rely on walls and roofs made of standard materials to be purchased from a building supply store. They would not make use of existing walls of buildings or of scavenged materials prepared by

Table 1.2 Estimates of Host-Area Shelter Capabilities and Needs, by State and Region[a] (in thousands)

Region/State	Number to be Sheltered[b]	Congregate-Care Spaces[c]	Host-Area National Shelter Survey (NSS) Spaces: Spaces above PF 40	Needed Upgrades (to PF 40)	Total NSS Spaces	Basement Spaces	Host-Area Crisis Relocation Planning (CRP) Survey Spaces: Total Upgradable Spaces[d]	Basement Upgradable Spaces[e]	Needed Upgrades	Congregate-Care Deficit (Surplus)	Shelter-Space Deficit (Surplus)
U.S. TOTALS	192,621.8	149,395.5	29,876.6	34,277.5	64,154.5	26,700.9	324,337.4	33,176.0	114,828.6	43,226.3	(195,870.1)
REGION I	10453.8	3532.3	756.6	1119.6	1876.3	790.7	6345.2	1192.5	6345.2	6923.5	2234.3
Connecticut	2558.2	0	0	0	0	0	0	0	-	2558.2	2558.2
Maine	1050.8	915.1	218.5	321.5	540.0	227.9	1703.0	255.1	510.8	135.7	(1192.2)
Massachusetts	4738.6	261.8	77.3	137.9	215.3	92.2	602.7	130.8	602.7	4496.8	3940.6
New Hampshire	827.6	931.6	187.3	277.4	464.7	153.8	1528.4	308.9	362.9	(104.0)	(1165.5)
Rhode Island	772.4	0	0	0	0	0	0	0	-	772.4	772.4
Vermont	488.2	1423.8	273.5	382.8	656.3	316.8	2511.1	497.7	-	(935.6)	(2679.2)
REGION II	20410.0	7553.2	2271.1	3200.0	5471.1	2502.7	15887.2	2518.0	14938.9	12856.8	(948.3)
New Jersey	6017.6	226.8	44.9	102.0	146.9	48.4	495.7	32.7	495.7	5790.8	5375.0
New York	14392.4	7326.4	2226.2	3098.0	5324.2	2454.3	15391.5	2485.3	9776.7	9766.7	(6323.3)
REGION III	20822.6	10587.5	3382.4	2526.7	5909.1	2672.3	25971.9	2804.4	14913.5	10235.1	(13033.6)
Delaware	515.0	367.9	40.2	84.0	124.2	31.2	1142.9	59.0	390.8	147.1	(752.1)
District of Columbia	510.4	0	0	0	0	0	0	0	-	510.4	510.4
Maryland	3467.0	283.1	118.6	112.4	231.0	96.5	572.1	70.9	572.1	3183.9	2663.9
Pennsylvania	9923.0	3067.6	1184.8	731.1	1915.9	970.7	6031.9	1060.7	6031.9	6855.4	1975.2
Virginia	4601.8	4929.4	911.7	964.3	1876.0	640.5	14916.9	1142.2	2725.8	(327.6)	(12191.1)
West Virginia	1805.4	1939.5	1127.1	634.9	1762.0	933.4	3308.1	471.6	43.4	(134.1)	(3264.7)
REGION IV	33979.6	47908.6	5654.0	9144.9	14799.0	3216.4	99678.8	4159.1	19180.6	(13929.0)	(80498.2)
Alabama	3407.8	3056.2	299.7	677.4	977.1	224.4	5428.4	356.1	2430.7	351.6	(2997.7)
Florida	8027.8	4201.9	302.8	745.4	1048.2	75.3	10948.8	84.5	6979.6	3825.9	(3969.2)
Georgia	4808.6	5469.4	1073.3	2215.2	3288.6	532.0	11555.6	526.7	1520.0	(660.8)	(10035.6)
Kentucky	3336.2	4030.9	1134.9	586.3	1721.2	860.9	7106.6	437.6	1615.0	(694.7)	(5491.6)
Mississippi	2383.2	4154.1	276.3	785.3	1061.6	118.5	8159.6	711.0	1321.6	(1770.9)	(6838.0)
North Carolina	5255.4	9634.8	934.6	1946.9	2881.5	408.9	19742.0	967.0	2373.9	(4379.4)	(17368.1)
South Carolina	2746.4	10291.3	579.3	1233.3	1812.6	252.1	19480.5	167.9	933.8	(7544.9)	(18546.7)
Tennessee	4014.2	7070.0	1053.1	955.1	2008.2	744.3	17257.3	908.3	2006.0	(3055.8)	(15251.3)
REGION V	8709.4	31543.5	7998.8	9751.9	17750.8	9381.0	68831.6	10414.0	20958.6	7165.9	(47873.0)
Illinois	9568.6	6285.4	1578.3	1103.5	2681.9	1607.4	14946.5	2418.2	6886.7	3283.2	(8059.8)
Indiana	4723.6	6156.9	1359.9	2487.2	3847.1	1570.6	13545.3	1901.3	876.5	(1433.3)	(12668.8)
Michigan	7726.8	4607.5	773.5	1314.3	2087.8	1239.6	11543.1	1378.7	5639.0	3119.3	(5904.1)
Minnesota	3550.6	3366.0	1505.0	1275.2	2780.2	1677.4	6724.6	1283.8	770.4	184.6	(5954.2)
Ohio	9063.8	4551.1	1199.2	1518.9	2718.1	1288.8	10207.9	1169.2	6345.7	4512.7	(3862.2)
Wisconsin	4076.0	6576.6	1582.9	2052.8	3635.7	1997.2	11864.2	2262.8	440.3	(2500.6)	(11423.9)
REGION VI	21588.8	19292.7	2217.4	3434.0	5651.5	1374.0	43164.3	3568.5	15937.3	2296.1	(27227.0)
Arkansas	2107.0	3759.2	462.8	564.2	1027.0	225.5	7471.8	231.7	1080.0	(1652.2)	(6391.8)
Louisiana	3670.8	2426.5	115.4	343.7	459.2	49.8	4349.5	56.3	3211.6	1244.3	(1137.9)
New Mexico	1189.8	1501.5	431.5	269.1	700.6	371.9	3409.8	112.3	489.2	(311.7)	(2920.6)
Oklahoma	26[illegible].0	3882.2	671.0	1120.8	1791.8	436.5	10141.9	1258.5	879.2	(1211.2)	(9262.7)
Texas	11950.2	7723.3	536.7	1136.2	1672.9	340.1	17791.3	1909.7	10277.3	4226.9	(7514.0)

Table 1.2 (Cont'd — values in thousands)

Region/State	Number to be Sheltered[b]	Congregate-Care Spaces[c]	Host-Area National Shelter Survey (NSS) Spaces: Spaces above PF 40	Needed Upgrades (to PF 40)	Total NSS Spaces	Basement Spaces	Host-Area Crisis Relocation Planning (CRP) Survey Spaces: Total Upgradable Spaces[d]	Basement Upgradable Spaces[e]	Needed Upgrades	Congregate-Care Deficit (Surplus)	Shelter-Space Deficit (Surplus)
REGION VII	10528.0	10748.6	2796.8	2131.4	4928.2	2951.4	22128.1	4549.7	5599.8	(220.6)	(16528.0)
Iowa	2680.2	2685.9	828.6	498.0	1326.6	833.5	5422.6	1328.2	1353.6	(5.7)	(4069.0)
Kansas	2141.6	2499.3	673.4	649.9	1323.3	861.7	5435.6	1148.7	818.3	(357.7)	(4617.0)
Missouri	4274.8	3215.8	882.6	671.4	1554.0	853.3	6741.2	894.7	2720.8	1059.0	(4020.4)
Nebraska	1431.4	2347.6	412.2	312.1	724.3	402.9	4528.7	1178.1	707.1	(916.2)	(3821.6)
REGION VIII	6131.2	6986.7	1886.1	989.9	2876.5	1906.7	16740.0	2558.2	2856.1	(855.5)	(13485.3)
Colorado	2421.8	2170.4	486.3	314.6	800.9	487.3	4808.7	550.6	1620.9	251.4	(3187.8)
Montana	749.2	768.8	190.3	128.9	319.2	195.4	2331.8	576.3	430.0	(19.6)	(1901.8)
North Dakota	605.2	895.3	192.6	131.7	324.3	194.2	2023.2	405.9	280.9	(290.1)	(1742.3)
South Dakota	668.2	1406.4	326.4	212.8	539.2	317.8	3436.3	682.3	128.5	(738.2)	(3307.8)
Utah	1230.2	1232.6	513.2	159.2	672.4	559.2	2941.4	257.0	159.2	(2.4)	(2383.6)
Wyoming	456.6	513.2	177.3	42.7	220.0	152.8	1198.6	86.1	236.6	(56.6)	(962.0)
REGION IX	22965.2	5834.4	974.4	957.1	1931.5	599.0	12552.8	304.4	10028.4	17130.8	8480.9
Arizona	2310.2	1132.9	228.4	265.7	494.1	114.5	3107.2	63.8	1816.1	1177.3	(1291.1)
California	19175.0	3582.6	420.0	441.5	861.5	281.2	7308.2	176.4	7308.2	15592.4	11005.3
Hawaii	812.0	791.4	134.3	117.5	251.8	81.9	1422.0	22.1	560.2	20.6	(861.8)
Nevada	668.0	327.5	191.7	132.4	324.1	121.4	715.4	42.1	343.9	340.5	(371.5)
REGION X	7031.2	540.8	1939.0	1022.0	2961.0	1306.7	13037.1	1107.2	4070.2	1623.2	(8966.9)
Alaska	365.0	848.7	89.7	73.9	163.6	40.6	1723.0	191.4	201.4	(483.7)	(1521.6)
Idaho	909.4	837.2	355.3	180.6	535.9	286.4	1939.4	285.0	373.5	72.2	(1565.9)
Oregon	2291.0	2185.6	491.7	321.4	813.1	316.9	5600.6	397.4	1477.9	105.4	(4122.7)
Washington	3465.8	1536.5	1002.3	446.1	1448.4	662.8	3774.1	233.4	2017.4	1929.3	(1756.7)

[a]Total for regions and the nation depend on the assumptions used concerning the crossing of state and regional boundaries.

[b]Based on 80% evacuation of the U.S. metropolitan population plus the entire nonmetropolitan population.

[c]Congregate-care spaces in CRP-surveyed host counties plus [(Congregate-care spaces in CRP-surveyed host counties / NSS spaces in CRP-surveyed host counties) times NSS spaces in host counties not CRP-surveyed].

[d]Upgradable spaces in CRP-surveyed host counties plus [(Upgradable spaces in CRP-surveyed host counties / NSS spaces in CRP-surveyed host counties) times NSS spaces in host counties not CRP-surveyed].

[e]Total estimated host-area upgradable space times [Basement upgradable spaces per CRP-surveyed host county / Total upgradable spaces per CRP-surveyed host county].

unskilled labor. Heavy equipment would be used to excavate the space for the shelter. Toilet facilities were included as part of the cost of the shelter. Electrical lighting and ventilation systems were designed into the shelter; generator sets independent of the local electric utility system were included.

While newly constructed, underground shelters proved to be more costly than the others considered in this study, their chararacteristics illustrate that more features and higher quality come at a price. Expedient shelter designs have very crude toilet and lighting facilities, if any. Ventilation systems, if present, are manually operated and hand-built. Upgrading offers the possibility of adequate toilet, lighting, and power ventilation facilities *if* the local utilties are not decommissioned by blast damages or electromagnetic pulse (EMP) effects. Alternatively, upgrading can be designed to include independent power systems for ventilation and lighting if failure of local utilities is expected. The 256-person underground H-shelter developed during this study suggested the need of a 12-volt system that could be adapted to upgrading situations. Our study did not examine the probability of utility system survival and the implications of that for shelter design, although concern over lighting and especially ventilation problems in upgraded shelters was raised by the analysis. The buried H-shelter (Sec. 2.2) might prove particularly attractive in areas subject to blast overpressures greater than 1.0 psi. Proper design could allow this shelter to be blast-resistant. Its independent closed ventilation system might be very desirable in areas of moderately high blast (causing utility destruction) and high fallout (in which case the filtering of particles would be extremely important). Such a system might also be essential in locations such as the deep South, where ventilation requirements are high.

1.3.1 The Blast Closure Problem

For those shelters located close to risk areas, there are especially severe total dynamic and static loads that will be placed on the shelter as a result of combined earth and blast loads. Furthermore, blast effects can propagate through openings in a shelter, potentially causing a building to fail and/or creating high-speed projectiles. Either effect can of course result in fatalities and casualties. Shelters in the vicinity of risk areas must therefore be reinforced and securely closed. Unfortunately, the point at which blast overpressure effects become inconsequential is not presently known.[11,12,13] However, past research does clearly show a problem between 1.0 and 2.0 psi. The 2.0 psi line is the theoretical boundary outside of which host areas (and evacuees from high-risk areas) are located. Furthermore, some types of major structural failure have occurred at blast overpressures as low as 0.6 psi. There is no doubt that special blast-closure techniques will have to be developed for use in many areas of the country. On the other hand, there are also vast areas of the country where such closures will not be necessary.[14]

1.3.2 An Estimate of the Potential for Upgrading

The upgrading cost estimates prepared for this study have been based on an assumption of upgrading to PF 40. However, if it could be expected that survival would be assured with a PF of less than 40, certain trade-offs might be considered. Construction effort might be directed toward getting more space per shelter occupant rather than a greater PF — once a certain minimum PF level had been reached. In some areas of the country, extra space per person could greatly enhance survival probabilities by easing ventilation problems. While shelter upgrading should always be directed toward ultimately achieving PF 40+ standards, both PF and ventilation requirements need to be met to assure survival. Currently, FEMA ventilation requirements are sensitive to expected outdoor conditions (heat and humidity), while radiation protection requirements are uniform throughout the country (PF 40), and do not vary according to expected outdoor conditions (radiation levels).*

In this study we estimated the number of spaces for which the PF 40 standard would be more than adequate to assure 100% survival — and the number for which it would be less than adequate. Since the lowest PF of any space included in the NSS is 10, we took state-level data based on the TR-82 attack scenario[15] and calculated the proportion of the host-area population (population living where blast will be less than 2.0 psi) to be found in areas with an "expected" outdoor radiation exposure of 500 ERDs or less and 1.0 psi or less overpressure. (Note on p. 2, Vol. 1, discusses the assumptions of the TR-82 attack scenario.) In areas occupied by those persons, the provision of shelter with a PF of 40 will be more than adequate for survival — because a PF of 10 would reduce exposure to 50 ERDs or less, an amount that should allow 100% survival. Moreover, blast closure should not be a significant problem in most of these areas. (The 1.0 psi value was selected because of limitations in the TR-82 attack scenario, not because the value is known to be a boundary beyond which blast overpressure problems cease to exist. Because of a decision to keep computer running costs manageable, areas of the country where blast overpressures are expected to be less than 1.0 psi were not evaluated for blast effects.) It was assumed that the first priority in evacuation would be to get people to these areas. Evacuees were assumed to cross state boundaries within FEMA regions, but not regional boundaries, in order to get to these locations. Shelter spaces were assumed to be distributed in direct proportion to host-area population.

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*In fact, the ventilation standard is a survival standard, while the radiation-protection standard is not. If the radiation-protection standard were set in such a way that every fallout shelter occupant were to receive a maximum 50-ERD (equivalent roentgen dose) exposure, then PF levels would have to vary with the expected level of fallout. One major reason for this difference is greater predictability of weather conditions than of fallout levels.

With these assumptions, it was determined that more than half of the expected shelter occupants (51.2%) could theoretically be housed in shelters with a minimum but adequate PF of 10 and with an ability to withstand blast pressures up to 1.0 psi. On a state basis (not allowing for crossing of state boundaries), it was estimated that 13 states could house all of their evacuated population in such shelters and still have space left over (Table 1.3, Fig. 1.14). Upgrading to the standard PF of 40 in these areas will provide a margin of safety that would reduce residual doses.

The next category of desirable shelter is the one FEMA is presently best prepared to provide instruction for, namely, a shelter designed to provide a PF of 40 but with little preparation for blast effects.[16-20] Estimates of upgradable shelter spaces in areas with 500-2000 ERDs of expected fallout and less than 1.0 psi of blast overpressure revealed that another 32% of evacuees could be provided adequate shelter in such buildings. Another eleven states could provide adequate shelter for *all* state evacuees by use of some shelters with a maximum PF of 40 and moderate blast-closure measures. (In many areas of these states a PF of 10 would be adequate.) In total, about 83% of evacuees could be sheltered by methods combining use of shelters designed for a PF of 10 or a PF of 40, each with limited blast-closure problems.

Sheltering of the last 17% of evacuees would be far more difficult. Shelters protected against overpressures from 1.0 to 2.0 psi and with a PF of 40 could house 6% of the population. Another 4% could be housed in shelters designed to withstand up to 1.0 psi and provide a PF of 200. However, even if every theoretically adequate upgrade were made (and many could not be), about 6-7% of the evacuated population could not be adequately sheltered in upgraded buildings. At least eight states would find it impossible to provide adequate shelter by upgrading. It is these states for which FEMA must continue to provide shelter options other than upgrading.

1.4 THE CONGREGATE-CARE PROBLEM

Since congregate-care facilities require 40 ft^2 per person, while shelter space requires only 10 ft^2 per person, it is obvious that cases could arise in which it would it would be possible to provide minimum shelter space for every evacuee but not minimum congregate-care space. About two upgradable 10 ft^2 spaces per person were found in the combined NSS and CRP inventories for each 40 ft^2 per person of congregate-care space. Thus, overall, upgradable shelter spaces should outnumber congregate-care spaces by slightly more than two to one when the CRP surveys are complete. Put in a more negative light, there will be fewer than half as many congregate-care spaces as upgradable shelter spaces. Consequently, many more states are estimated to have a congregate-care deficit than an upgradable shelter space deficit.

As one would expect, the same eight states that have upgradable shelter deficits also have severe congregate-care deficits. However, another seven

Table 1.3 Shares of Shelter Space That Could be Provided by Risk-Sensitive Shelter Upgrading and Crisis Relocation Planning

Upgradable Spaces in Risk Category[a]		Host-Area Risk Category of Shelter Spaces in Upgradable Buildings		
Total Spaces (million)	Percent of U.S. Shelter Occupants	Expected Outdoor Radiation (ERD)	PF Needed	Expected Blast Overpressure (psi)
98.55	51.2	$\leq$ 500	10	$\leq$ 1.0
61.66	32.0	500 - 2,000	40	$\leq$ 1.0
10.84	5.6	0 - 2,000	40	1.0 - 2.0[b]
4.13	2.1	2,000 - 10,000	200	$\leq$ 1.0
4.59	2.4	2,000 - 10,000	200	1.0 - 2.0[b]
2.12	1.1	$\geq$ 10,000	$\geq$ 200	2.0[b]
10.72[c]	5.6[c]			
192.62[d]	100.0			

[a]Includes for purposes of completeness the number of shelter spaces that are *not* provided by this program (10,720,000, or 5.6% of all the spaces that ideally should be provided in upgraded host-area buildings but cannot be provided because of the finite supply of upgradable buildings). See also notes c and d below.

[b]Blast closure clearly needed in all shelters.

[c]Represents the nonserved part of the evacuated population.

[d]This total is based on 80% evacuation of the U.S. metropolitan population plus the nonmetropolitan population — 20% of the U.S. metropolitan population (15% of the total) is *not* served by this program. People in the nonserved category are not necessarily assumed to be casualties. Some spontaneous evacuation is expected. A separate shelter program for key workers also exists.

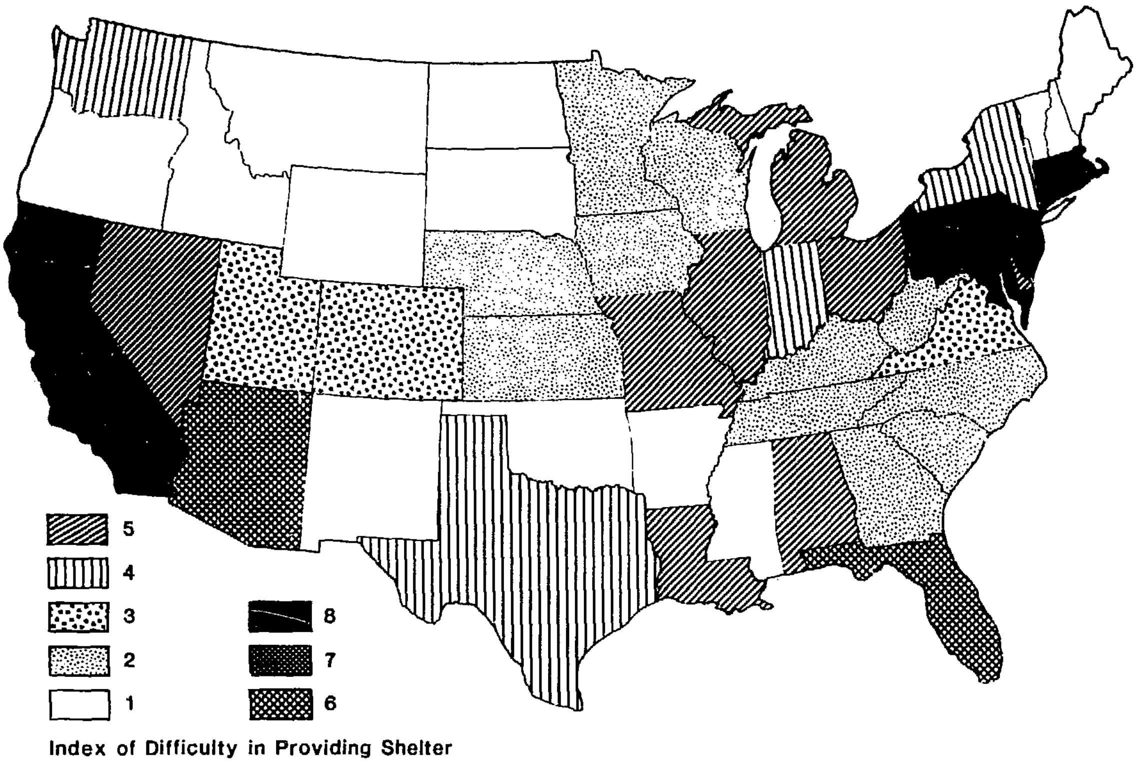


Fig. 1.14 Difficulty in Providing Shelter, by State

states also have moderate congregate-care deficits (Fig. 1.15). These congregate-care deficits occur even though host-area residents do not occupy congregate-care facilities, which are merely housing facilities to be occupied as fallout shelters are completed.

1.5 ADVANCE PREPARATION OF HOST-AREA SHELTERS

As the severity of the shelter problem increases, the relative benefits of detailed advance preparation increase. For example, providing shelter in zones of high fallout and high blast overpressure requires advance structural analysis of new and existing buildings, to determine how they might be modified, and upgrade planning. One approach already used by FEMA is the slanting method, in which buildings are designed in advance to have the capability of acting as fallout shelters.[21] A complementary approach suggested in this research would encourage slanting-for-upgrading. In this approach, plans are developed in advance for upgrading should it eventually become necessary. It may not be possible to undertake all of the measures necessary to provide adequate fallout protection in an existing building; but certain inexpensive modifications, such as selective structural improvement, might at least be undertaken. Such an approach would be less costly than slanting, possibly making it more readily accepted.

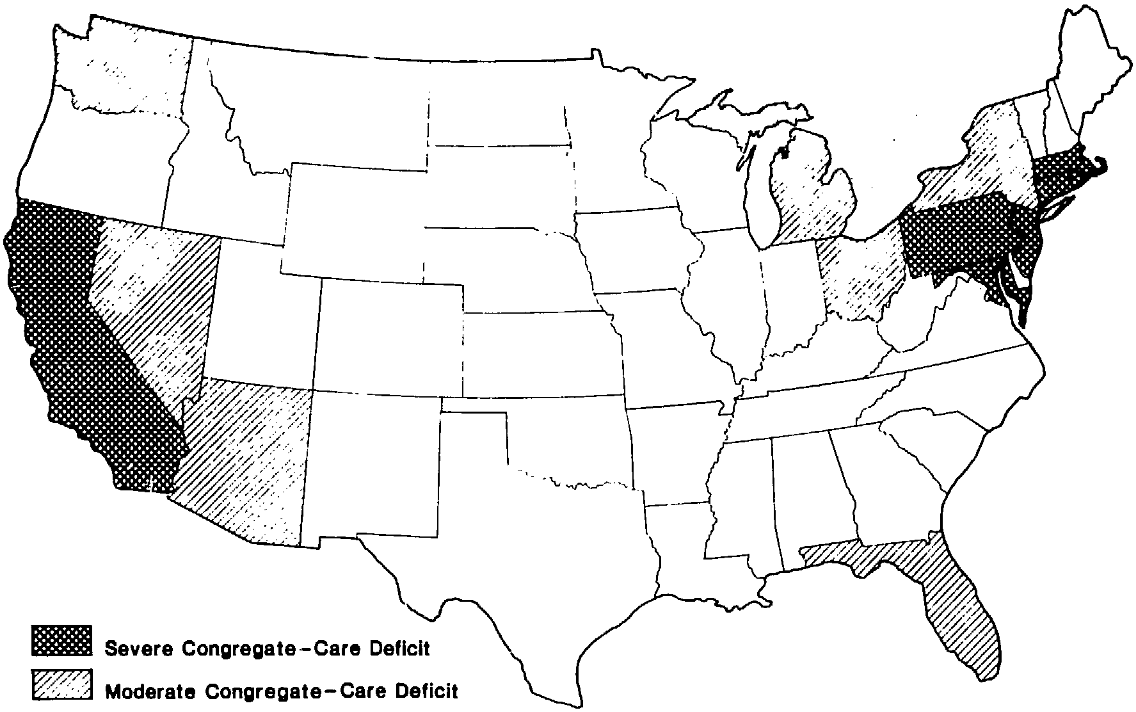


Fig. 1.15 Congregate-Care Deficits, by State

Most laws requiring consideration of slanting have cost loopholes or are not enforced. They often apply only to public buildings, a category which can provide only 20% or less of the needed shelter spaces. No present laws distinguish between risk and host areas, a situation that can actually lead to shelter spending where it is expected to be ineffective.[22,23]

In addition to encouraging new-construction slanting and slanting-for-upgrading in nonresidential buildings, some states might want to encourage residential shelter construction by host-area residents. The fewer host-area residents needing space in upgraded public shelters, the less difficult it will be to provide an adequate number of shelters for evacuees from metropolitan areas. In some states and regions where shelter deficits exist, there are enough upgradable spaces to house metropolitan evacuees only. Thus, if a program encouraging residential shelters for host-area residents could successfully be developed, it would either alleviate or eliminate the problem of sheltering metropolitan evacuees.

In at least two states, Nevada and Rhode Island, a property tax deduction has been granted on property that includes a fallout shelter.[24] The deduction is not for the shelter itself but for the entire property value. These deductions now have a relatively low value ($1000 in Nev., $1500 in R.I.). In most states, the effect of the property tax is to discourage the construction of a fallout shelter because the shelter itself may be taxed. A more powerful tax incentive than those used in Nevada and Rhode Island would be to exempt that portion of a residence used as a fallout shelter from the property tax. Such an approach would be better than the Nevada and Rhode Island approaches because the value of the exemption would increase with property values. The exemption might be tied to capacity of the shelter and normal occupancy of the house. As with nonresidential buildings, it might also be possible to encourage host-area residents to plan for possible upgrading of their homes.

The authors of this study briefly examined some methods of encouraging slanting in the construction of new buildings, though we did not specifically investigate how slanting for upgrading might be encouraged. Several approaches are clearly possible to encourage both methods of advance preparation of shelters. Our research indicates that emphasis on particular states and regions may be more effective than trying to encourage state legislation in every part of the country. Further, it suggests that federal legislation would have to be carefully drafted if it were to selectively encourage slanting, shelter construction, and planning for upgrading in areas of greatest need. (See Sec. 2.1.1 for further discussion.)

1.6 SURVIVABILITY ENHANCEMENT VERSUS COST OF SHELTER OPTIONS

The objective of any NCP program is to increase the probability of the population's survival in the event of nuclear war, but to do this within the limits of reasonable cost. Upgrading satisfies the need to provide protection at reasonable cost.

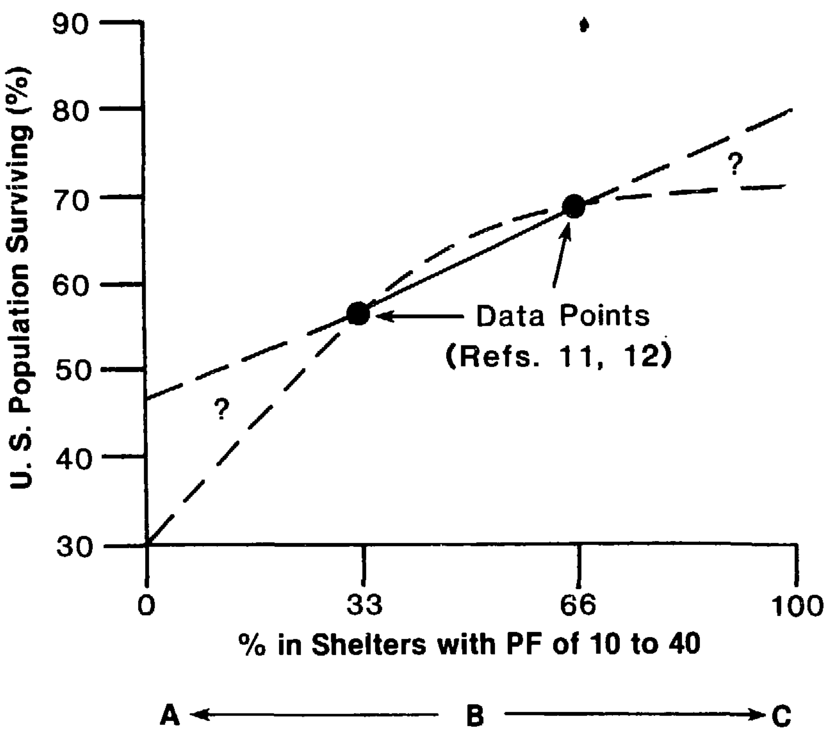
1.6.1 Cost

Several factors combine to determine what is possible at a given cost. For example, it may not be possible to adequately upgrade a structurally weak building if the fallout PF needed is extremely high. The costs of upgrading a particular building may go up slowly as the PF increases, and as larger earth loads are needed, and then jump substantially as the design load is exceeded and shoring must be added. Cost patterns for individual shelter types are difficult to pin down precisely. As a result of the cost-estimating work done in this research, several rules of thumb can, however, be established.

1. Depending on the shelter design, construction may be completed before preparations are made for nuclear attack (the surge) or during those preparations. Shelter options in which construction and preparation are delayed until the surge period will have a lower implementation cost to FEMA. The trade-off involved is that the later construction occurs, the less likely the population is to be adequately sheltered at the time of a nuclear attack.

These trade-offs are illustrated in Figs. 1.1, 1.2, and 1.16. The CRP option of upgrading is the most cost-effective alternative, but the survival estimates used in Figs. 1.1 and 1.2 assume that shelter upgrading is complete.

2. Labor costs for shelters constructed before the surge period will have to be paid. Most labor provided during the surge period will be voluntary. It is argued in



Program to be Assessed by ANL:

A. Crisis relocation; congregate-care only

B. Crisis relocation; some upgrading completed before attack

C. Crisis relocation; upgrading completed

Fig. 1.16 CRP Programs with Variable Attack/Upgrading Assumptions versus Expected Population Survival

Sec. 3.1.3 that there is actually a psychological benefit from putting people to work during the surge period. Labor costs should be included for all aspects of shelter programs occurring before the surge. During the surge, low-skill labor costs should be ignored. There is a possibility that workers with greater skills will have to be paid in order to encourage them to participate in the CRP upgrading.

3. Upgrading of buildings is generally less costly than constructing expedient shelters because walls and a roof do not have to be built from scratch. Unless expedient shelters can be dug into soil so that their walls will be stable without use of reinforcing materials, this relationship will hold.

4. New power-ventilation systems can cost more than the materials in the shelter and as much as materials and labor combined. The benefit, however, is enhanced survivability.

5. Mines, caves, tunnels, and existing shelters have a lower material cost than that of any other alternative. They are already in place.

6. The greater the emphasis on surge-period construction, the more money will have to be spent planning for the management, organization, and education of the sheltered population during a surge.

1.6.2 Survivability

There are two aspects of survivability: the effort to get the population into shelters before the attack occurs and the need to increase the PF of the shelters that are occupied. The first criterion can be met by selecting shelter options that can be constructed at the earliest date. When surge-period options are used, the more rapidly completable shelter options are the more desirable. In the event of early attack, it is desirable to be in a building that can be upgraded further, if necessary, even after the attack occurs. For shelter upgrading alternatives, this means that the sooner all components of interior upgrading are in the building the better.

There is a technical limit to the desirable level of upgrading for a given area. While it is desirable to increase the PF, it is not wise to waste effort unnecessarily in doing so. This can be understood by examining the relationship of PF, survivability, and outdoor radiation levels.

Basically, fallout shelters protect occupants against potential damage to the human body resulting from exposure to the fallout (gamma radiation) from nuclear explosions. The damage caused by gamma radiation to the body is cumulative, and it is thus important to reduce the exposure to radiation. It has been estimated that a dose of 250 R would kill 50% of the population exposed to this radiation level. It would therefore be conservative to estimate that doses above 250 R would kill 100% of the population (Fig. 1.17). Alternatively, doses less than 50 R are considered safe and represent 100% survivability. This indicates that any shelter should provide protection that limits the radiation dosage received by the occupant to no more than 50 R. Further efforts at reduction are unnecessary to assure simple survival (ignoring the desire for a safety factor, a separate issue). However, lower exposure will improve the post-attack health of the population and improve recovery capabilities (capacity of the population for work).

A measure of the effectiveness of any shelter to shield its occupants from fallout radiation is known as the protection factor (PF). The protection factor for a shelter is the ratio of the amount of radiation received by a theoretically unprotected individual person to the amount of radiation that would be received at the same location with the shelter barriers present. Thus, a shelter with a PF of 40 means that the radiation inside the shelter is 1/40, or 2.5%, of the radiation dose of the theoretically unprotected individual.

Figure 1.17 shows the variation of radiation dose with survivability for various protection factors. For a no-shelter option (PF=1), the probability that populations exposed to less than 50 R would survive is 100%, as previously indicated. However, if the same population is protected by a shelter having a PF of 40, the population would survive radiation levels outside the shelter up to a maximum of 2000 R. Obviously, the higher the protection factor offered by a shelter, the greater the survivability up to the 100% survival maximum. This clearly illustrates the need to provide effective shelters for populations that could be exposed to the hazards of fallout radiation — but at the same time to limit the expenditure on the shelter to no more than the PF necessary to protect occupants at a given location.

An important trade-off to consider is the cost-reducing benefit of overdesign with "standardization" (e.g., designing all shelters to PF 40, 100, 200, or some other value) versus the survivability-enhancing benefit of designs adapted to the desirable PF value for each particular location. A combination of the two approaches will probably prove most effective.

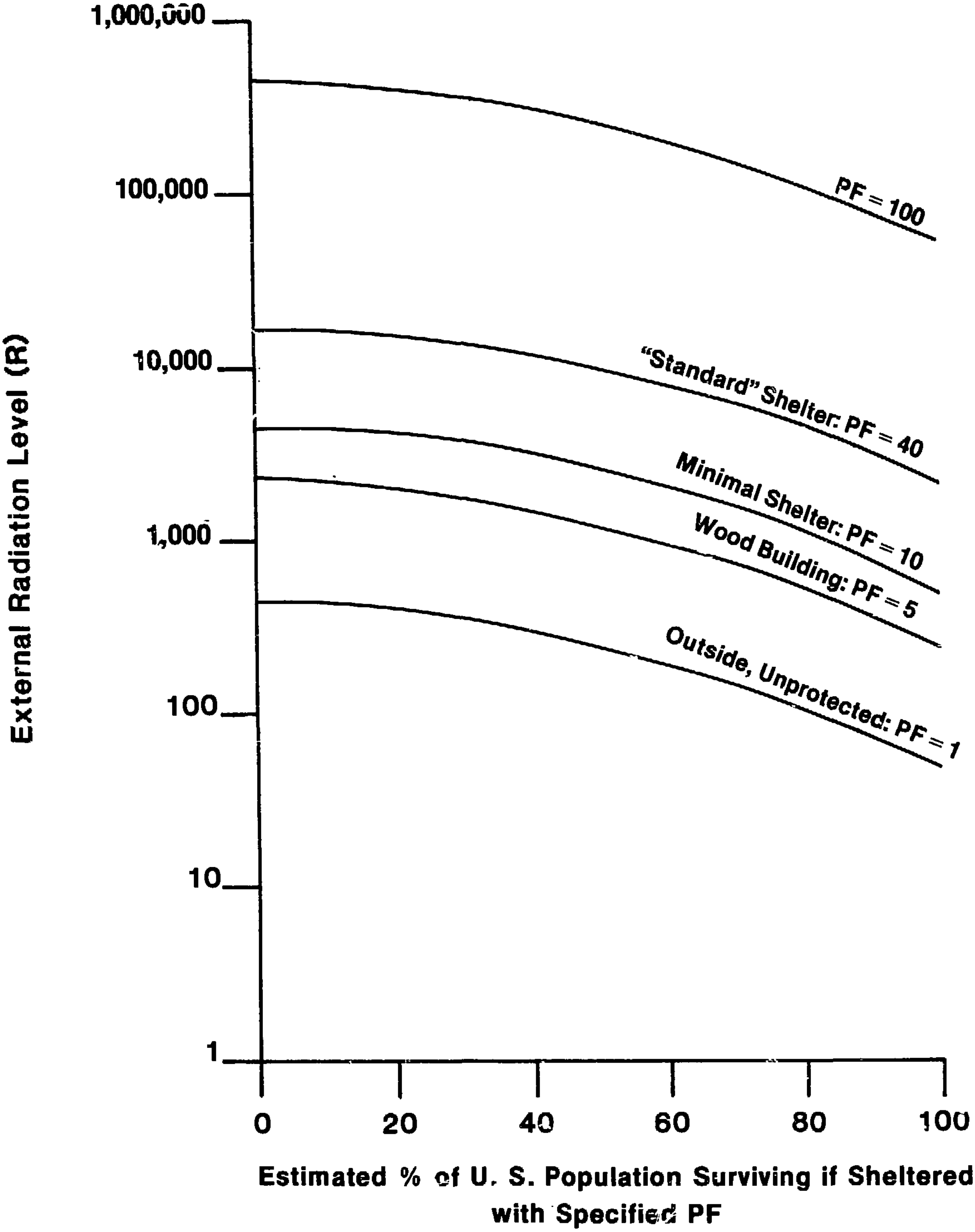


Fig. 1.17 Variation of Radiation Levels versus Survivability for Differing Protection Factors

2 SHELTER OPTIONS CONSIDERED IN DETAIL

The shelter options discussed in this section are only a subset of the options reviewed in Sec. 1. Because of the findings of the previous section, the analysis in this section emphasizes the upgrading and preconstructed-shelter options. Three upgrading options are discussed. The first two options, generated earlier by FEMA, must still be refined. The third option is an entirely new upgrading approach: the rapidly erectable, pre-engineered shelter, which was developed before the analysis in Sec. 1 indicated its relatively high cost. This idea, nevertheless, has much to recommend it for application in certain high-risk areas where upgrading would be inadequate and where high-skill workers need special protection from radioactive fallout. It represents a creative and sound improvement of the expedient-shelter concept.

The barn and preconstructed-shelter concepts have both received attention in the course of the project. They and the upgrading options are analyzed in detail below; other options discussed here will not receive detailed analysis, in light of the clear need to focus attention on the upgrading options. The emphasis has been on a preliminary scoping of ideas and concepts rather than a complete research and engineering analysis. The shelter ideas presented in this section should therefore be regarded as concepts only. Admittedly, each requires much further refinement and detail.

2.1 UPGRADING OF BUILDINGS TO SHELTER STATUS

If people are to be evacuated from large cities and other likely target areas, they need to be provided with shelter. A shelter must satisfy three primary criteria to be effective. First, it must provide for basic human needs, such as adequate ventilation. Second, because most host areas are likely to be exposed to radioactive fallout, the shelter must reduce the total radiation dose so as to keep it within the limits of human tolerance. Third, the building structure must currently be strong enough (or must be of such a design to allow for sufficient strengthening) to accommodate the additional structural loads imposed by the radiation shielding as well as those resulting from the blast-wave pressure effects. Only a few structures can meet all the above criteria without modification. Most buildings require some modification to make them usable as fallout shelters. This modification process is called "upgrading." The CRP surveys have so far identified 1.1 million buildings in host areas that could serve as fallout shelters. However, many of these buildings can serve as shelters only if they are upgraded or modified to incorporate additional shielding and ventilation.

Most of the identified buildings can provide for basic human needs. However, modifications in ventilating systems are usually necessary to keep reasonable comfort levels and also to provide the required amount of air for an increased number of people. The Appendix contains a detailed discussion of ventilation problems.

Protection against fallout radiation is provided by any kind of mass interposed between the fallout and the people being protected. While any kind of structure provides some protection, the majority of structures, even in host areas, do not provide sufficient protection. Buildings can provide protection against the radiation from fallout partly because of the mass of the walls and the roof and partly because those structural components keep the fallout some distance from the shelter occupants. The greater the distance between the occupants and the fallout, the greater the protection. In order to provide additional shielding against the radioactive fallout, additional mass must be provided. This can be accomplished by placing soil or sand overhead (on the floor or the roof of the structure) and along exterior walls. The protection provided by a building is expressed as a protection factor, the ratio of the exposure one would receive if completely unprotected to the exposure in the protected area.

When earth or sand is bermed around the walls and additional earth placed on the floor or the roof of the building, the structure is subjected to loads for which it was not designed. In addition, the structure may be subject to blast-wave overpressures of up to 2 psi, which would impose additional loads on the structure. To accommodate such additional loads, it is frequently necessary to increase the structural strength of the floor(s), roof, and walls. Whatever modifications may be necessary to provide the extra strength required can be determined by analyzing the structural capability of the original building; appropriate shoring and bracing can then be added to the structure to prevent a potential collapse. Once the floor and/or roof are shored and the wall(s) braced, the structure can safely be given an earth cover.

2.1.1 Upgrading of Buildings during Construction

2.1.1.1 Slanting for Dual Use

Establishment of shelters in the host areas *prior* to a crisis would eliminate many logistical and material problems associated with the upgrading of shelters *during* a crisis. However, this approach is only economical when the shelter structure primarily fulfills another function. The most appropriate time to make a building serviceable as a fallout shelter is during its design phase. The process of designing a building for secondary service as a shelter is called "slanting." Slanting is defined as an architectural design technique that incorporates additional shielding into a structure without adverse effect on the appearance, function, or cost of the structure. Slanting primarily consists of arranging building elements, careful positioning of doors and windows, special consideration of building materials, location of external decorative features, use of retaining walls, and grading of the site.[25-30]

For energy-conservation purposes, some new public, commercial, and industrial buildings are constructed underground; in other cases, the walls are partially buried or else bermed. If the structure is totally underground, only minor modifications during the design stage might be required to make it usable as a fallout shelter. If the structure is bermed, the height of the berm might be increased without major problems. In some instances, it may be possible to provide heavier concrete walls and/or floors and offset the cost by decreasing the reinforcement.[30]

When parking facilities are to be built, consideration should be given to placing them underground, where they could serve as excellent shelter areas. The possibly increased cost of underground construction may be justifiable from the standpoint of preserving valuable space above ground for other construction, or for open space.

Modification of existing buildings is inherently more difficult. However, even in this case there is an opportunity to promote berming for selected buildings — it can enhance the building's energy efficiency as well as upgrade it to shelter status.

This upgrading effort, both in terms of new construction and the modification of existing buildings, would not detract from the primary use of the building. Even where a building could not be totally modified to meet shelter criteria prior to a crisis -- e.g., the building walls might be bermed, but there might not be any dirt on the roof -- any improvement would make crisis upgrading much more feasible. This possibility is discussed in the next section.

2.1.1.2 Slanting for Future Upgrading

A concept not yet considered by FEMA is the idea of slanting for upgrading. In this concept, an evaluation of the building for upgradability would be made in the design stage. Areas of the building that could readily be strengthened for purposes of accepting earth loads would be identified. Instead of adding mass to the building to provide the equivalent of a preconstructed shelter, structural strength would be added to allow for subsequent easy upgrading. In wood-frame buildings, this might involve adding depth to beams, reducing the spacing between spanning members, or tying certain structural members together to add strength. Screws might be used in some walls and floors instead of nails. Such modifications could be accomplished at far less cost in many cases than normal slanting. Where concrete or block construction materials might have to be substituted in the building to get a PF of 40, substituting 2" x 6" for 2" x 4" members in some walls and 2" x 12" for 2" x 10" members in roofs and floors might allow ultimate, safe, earth-based upgrades to PF 40 in many wood-frame buildings.

Slanting for upgrading is justifiable not only on grounds of nuclear civil defense. It would also greatly improve building safety by enabling it to withstand possible tornadoes, hurricanes, and earthquakes. The general improvement of public and publicly used buildings on grounds of public safety has been the common justification for building codes. Since rural and small-town areas (host areas) are often deficient or lax in their use of building codes, a program to improve building strength in host areas could be generally beneficial.

2.1.2 Upgrading of Existing Buildings

2.1.2.1 The Problem of Materials and Equipment Availability

One of the most critically important elements in successful crisis relocation planning is the availability of materials and equipment for shelter upgrading during a crisis period. In most cases the construction resources and the shelter-development job site will not be collocated. Depending on the state of the economy just prior to a crisis, the amount of materials available in the manufacturer, wholesaler, and retailer stockpiles could vary substantially. There are really only two basic approaches to this problem. One is to assume that sufficient material (lumber, plywood, nails, hammers, saws, etc.) will be available from regular stockpiles, which may or may not be so. The other approach is to stockpile material and at least some basic equipment strictly for this purpose.

If the materials and equipment are not stockpiled for shelter upgrading, they may not be available at all when needed, or even if available, they may not be available locally. Since the need would be universal and the time available would be limited, distribution could pose a problem even if the materials and equipment are available.

To avoid these problems, materials and equipment should be stockpiled at the local level, specifically for shelter upgrading. This would make a known amount of materials available at a designated site and thus insure the availablility of at least basic supplies. However, several problems must be considered. Funds must be made available to procure the material for the stockpile. Facilities to store the material must be made available. Depending on material and local conditions, certain materials may deteriorate in prolonged storage (e.g., nails may rust so badly as to be unusable). Prolonged storage also increases the probability of pilferage. Providing very localized stockpiles virtually eliminates distribution problems, but increases storage and security problems.

2.1.2.2 Upgrading by Means of a New Concept: Modular Upgrading Systems

The modular upgrading system (MUS) has been developed in order to combine the best features of expedient shelters and upgraded buildings, while eliminating many of the drawbacks of each. Major advantages of expedient shelters include their ability to be built nearly anywhere using a wide range of different materials. They can also be built without the use of heavy equipment. Major drawbacks include their lack of basic amenities such as power ventilation, cooking equipment, and latrine facilities. Moreover, because of their small size, a great many individual expedient shelters would be needed to house large numbers of people. Since the number of trained radiological monitoring officers will be limited, an officer for each expedient shelter would be uneconomical.

Food supplies would actually have to be greater for expedient shelter occupants for two reasons. First, the assumption of fatalities would generally not allow reduction of food supplies as significantly for an expedient shelter as for a normal or upgraded shelter. If there were four people per expedient shelter and 10-15% expected fatalities, would 75% or 100% of the food allotment be made? In a normal size of shelter containing 100 or more persons, 90% of the food requirements could be distributed and a reserve maintained. Furthermore, there would be far less debate in a large shelter over allocation of food supplies before an attack. A second consideration is the ability to spread risk to food foragers over a large number of people. If the probability of finding large food supplies were 10% per half-hour trip outside the shelter, the larger shelter could send many more people out without unduly raising the risk taken by any single individual but with a greater assurance of finding food. Another drawback of expedient shelters is their sensitivity to weather. Most expedient shelters could not be built in frozen ground. In a rainstorm some underground expedient shelters could be subjected to flooding.

Upgrading has the advantage of being possible, in many cases, indoors. The walls and roofs of indoor upgrades, unlike those of expedient shelters, do not have to be built before earth can be added. Some buildings will have auxiliary power supplies and could thus maintain power ventilation and lighting even after an attack.

The present FEMA upgrading concept has the drawback of requiring analysis of the structural integrity of a building before upgrading can begin. As was noted in Sec. 1.2, the CRP survey provides no specific structural information that would allow planning for upgrading before the surge.[1] Buildings identified as upgradable in the CRP survey would either have to be resurveyed or would have to be examined by a qualified engineer during the surge period. Drawbacks to the present upgrading concept include the prior assumption of adequate structural strength, the present recognition of the need to add shoring to a building, and the need to get earth on the floors of the building. Also, because many upgrading situations require addition of earth to the outside of the building, frozen ground and rainstorms can prevent both the upgrading of buildings and the construction of expedient shelters.

The simplest upgrading case would be a basement upgrade. Here, earth could easily be wheeled into the first-floor level, dumped, and spread.

Shoring materials could be carried downstairs with ease. However, as Table 1.2 showed, basement upgrading represents a minority case. In NSS shelter spaces with an initial PF of less than 40, there will probably be an opportunity to upgrade basements in 20-40% of the upgrading situations on a national basis. For CRP-only upgrades, however, the share of upgradable basements falls to around 10%. Clearly, the majority of building upgrading cases will be for ground floors. A first-floor upgrade implies lifting earth 10 to 20 ft in the air (the CRP survey recognizes the problem and eliminates as shelter possibilities buildings with roofs more than 20 ft in the air). This raising of earth will have to be done by hand in nearly all cases. Even when mechanical equipment is available, it is doubtful that the equipment will be able to delicately deposit earth on the roof of wood-frame buildings. Instead, huge shovel loads would have to be dropped in piles on the roof and then spread out. The impact of such shovel loads would damage all but the strongest roofs.

The modular upgrading system concept can conceivably overcome nearly all major objections to expedient shelters and to traditional upgrades. The concept is to bring the expedient shelter inside and to guarantee structural integrity by means of previously developed standardized designs, which place no structural loads on the shell of the building to be upgraded. One of many possible manifestations of the concept is illustrated in Fig. 2.1.

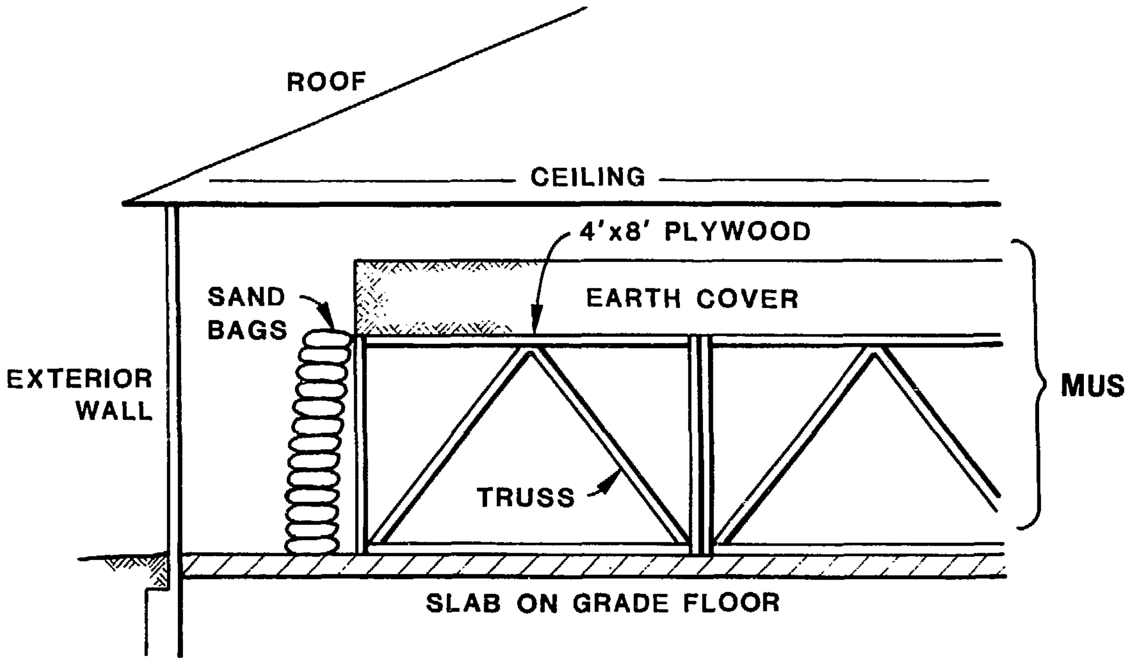


Fig. 2.1 An Example of the Modular Upgrading System

The basic idea is to create a lightweight, materials-conserving structure in order to get 1-3 ft of earth above the heads of those in being sheltered; the MUS structure is built entirely within another building. Since standard (minimum) ceiling height in a building is eight ft, this structure would have to be seven ft high or less to allow one ft of earth to be placed between the structure's "roof" and the building's ceiling. Another consideration is the height of a standard door — 6 ft 8 in.

The side "walls" of the modular upgrading system would actually be trusses capable of holding the desired overhead earth load. If these trusses were designed to support a roof made of standard 4' x 8' plywood sheets, then they would be eight ft long and seven ft or less in height. Actually, a height from 6-6.5 ft would probably be an ideal compromise between head room and overhead protection (earth thickness). Such a height would allow easy movement of prefabricated truss units through standard door openings in a building. By bringing the height of the overhead earth load down from 10 or 20 ft to 6 or 8 ft, the problem of providing overhead mass is greatly reduced. Earth can now be easily lifted into place by hand. It can be brought inside at ground level by wheelbarrow.

If the side-wall trusses of the modular upgrading system are designed to accept an earth load of hundreds of lb psi, then it stands to reason that they could also resist fairly substantial blast loads. The closer a shelter may be to a risk area, the higher the fallout radiation and blast will be. In such areas the modular upgrading system might be designed to accept as much as three ft of earth (even though head room is sacrificed). If this is the case, then some of the truss units could be used as shoring devices for walls and ceilings to provide strength against blast. Such a possibility is illustrated in Fig. 2.2. In fact, it is possible that the modular upgrading system could be "unitized" to act as a single large truss structure (like a bridge). The MUS could be built and anchored wall-to-wall within an upgraded building. This would protect against horizontal blast loads. If earth were packed between the MUS roof and the building ceiling, the ceiling could be protected against downward-acting blast loads. Wire anchors between the MUS and the ceiling could resist upward-acting blast loads. Such measures should generally be unnecessary, but they are possible for special circumstances.

What are the potential advantages of the MUS under "normal" upgrading situations? The 12 advantages are as follows.

1. <u>A greater variety of materials can be used than is possible for the conventional expedient shelter.</u> Because of weather protection, more alternative materials could be used to provide triangulation in trusses (diagonal members). Cardboard and/or gypsum wallboard over wire or a wood frame could be used for the roof of the MUS. Cardboard boxes loaded with books, newspapers, and magazines could be stacked around the MUS to provide mass

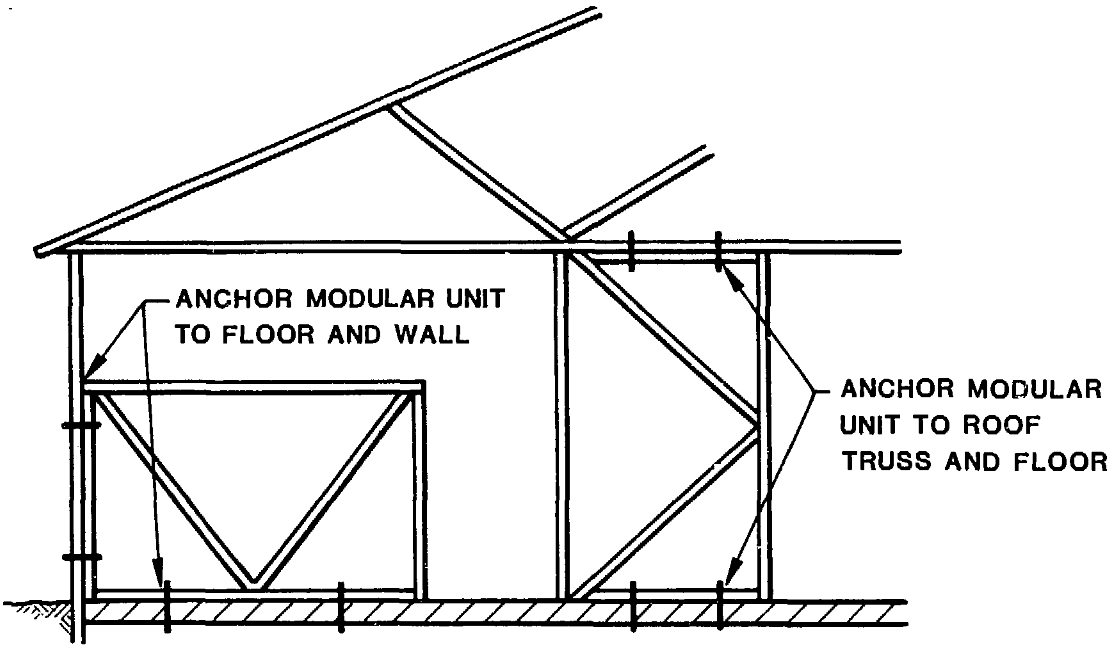


Fig. 2.2 Examples of the Use of Truss Units for Shoring Modular Upgrading Systems

to reduce radiation exposure from the horizontal plane. Bookshelves could similarly be used. Large quantities of these materials would often be on hand, and many of them would provide both physical protection and reading material. Earth would not have to be wrapped in waterproof material, as is the case in expedient shelters. The standard materials that *are* used in expedient shelters could also be used for the MUS. Tables and benches could be used instead of plywood for the MUS roof. If the MUS standard width were reduced to 6 ft 8 in., people could remove the doors from their homes and bring them to the shelter site for use as the MUS roof. Wire and wire mesh could be used for truss cross braces or as a part of a cable roof (as in the catenary wire roof expedient shelter); such a roof could support plastic, cardboard, gypsum board, newspapers, or any other material to prevent earth from filtering down through the wire mesh. Steel rods, bars, columns, and pipe could all be used in place of some wood truss members. Sandbags could be used on the roof or around the MUS. Brick and block could be stacked around the MUS to provide mass for protection against horizontally directed radiation. Brick stacks with steel rods or block stacks with 2 x 4's inside could substitute for solid wood columns in the trusses. Water storage and radiation protection could be provided by placing thin-walled plastic swimming pools on the roof, and filling them or filling trash cans with water and surrounding the MUS with these. Stacks of food could be used similarly.

2. Prefabrication would be possible. For the standard wood truss members, prefabrication before or during the surge would be possible. Prefabricated housing construction firms could rapidly build MUS truss units after being given templates and instructions by FEMA. Similarly, a central fabrication facility could be set up in host towns during the surge period. Centralized, standardized construction of the truss units could assure rapid completion and structural integrity.

3. Evacuees could very often remain in the same building after relocation. The MUS concept would allow upgrading of more congregate-care facilities and would reduce the need to direct relocatees to regroup and move to (or build) another shelter. Logistical problems would thus be reduced.

4. Less shoring would be required than for normal upgrading. By removing earth loads from the building, the MUS eliminates the combination of earth and blast loads on the building. Shoring is only necessary for blast loads. In many cases, the MUS would eliminate the need for shoring altogether.

5. Shelter construction could move ahead while shoring is being done. When shoring against blast loads is necessary, the MUS can be constructed at the same time shoring is being done. Since overhead placement of earth does not itself require shoring, construction of the MUS and the shoring process can proceed independently.

6. Buildings that might collapse because of normal upgrading could now be used. In areas where insignificant blast effects are expected, the MUS would enable some very weak buildings to serve as fallout shelters.

7. When multistoried buildings are upgraded, every story of the buildings can be used. Since the MUS does not require placement of earth on the floor, no story (not even the top one) is eliminated from use as shelter because it is covered with earth.

8. Standardization makes upgrading relatively easy.

9. By enhancing the concept of upgrading and allowing shoring for blast only, the MUS allows maximum use and protection of existing buildings. This should enhance post-attack recovery by keeping more buildings in working order after the blast.

10. When the ground is frozen, the MUS can still be completed. Because an MUS would most frequently be constructed in a building one story high, it is possible to remove the floor from the building to get at unfrozen or dry earth if necessary. Footings of buildings go below the frost line. In a heated building, therefore, an ample supply of unfrozen earth can be found under the floor.

11. If an attack occurs before the MUS is complete, the work on the shelter can still continue. While standard upgrading and expedient-shelter construction would be extremely hazardous with fallout on the ground, the MUS could still be constructed without contamination if all of the components of the system were in the building. If all components but earth were within the building, the floor could be removed and earth obtained as suggested above.

12. Because the MUS does not require earth on the roof, buildings with 20-ft ceilings can now be reclassified as upgradable. Gymnasiums, auditoriums, warehouses and the like can now be considered for upgrading. Many would prove to be very desirable shelters.

It should be stressed that the MUS is a concept. In fact, it should be thought of as a concept parallel to that of the expedient shelter. Generically, an MUS shelter can be constructed inside of buildings, but the option is best thought of as a versatile design that can be adapted to the particulars of a given location. Particulars such as building design, material availability, expected fallout levels, and expected blast overpressures need to be considered. A process of design development for several different situations would be necessary to reveal the option's full range of possibilities, as would test applications of the different designs. Given the advantages of the concept and the clear niche that it would fill in a national shelter program, it does seem obvious that refinement of the concept should be pursued.

2.2 PRE-ENGINEERED, RAPIDLY ERECTABLE COMMUNITY SHELTERS

The shelter shown in Fig. 2.3 consists of four modules, each 8' x 8' x 80'. A total of 256 people could be accommodated in this complex. The size of this shelter is ideal both from an economic and organizational point of view. It was shown earlier that larger expedient shelters are less costly per space than the smaller shelters. This shelter is about four times as large as the biggest previously developed expedient shelters. Its size allows the relatively economical addition of "amenities" such as a latrine, lighting, and power ventilation. As Sec. 3.1 points out, the sizes of 60 and 250 are logical organizational dividing points. This shelter takes advantage of both of those points since it consists of four 64-person modules. Moreover, this design concept could also take advantage of the organizational capabilities of even larger groups. It is envisioned as one of a "field" of shelters, all constructed in the same area. Shelters would be able to communicate with one another by CB radio, taking advantage of the very specialized skills available in a large group. Group services such as entertainment, religious services, medical assistance, and psychological counseling could all take place by CB radio.

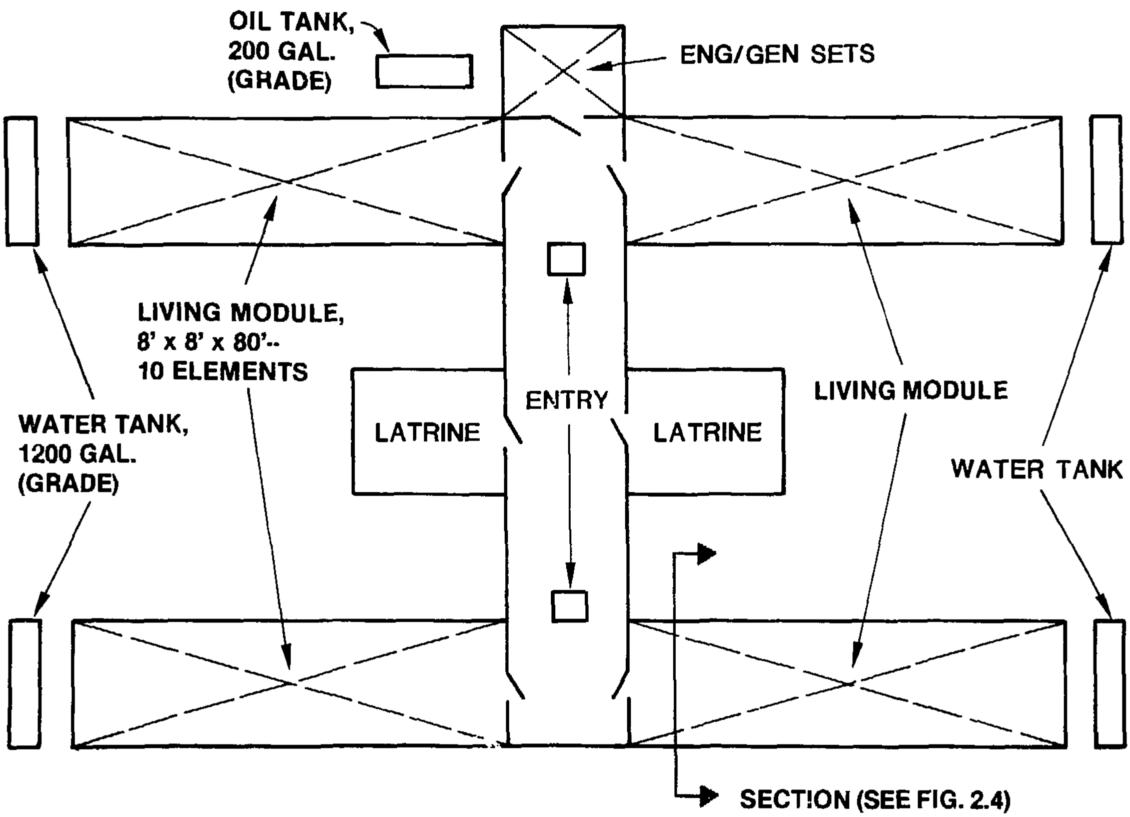


Fig. 2.3 Top View of a Modular Community Shelter (pre-engineered for rapid erection in an excavated area and burial with an earth cover)

Because this shelter is placed underground, it can be modified at little cost to serve as a blast shelter capable of sustaining pressures somewhat above 2.0 psi. It is a very good candidate for sheltering of families of key, highly skilled workers close to (or even within) risk areas. It might also prove desirable for areas with severe evacuation problems. In order to reduce evacuation traffic, shelters such as these might be considered for selected communities of the general population within or very near some of the largest risk areas. The modifications required for blast protection include:

1. Provision of blast doors for the entries,

2. Modification of the ventilation ductwork,

3. Burial of water tanks and an oil tank instead of putting them above grade, and

4. Provision of shielding for all electrical equipment, including portable and CB radios, against electromagnetic pulse effects.

The shelter modules are constructed of 8' x 8' x 8' elements. These would be fabricated at the site, while the trenches the modules will be located in are being excavated and, if necesssary, shored. Hydraulic boom mobile cranes, known as "cherry pickers," would be used to lower the elements into a trench, where they would be leveled and bolted together to form a module. Each element would be encased in polyethlyene film before it is placed in the trench.

The cross-corridor and latrines shown in Fig. 2.3 are constructed in a similar manner from modular elements, with certain modifications to the latrine facilities. The cross-corridor connects the living-area modules with each other, the latrines, and the engine/generator room. It also contains two entry/exit ways.

The modular elements are constructed of lumber and plywood (8' long x 8' deep). A typical cross-section is shown in Fig. 2.4 — 50 elements will be required. Four able-bodied adults should be able to construct four of these in a 16-hour day if the lumber and plywood is precut and enough tools are available. If we assume that about 20% of the shelter population consists of able-bodied adults, we would have 12 crews (four persons/crew) working on the four modules — all of which could thus be fabricated in as little as 18 hours. A more realistic figure is three days. This will allow for unforeseen problems.

The water tanks and fuel oil tank could be installed and piped by people with only a rudimentary knowledge of pipefitting. The water tank must be vented properly to avoid contaminating the water with fallout particles.

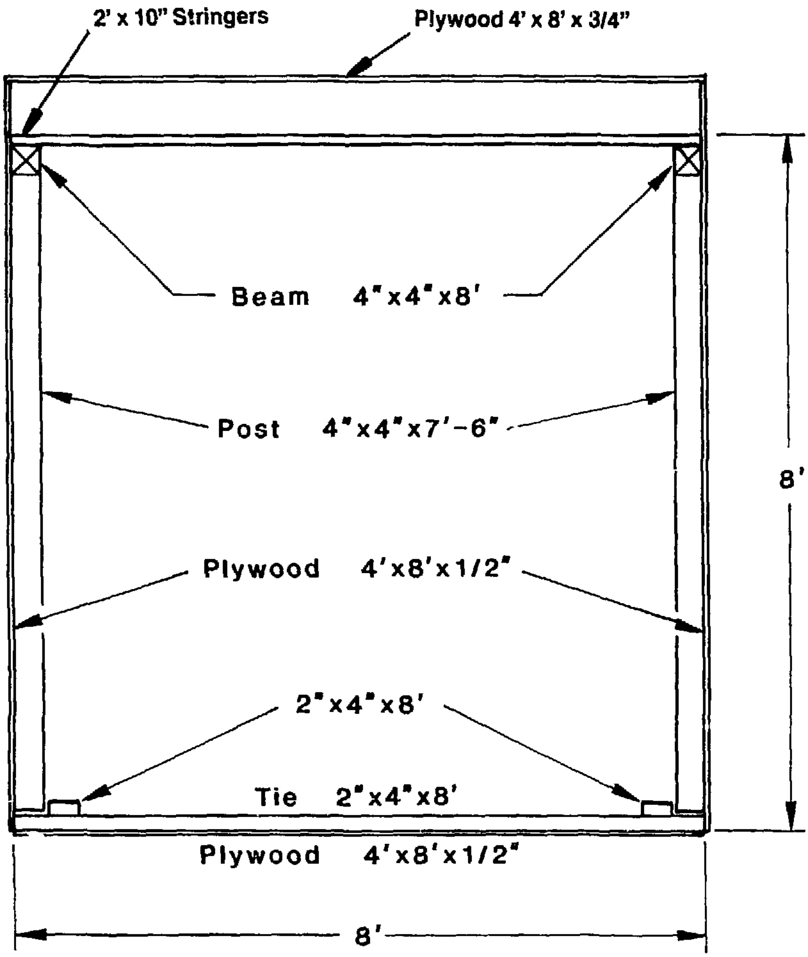


Fig. 2.4 Cross Section of Fre-Engineered, Rapidly Erectable Community Shelter

The engine/generator sets, blowers, and lighting should be installed and wired by electricians. If no electricians are available, this work can be done by anyone with a rudimentary knowledge of electrical work. A 12-volt electrical system was chosen to minimize danger. It also permits the use of emergency power from automobile batteries.

Two blowers, one sump pump, and one water tank are required for each module. Ten "courtesy" automobile lamps and two automobile headlamps (for emergency use) are also required for each module.

It is estimated that this complex could be installed, ready for use, within 7-10 days if all the material, construction equipment and tools, and personnel are available at the site.

2.3 EXPEDIENT FAMILY SHELTERS

For purposes of the cost comparisons made in Table 1.1, two simple shelter concepts were analyzed. The first of these is the construction of a small lean-to against a basement wall. This shelter would have less head room than is standard in an upgraded shelter space. It would have enough floor space for about four people. This concept is illustrated in Fig. 2.5. When earth is used as the cover for this shelter, the costs are fairly low. This is ANL Option #2 in Table 1.1. When purchased sandbags are used as the cover for this shelter, the costs are relatively high. Covered with sandbags, this is ANL Option #1 in Table 1.1.

A second simple shelter concept is the outdoor, family-sized, aboveground A-frame shelter. This shelter, illustrated in Fig. 2.6, is covered with earth on the roof and closed at both ends with sandbags. No positive ventilation or latrine is included. The design is very crude in comparison to those of several other FEMA expedient shelter concepts. It does, however, serve to provide a reasonable estimate of the costs of the cheapest possible outdoor family-sized expedient shelter. This shelter type is listed as ANL #3 (fully above ground) and #4 (semiburied) in Table 1.1.

2.4 BARN SHELTERS

When this study was proposed, the possibile of use of barns as shelters to make up for shelter deficits was suggested. It was expected at the time

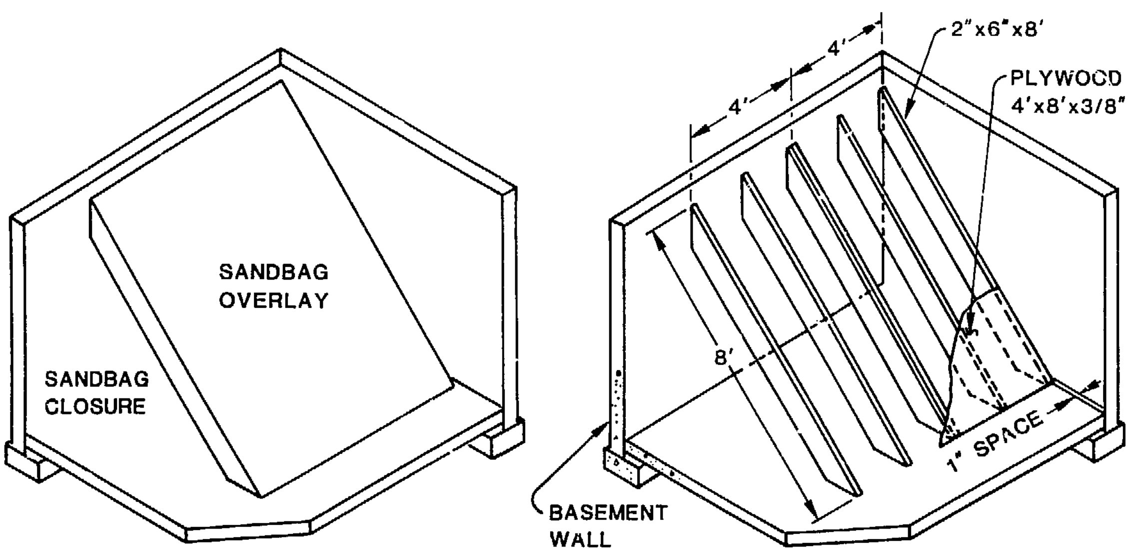


Fig. 2.5 Indoor Lean-to Shelter of Family Size for a Residential Basement (sandbag closure at the open side)

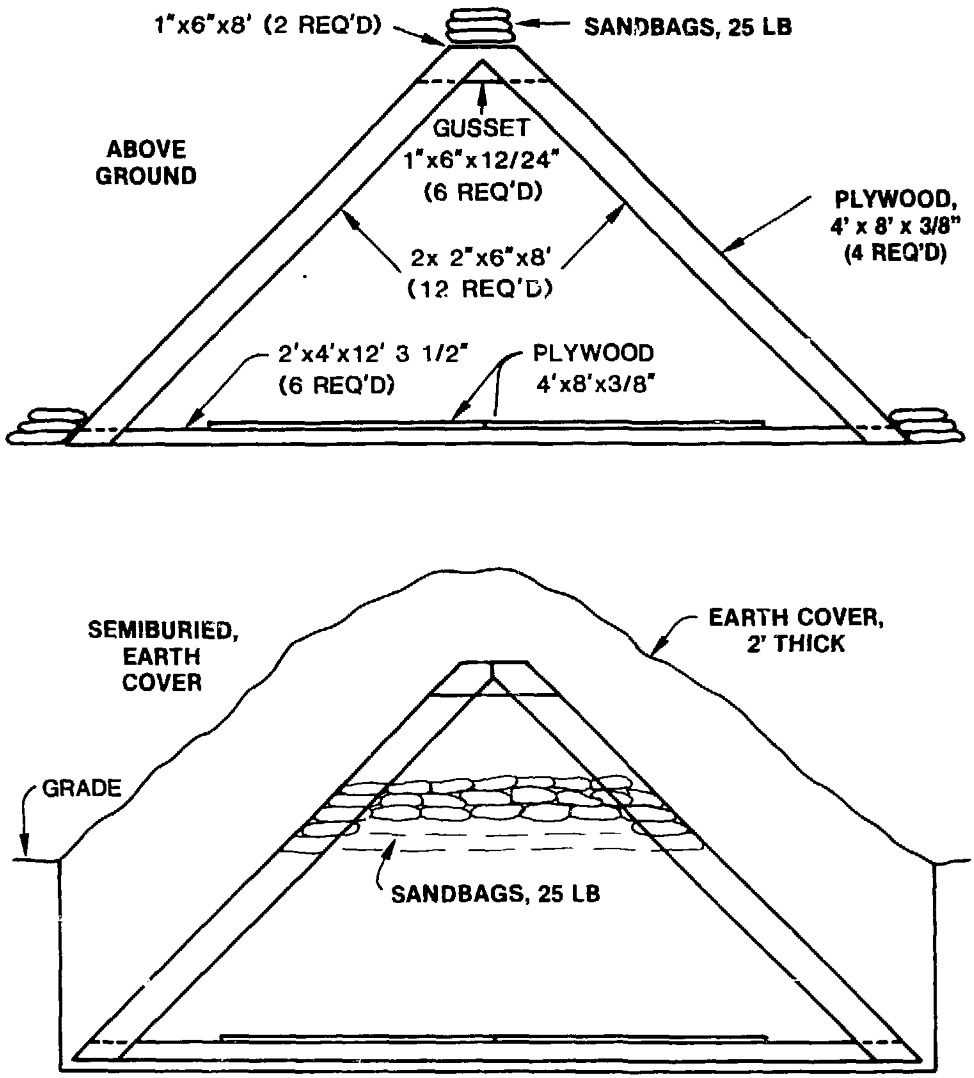


Fig. 2.6 Outdoor A-Frame Shelter of Family Size
(sandbag closure at both ends)

that upgradable barns might provide substantial amounts of space in geographical areas where shelter shortages could be expected to occur. While a significant number of barns was found in areas of upgradable shelter deficit in the northeastern U.S., as a general rule it was found that it would not be necessary to develop alternatives to upgrading such as barn shelters (see Sec. 1.5).

In spite of barn shelters being unnecessary in most states, there are several reasons to develop a barn-shelter program. The predominant reason would be to assure post-attack recovery of the farm sector. Because this is potentially so important, the virtues of barn shelters bear repeating here.

The literature we have reviewed (Refs. 2-4) suggests that farmers will be provided with relatively little training about farm operation in a high-radiation environment. More importantly, the literature suggests no substantive efforts to increase radiation training and post-attack manpower availability to farmers. Instructions to farmers do imply that they are expected to stay on the farm. If these characterizations of current farm operating procedures are correct, then the following scenario for the current civil defense CRP program seems reasonable:

> Farmers, without adequate radiological training and often with livestock-protection needs, take relatively high doses of radiation because of efforts to feed and water stock. Farmers, who are more elderly than the general population, then begin dying more rapdily than the sheltered population. A great deal of the farming-knowledge base is thus lost, severely affecting post-attack, long-term agricultural recovery.

When considered in this light, the current emphasis of the civil defense program on industrial recovery may need to be augmented somewhat to account for the continuity of agricultural production. Another key assumption in the "Candidate U.S. Civil Defense Programs" document (Ref. 2) is that there will be a reconfiguring of the "peacetime wholesale/retail food-distribution patterns to support evacuees in host areas." This supposedly will occur during a two-week surge period.

Farm buildings — e.g., barns — are apparently judged to be inadequate fallout shelters. Consequently, the possibility of relocating population directly to host-area farms has been downgraded relative to small towns in the host areas. However, considerable effort has been expended on the creation of "expedient fallout shelter" designs whose common characteristic is the use of digging and earth-mounding to create a protected area. All of these designs are very cramped in nature, allowing only for a few people. The possibilities of combining groups of people with desirable talents (e.g., mechanical, carpentry, health care, electronic communications, radiological, food preparation) in such small expedient shelters is minimal. Opportunities for training and the transfer of knowledge in an expedient-shelter environment would consequently be very limited.

Suppose, however, that the expedient shelter concept were applied for use *within* barns. Those barns with a dirt floor could be turned into expedient shelters for both livestock and people. Even in a post-attack situation, shelter upgrading could continue. As trenches were dug in the center of the barn, dirt could be piled next to the walls within the barn. Many barns have haylofts with very substantial structural strength. Hay is often piled several bales thick. Hay or other animal feeds could, therefore, provide substantial protection from "skyshine" radiation. Over the longer term, it would be possible to replace feed with dirt in the loft, given the strength of those lofts.

2.4.1 Major Advantages of Farm Shelters

- Food Supply

By placing segments of the relocated population in barns, the civil defense program would be taking people directly to food supplies. This would eliminate the complexity of the problem of reconfiguring wholesale/retail food-distribution patterns. Logistical problems would actually be reduced, since health supplies and some nonstaple foods (fruits, some vegetables) might be all that had to be delivered to the farm shelters.

- Rapid Building-Modification Possibilities

Barns would have the advantage of a rapid stocking capability because vehicles can be driven directly into the barn and unloaded. In fact, the building could be "modified" to include shower, stove, sleeping accommodations, heating capabilities, cold storage, and a chemical toilet simply by driving some well equipped recreational vehicles or trailers into the barn. During the surge period, the building could be easily upgraded by placing dirt around the outside walls, even including a vehicle-size entryway.

- Health Sufficiency

Some medical supplies might already be present on the farm, though intended for animals rather than humans. Nevertheless, we suspect that a study of medical supplies normally used on farms for animals would reveal some value of those supplies for use by humans, especially for emergency needs. Methods used to maintain adequate health and sanitary conditions for animals should, in many cases, be adequate for humans under crisis conditions.

- Sharing of Radiation Exposure

One of the primary reasons for placing people in barn shelters would be to allow long-term maintenance of a civil defense posture that would maintain agricultural production while presenting the enemy with few population concentrations to attack, making people-targeting highly undesirable in terms of kill-ratio per warhead. To this end, the expanded personnel of the farm could be used to share farm chores in such a way that individual radiation exposure levels would remain tolerable. The barn-shelter option, then, could prevent a collapse of agricultural production due to a high incidence of radiation sickness in the farm population.

- Psychological Advantages

If barn shelters were specified to have more square feet per occupant than normal building shelters, while also allowing for animal occupancy, they would actually be relatively livable. Animals (pets) have been found to give a psychological boost to elderly shut-in patients, a boost reflected in their enhanced physical well being. There is a good chance that this phenomenon would also exist for those sheltered in an animal barn (poultry barns are clearly excepted). Since one purpose of barn shelters would be to get manpower onto farms in order to share radiation exposure during farm operations, it would be necessary for most shelter residents to take part in the running of the farm. This would give a sense of control over one's destiny and participation in a group effort. By contrast, people in normal shelters would more often be completely dependent on the actions of others and would undoubtedly feel less secure, even though radiation exposure might be less.

- Upgrading as Needed

In a barn shelter as described, the possibility of upgrading after the attack could be used to advantage. If, because of unfortunate wind patterns, the radiation levels on a particular farm were unusually high, additional upgrading within the shelter would be possible by rearranging shielding materials or digging deeper. In a normal shelter this would not be possible without exiting the shelter.

- Dependable Utilities

Many farms, we suspect, have back-up sources of power supplementing power provided by the electric utility. Farms are also less likely to depend on grid-connected heating sources such as electricity or gas. Most frequently, they use oil and LPG as fuel. Disruption of natural gas fields or pipelines would be of less concern to farm shelter operators. Over the long haul, with very limited transportation, oil and other fuel stocks in rural supply depots should last far longer than at normal consumption rates. Gasoline and diesel fuel brought in the cars of evacuees would also be of potential use in farm equipment.

Water, being provided by wells in most cases, will not be shut off by failure of utility pipes or pumping stations. Also, a farmer will know where the pumping equipment for the water supply is located and have an idea how to maintain it. In an urban shelter, failure of the water supply might require the exposure of key workers, for an unknown period of time, to find and correct the problem.

- Available Earth-Moving Equipment

While farms generally do not have equipment such as bulldozers and front-end loaders, they do have equipment capable of loosening earth (plows) and moving earth (trucks). They are also located in a place where the earth is readily available in the immediate vicinity of the shelter.

2.4.2 Major Disadvantages of Farm Shelters

- Susceptibility to Fire

In addition to being susceptible to fire from nuclear blast effects, barns would also be far more susceptible to fire from careless use of matches by occupants than would conventional high-PF shelters.

- Remoteness from Medical Facilities

While farms may have food available, they will often be far from medical facilities. If trained personnel and supplies are not available, the risks of complications from inadequate treatment could be substantially greater than in urban areas with hospitals and doctors.

- Low Initial PF

Until the farm shelter is upgraded, it will have a very low PF. In the case where attack immediately follows evacuation, this works to the short-term disadvantage of shelter occupants. However, over the longer term, in cases of moderate to low initial fallout levels, the farm-shelter occupants could build their shelter up to quite a high PF -- and have a lower net dose than those in urban shelters that cannot be upgraded after occupancy.

2.5 GENERAL MANAGEMENT CONSIDERATIONS FOR SHELTER OPTIONS

During a pre-surge period, fallout shelters hardened for blast protection may actually be constructed using concrete and structural steel. These are not expedient shelters. By definition, an expedient shelter is one that can be constructed rapidly by relatively untrained people during a surge period. Expedient shelters will be fabricated from lumber, plywood, sandbags, polyethylene film, etc., and will contain a minimum quantity of prefabricated steel. The material to construct these expendient shelters, however, should be purchased and stored before the surge period.

Several steps should be taken to assure that expedient shelters can be constructed in a surge if required.[31,32] The steps are as follows:

1. Select the types of shelters that will be required in different geographical areas of the United States. Compile existing drawings and instructions appropriate for the geographical area in question.

2. Determine the number of shelters of each type that will be required and prepare complete bills of materials for supplies, tools, and ancillary equipment.

3. Select the sites, preferably on federal or state land, where these shelters will be located.

4. Inspect each selected site to determine if it is really suitable. Take soil borings or dig to design depth to test whether buried shelters can be used at all and, if so, what types can be used.

5. Determine whether or not the necessary construction equipment is available in the immediate area. If it is, consult with the owners and arrange to have this equipment at the site when required. If it is not available, include this equipment in the bill of materials.

6. Purchase the material required.

Storage of purchased material should be done in such a way that pilfering is minimized. National guard armories could provide excellent storage facilities. The material would be protected and members of the guard could operate the various items of mechanical equipment periodically to assure that they are in good condition. Also, the material could be transported to shelter sites on national guard trucks in a surge period.

A set of similar steps must be taken to assure that upgrading of buildings can be accomplished during a surge.

1. Select the methods of upgrading appropriate to construction types occurring in different geographical areas of the U.S. Compile loose-leaf handbooks from existing drawings and instructions. If certain upgrading components are to be rapidly manufactured, notify selected industries to begin manufacture. These steps should also be geographically specific.

2. Determine the approximate numbers of shelters of each type that will be required. Notify risk-area residents to be

ready to bring appropriate materials and equipment with them when they relocate.

3. After relocation to congregate-care facilities, select the buildings where upgrading is to occur. Develop an upgrading plan based on early completion of upgrades that are both relatively easy to accomplish and represent a very large number of spaces.

   a. Inspect buildings.

   b. Assemble skilled workers.

   c. Inventory available construction materials.

   d. Obtain construction equipment.

   e. Train manual workers.

   f. Develop an inspection and quality-control program.

   g. Start upgrading.

   h. Repeat steps a to g for progressively more difficult and scarce upgrading situations until upgrading adequate for all evacuees is underway. If adequate upgradable space is not available, develop expedient shelter plans.

   i. Assess support facilities for post-attack shelter period.

   j. Protect support facilities and supplies — i.e., power, food, water, medical supplies, emergency equipment.

3 ORGANIZATIONAL, SOCIAL-PSYCHOLOGICAL, AND ECONOMIC MANAGEMENT ISSUES RELEVANT TO SHELTER EVALUATION

The following discussion should be viewed as a preliminary identification of some of the important organizational, social-psychological, and economic management issues affecting the choice of shelter options for use with the crisis relocation program. A tremendous body of literature relevant to these issues exists. Only a small fraction of that literature has been reviewed up to now, due to time constraints. Obviously, not all of the literature would be useful in distinguishing between shelter options. Nevertheless, the point of diminishing returns in the literature review in this area has not yet been reached. Consequently, the reader should not perceive the issues discussed below as totally inclusive of all organizational, social-psychological, and economic management considerations relevant to evaluting shelter options.

3.1 ORGANIZATIONAL AND SOCIAL-PSYCHOLOGICAL ISSUES

3.1.1 Shelter Leadership

The principles of leadership and social organization (broadly defined), as they apply to human activity in fallout shelters, cover many tasks and functons. The more important of these may be grouped under four broad headings: decision making, including resource allocation; coordination of members' efforts; social control and conflict resolution; and the maintenance and monitoring of individual and group morale. A variety of decisions will need to be made and resources distributed. How are food, water, and space within the shelter to be allocated, given differing needs of individuals by age and health status? Are noisy chldren and/or ill shelterees to be spatially segregated, to the extent feasible, even if it means separation from their family units? Given a concern for contagious disease and/or a low tolerance for noise in dark and crowded shelters, pressures for such segregation could build within the group. How are such decisions to be made and implemented? By a predesignated shelter manager? By group discussion and consensus? Or by a more mixed process? These and similar issues illustrate what is included under the decision-making and resource-allocation function of shelter organization.

A second functional area consists of coordinating the movements and activities of the sheltered population. During the surge period, this may consist of organizing people to help in the upgrading or expedient-shelter construction efforts. In the post-surge period, this could entail such activities as feeding the shelterees, cleaning (to the extent possible) the shelter, operating manual ventilation systems, and perhaps caring for dependent shelterees. These and similar tasks would entail assignment of responsibilities to individual persons and subgroups, and at least some level of interpersonal or group coordination of efforts.

Since personal values, morals, preferences, and expectations of others vary somewhat according to social class, race/ethnicity, age, sex, and other background characteristics, we would expect differences along such dimensions to exist within any group of sheltered individuals. Given the close physical proximity and interdependence of individuals within a shelter, such differences can lead to interpersonal tensions and possibly open conflict, hostility, and physical aggression. Some persons, for example, may wish to exercise to the degree spatial constraints allow, even if that raises already uncomfortable shelter temperatures. Other shelterees may prefer to sacrifice physical fitness to lower temperatures. Resolving such conflicts, maintaining group discipline, and enforcing group norms will be a third function to be performed by the shelter organizations.

The final functional area is somewhat more vague, but nonetheless as important as the previous three: maintenance of individual and group morale. Living for up to two weeks in potentially cramped, spartan quarters with others who do not belong to one's immediate household will require considerable adjustment on the part of shelterees. One's usual, everyday routine of work, school, and leisure activities will be disrupted. The future of one's home, job, health, community, and friends will be open to question. With little to do during much of the post-surge period day but ponder such unknowns, the average individual may experience a decline in self-confidence and an increase in anxiety and despair. Such reactions will constitute a potential problem that will need to be alleviated, if not solved, by the shelter management and organization.

These four functional areas are causally interdependent, in that means used and success or failure experienced in one functional area affects the options available and the magnitude of the problems in other functional areas. Considerable social-psychological evidence exists, for example, that participation in group decision making heightens individual and group morale. Group or interpersonal conflict, which may be tied to coordination efforts or resource allocation, may lower morale, as well as complicate or hinder coordination and the decision-making processes. Thus, although each of the four shelter-management functions is conceptually distinct, they are closely interconnected in a group living context.

The following discussion will treat each shelter-management function separately in terms of how it affects the evaluation of shelter options. In so doing, we ignore the interaction of the functions, the compounding of effects that occurs when a problem develops in any one function. That is unfortunately necessary both for the sake of exposition and due to time constraints on the study. Additional literature review could provide the basis for future consideration of the interaction of shelter-management problems.

Shelter options will be evaluated along two distinct dimensions: shelter size, and shelter type. In each case, the evaluation will point out the relative advantage of a shelter option in terms of either exacerbating or lessening a problem or task facing the shelter organization, and/or affecting the organization's capabilities for accomplishing the task or solving the problem. Shelter options are first evaluated along the size dimension, and subsequently by shelter type.

3.1.2 Evaluation of Shelter Options by Shelter Size

Shelter options range in potental size from a low of 2-4 persons in a one-family shelter to 31,600 persons.[33] For our purposes, a four-fold division of this range is adequate: fewer than 10; 11-60; 61-250; and more than 250. This division, although somewhat arbitrary, roughly reflects threshold levels of group size as related to group cohesion and dynamics. In small groups (10 and fewer), persons can make frequent eye contact and in general be sensitive to the facial and other nonverbal expressions of most or all of the other group members at one time. Leaders of small groups can likewise become and stay attuned to individual needs, abilities, and other relevant characterisics of their followers. In this connection, it is not an accident that the number of athletes playing at the same time on one team rarely exceeds 10: effectively coordinating individual efforts on a team much beyond that size becomes too complicated a task for one person. Groups exceeding 10 members will frequently divide into subgroups for the accomplishment of specific purposes or tasks. Since the activities of such subgroups frequently need to be coordinated, the leaders form a leadership subgroup. Thus a group of 30 persons will frequently consist of four subgroups: three subgroups of 10 each and a fourth, leadership subgroup.

The formation of leadership subgroups is one of the first steps in creating a hierarchial bureaucracy. This will be referred to here as organizational layering, since the hierarchy of a bureaucracy is depicted on organizational charts as a series of levels, or layers. The leadership subgroup can frequently operate informally, without a formally designated leader, as long as it is significantly below 10 in number. When seven or more persons form a group, a formal leader is generally necessary. The action of choosing such a leader would generally occur after the total number of shelter occupants reaches 60; that number is chosen as the next shelter-size threshold. Up to 60, a well structured shelter will have two hierarchial layers, but after that point there would probably need to be three layers: the leader of the leadership subgroup; the leadership subgroup; and the basic-level subgroup. Assuming no organizational subgroup exceeds 10 members, one could expand the shelter-group size up to 600 without forming more than three organizational layers, if no other factors were involved.

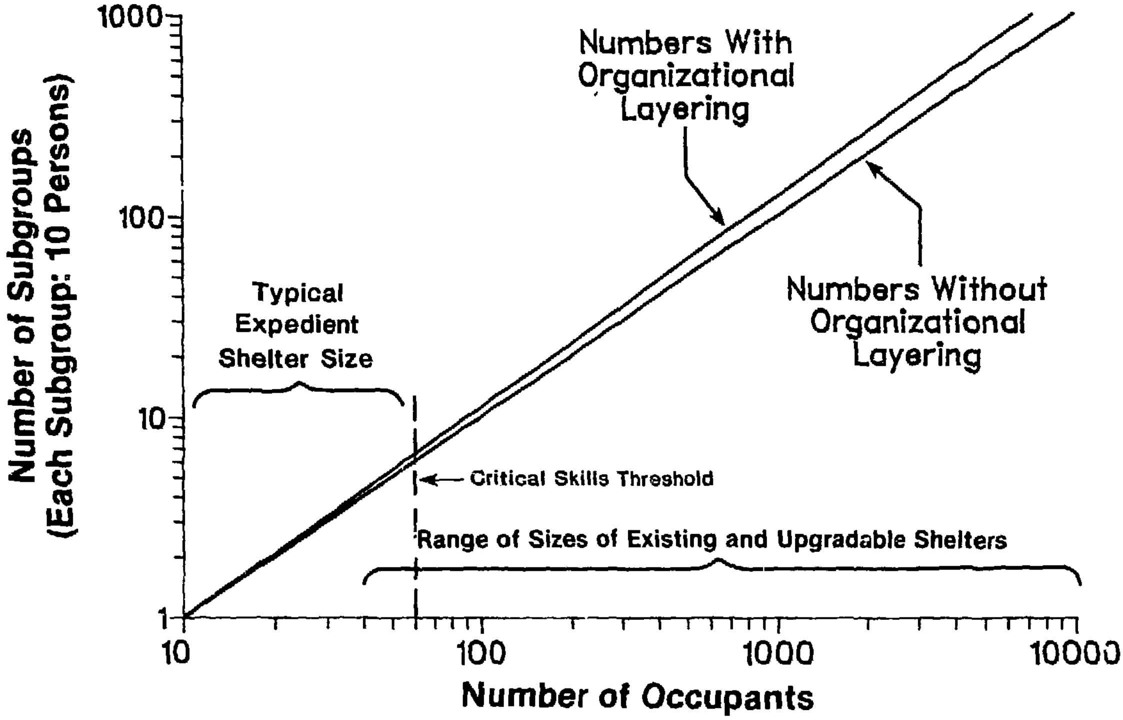
In fact, however, organizational complexity grows at a more rapid rate due to the creation of informal subgroups. As groups increase in total size, they typically become more heterogeneous unless filtering mechanisms are used to select new members. Heterogeneity increases the likelihood of the formation of homogeneous informal subgroups within the larger group. Informal groups in formal organizations not only parallel the organizational layering in terms of status distinctions; they also reflect such differences as age, sex, race, and class within the group. The communication function of an informal subgroup (the "grapevine") and its consequences to group morale are not to be underestimated. Creation of informal subgroups is not the only reason why growing organizations become more complex — other technical and external factors are also involved — but it is among the more important and relevant for the fallout shelter organization. As will be shown below, informal groups will have very significant consequences for morale and social control in fallout shelters.

The number 250 was chosen as the upper limit of the third division of shelter size because up to that point it is still feasible for the average shelteree to know the majority, if not all, of the other shelter occupants, possibly on a first-name basis. This is important for both the authority of a shelter manager and for the maintenance of group morale and cohesion. Beyond 250 persons, however, allegiance and identity are more likely to be attached to specific subgroups, unless other organizational mechanisms are used to avoid this.

Empirical studies have documented the group size-organizational complexity relationship in a number of cases. A 1970 study of organizational size and vertical and horizontal complexity in voluntary national occupational organizations found that "the larger the organization, the more vertically and horizontally complex it is and the greater the total size of its staff component."[34] This is not to say, however, that large organizations are necessarily top-heavy with administrators and therefore inefficient. On the contrary, the staff-to-member ratio decreases with increased size, suggesting an economy of scale in large-group administration. A similar study of western Canadian school systems found administrator-to-member ratios to be smaller in larger organizations.[35]

The relationship between group size and organizational complexity is graphically shown in Fig. 3.1, which also shows the greater importance of organizational layering in determining the total number of organizational subgroups as group size increases. This figure also indicates a "critical skills threshold" — the point at which the group reaches 60. The critical skills in question are those of the shelter manager or leader, whose tasks and responsibilities are immediately affected by increases in group size.

Increased group size and complexity directly exacerbates two of the four functional problem areas confronting the shelter leadership and organization: decision making, especially in terms of resource allocation; and the coordination of efforts. The effects on decision making are documented by a study[36] of communication patterns in crowds and other large groups. That study reads in part:



Relationship of Key Factors in Shelter Organization

Number of Subgroups	Total No. of Occupants	Layers of Leadership Needed
1,111	10,000	4
111	1,000	3
11	100	2
1	10	1

Fig. 3.1 General Relationship between Shelter Group Size and Organizational Complexity

As numbers increase and attention becomes commonly focused, conditions for exchanging information become more rigid. Once the number of observers exceeds a small group, it becomes impossible for all listeners and a speaker to maintain mutual eye contact. It thus becomes difficult to interrupt gracefully, and only those who feel strongly about a situation are likely to break into the conversation. Whether the discussion becomes a debate or a common affirmation, most persons who speak are likely to accept claims being made about *what is at issue*, that is, they accept the context, rather than an alternative. As numbers increase, other contexts that occur to some observers are not likely to be shared widely, because problems of seeing and hearing what is going on often keep observers from more than momentary conversations with their neighbors.

> When an unusual act draws many people to observe it, the sheer impact of numbers may work to simplify discussion of what has happened. As the number of listeners increases, people who speak out often change their style of language. They tend to use symbols or long-standing cliches that will be understood by a maximum number of persons persons present, and to avoid complicated details requiring a specialized background to follow. This simplifies the arguments presented, so that complex linkages of information are ignored.

As the size and complexity of the group increases, leadership groups frequently attempt to cope with their tasks by making broad, general decisions designed to cover a variety of situations. Such decisions, generally referred to as policy, cannot consider the peculiar circumstances of each case, and thus result in the relative nonresponsiveness of large bureaucratic organizations to the individual needs of specific people. Since policy is generally slow to change, this can also result in organizational inflexiblity. A 1972 shelter-management study[37] identified as a central concern the need for organizational flexibility within a shelter.

> Some type of pretrained existing shelter organization is necessary. The organization must be flexible enough to meet and react to changing goals and situations. Existing manuals on shelter organization will meet only part of the problem. Future organizational and training manuals will need to consider more of the changing dynamics of social behavior and management response. In order to meet the needs of shelter management, better communication equipment is necessary. If protective postures are to be accomplished, it will be necessary for the shelterees to understand the purpose of the actions they are to take. This can most effectively be accomplished in fairly small groups, e.g. 35 to 40 people.

What holds for decision making also is valid for resource allocation: a single large organization serving food to large numbers of people has much less flexibility in responding to each persons's particular tastes and preferences than would several small restaurants. Personal taste and preference may also have to be sacrificed in allocating tasks and responsibilities within a large shelter group; more personal, informal techniques can be implemented in smaller group settings.

Increased group size and organizational complexity also affect, both directly and indirectly, group morale and cohesion and the social-control/conflict-resolution problems facing shelter leaders. Unless occupant-selection techniques are used to create group homogeneity, large groups will generally be more heterogeneous than small groups. Increased heterogeneity in turn may threaten group cohesion and morale, its "we-ness." A shelter occupant may silently ask the question, what do I have in common with these strange, different people? This loss of group identity may both be heightened by, and in turn exacerbate, intra-group conflicts: the issues in conflict accent the within-group differences, and the within-group differences may make communication and conflict resolution difficult. Thus, in all four functional areas of organization, large shelters pose greater problems than do small shelters. This is shown in the top row of Table 3.1. The plus and minus ranking notation reflects the measurement limitations in this area; further literature review would be necessary to more accurately measure these relationships.

As also shown in Table 3.1, increased shelter group size exacerbates individual and group morale problems. There is, however, one area in which increased group size may have the opposite effect, actually lessening morale problems: the area of health and physical-safety reassurance. One might expect health complaints and anxiety to be a central concern in fallout shelters for a number of reasons, irrespective of the shelter size. The close physical contact between people, at least some of whom may be carrying contagious disease (colds, flu, etc.), may cause an increase in actual illness in the sheltered population. In addition, a certain percentage of most populations will evidence hypochondria to a greater or lesser degree. Cramped and relatively unpleasant shelter conditions are likely to increase instances of hypochondria, especially if health complaints produce preferential treatment by leaders or others in the shelter. Hypochondria will also be exacerbated by uncertainty concerning the levels and effects of radiation both outside and within the shelter. People who are pessimistic by nature will tend to give the worst interpretation to any symptoms, whether of physical or psychosomatic origin. The similarities between flu symptoms and the early symptoms of radiation sickness will also be a source of concern to such individuals, as well as to others not inclined toward hypochondria. For these and related reasons one may expect health to be a major concern of a significant minority of shelterees, irrespective of shelter size, even with no actual cases of radiation sickness. One or more actual cases of radiation sickness could turn this minority into a majority. The ensuing widespread feeling of anxiety could have devastating impacts on individual and group morale, since the hardships endured in shelter living would then appear to have been for naught.

Under the circumstances outlined above, large shelters would have a distinct advantage over their smaller counterparts. For it would be much more feasible to provide radiation-monitoring equipment to a (relatively) small number of large shelters than to a large number of small shelters. Likewise, the probablity of having at least one person with some medical training increases with group size. For these two reasons one would expect large shelters to be better able to manage health-related morale problems than their smaller counterparts. It is a statistical property of groups randomly

Table 3.1 Degree of Problem Variation[a] by Shelter Size

Potential Problems	Shelter Size: Under 10	11-60	61-250	250 or more
Group cohesion, complexity of decision making, and resource allocation -- intra-group conflict	+	0	-	-
Probable skills/capabilities within group to manage/ solve potential problems	0	+	+	+

[a]Key: + = Relative advantage for the social-psychological dynamics of the sheltered population.

- = Relative disadvantage for the social-psychological dynamics of the sheltered population.

0 = No advantage or disadvantage for the social-psychological dynamics of the sheltered population.

Table reflects the expert judgment of an ANL staff sociologist. Consideration of prior FEMA research is included.

selected from a population that a relatively scarce characteristic, such as medical skill, has a higher probability of appearing in a large sample than in a small one. For this reason we suggest that large shelters may be better suited to address medical-related morale problems than small shelters. The same principle holds, of course, for other relatively rare skills, such as decision making, group coordination and leadership, conflict resolution, and individual and group morale boosting. This is shown on the bottom row of Table 3.1: the three largest shelters are more likely than the smallest to have these necessary skills present among the shelterees.

Given the greater relative complexity of problems in a large shelter (shown in the top row of Table 3.1), it seems unlikely that all the skills one might find present in the population of a large shelter would still prove adequate for the situation. A 1972 study[38] concluded that "there is a strong evidence that a large percentage of volunteer managers would break down when subjected to severe stress." Given the greater level of stress-filled complexity, and difficulty associated with managing a large shelter group, organizational and social-psychological considerations would indicate that *volunteer* managers should only be used with small groups, and thus in small shelters. The British experience with population relocation in World War II showed the process to have been more complex and the problems to have been greater than originally foreseen.[39] Given this uncertainty, the prudent or conservative approach would be to use smaller shelters whenever possible. Not all organizational and social-psychological considerations favor smaller shelters, as was seen above in the cases of medical and radiological monitoring; but the majority do.

The above discussion reflects an assumption that households would be assigned to shelters on a more or less random basis. This assumption was made due to the limitations of this study: our task is to evaluate shelter options absent any consideration of the actual population-relocation procedures used to fill the shelters. In fact, however, such procedures will determine the composition, and thus heavily influence the organizational and social psychological characteristics, of the groups of shelterees. These procedures could be used, however, to reduce some of the organizational and social psychological problems mentioned above, especially for the case of large shelters.

Our society contains countless voluntary organizatons, which vary widely in size, function, and average intensity of membership participation. Most such organizations, whether economic units of production or distribution, or based on religious, occupational, community or other social ties between the members, have at least informal leadership structures. Often the structures are formal. Such structures, together with the general agreement about commonly held values and homogeneity found within such groups, could alleviate many of the problems noted above — in decision making, resource allocation, conflict resolution, social control and coordination, and individual and group morale. This is not to say that such problems would be completely eliminated. They would, however, be reduced due to the group's homogeneity and consensus about values. Homogeneity and consensus would be enhanced by the group's pre-existing leadership structure. A thorough evaluation of the uses of such pre-existing organizations is beyond the scope of this study. A few general comments on one such organizational type — the religious organization — are appropriate.

There are a number of potential advantages to sheltering people by common religious affiliation or church membership. First, the entire experience of being physically relocated, suffering the potential loss of one's home and other property in the risk areas, and related uncertainty about the future will constitute a high-stress personal crisis for most people. Religious leaders are generally trained and accustomed to counseling people during times of stress. Religious people are likewise familiar with both religious or spiritual interpretations of events affecting their fate, and with the idea of turning to clergy for guidance and solace in times of crisis. Since most local churches serve the population in their immediate proximity, neighborhood or community ties would also be likely to be evident among shelterees grouped by church membership, which could also strengthen group cohesion and morale. In addition, the increased social homogeneity found within a congregation, relative to that found in a random sample of the population, could decrease the potential for conflict and social-control problems. Finally, matching whenever possible the religious affiliations of the relocated shelterees with those of the host-area populations may diminish any feelings of resentment or mistrust between the two groups.

Public attitude surveys have shown that a majority (77%) of the American families asked to share their home and basements expressed willingness to do so. However, that general willingness has an important qualification: "If respondents were requested to share with more than one family, they tended to refuse to share at all."[40] The British experience with population relocation in World War II indicated that complaints about and tensions over the evacuees increased with time, especially where class or other social differences between the host and relocated populations were great.[41] Organizing relocation by religious affiliation could potentially reduce, although probably not completely eliminate, such problems.

There are limitations to using church membership or religious affiliation as an organizational base for sheltering families. Not all families have religious affiliations. Nonreligious households would have to be organized and sheltered on some other basis. Previous work has indicated a potential basis for cooperation between local officials and labor leaders.[42] Places of employment would likewise be important organizational bases for sheltering workers with critical skills in key industries, especially when they would need to commute between host and risk areas to maintain vital services. Finally, other organizational forms, such as neighborhoods, school districts, or professional or service organizations might prove advantageous as a basis for assigning people to shelters. Any of these procedures would complicate the relocation process, in that relocating groups is more difficult than moving individual households. The potential benefits of these procedures for reducing organizational and social-psychological problems in medium-size and large shelters should not be overlooked. In this sense, procedures applied to crisis relocation of populations are closely interdependent with the evaluation of shelter options by shelter size.

Sheltering households on the basis of some prior organizational affiliation is not the only way to manage the organizational and social-psychological problems that are likely to be found in large shelters. A thorough training of the managers of such shelters would be beneficial in any case, and would be absolutely essential if households are assigned to shelters randomly. Even with training, however, shelter managers may experience difficulty gaining legitimacy in the eyes of the shelterees, especially when significant social differences in backgound exist between the manager and the shelterees.

3.1.3 Evaluation of Shelter Options by Shelter Type

Organizational and social-psychological conditions are affected by the type of shelter both directly and indirectly. Two shelter types, upgraded and expedient shelters, are likely to require at least some participation and labor by shelterees during the surge period. Preconstructed shelters will require no such efforts or participation. This difference, including its implications for the four organizational and social-psychological problem areas, is shown in the top three rows of Table 3.2, including the surge period. As can be seen, the preconstructed shelter has either an advantagous effect or no effect on most of the problem areas listed. It does have a disadvantage in terms of managing the tension in a shelter; occupants of preconstructed shelters are placed in a passive situation in which they have no way of doing anything to affect their fate. This passivity will also be burdensome for those people (including the majority of pre-retirement adults) who played active roles in the society prior to crisis relocation. Meaningful constructive activity is an important means of tension release, confidence building, and maintenance of group morale, especially for previously active people with nothing to do. For these reasons, occupants of preconstucted shelters will be at a disadvantage in this problem area during the surge period. The one likely exception to this is older, retired, or otherwise incapacitated populations, for whom preconstructed shelters would be the preferred option.

Upgraded and expedient shelters also have their disadvantages during the surge period, as shown in the top half of Table 3.2. Even with instructions and guidance from shelter leaders and managers, the construction efforts of the shelterees will force them to make at least some decisions and allocate some resources (who does which task?), coordinate their efforts (earth or sandbags come *after* the nails!), and resolve their conflicts as a group or as subgroups. These efforts on top of the physical efforts exerted and the stress and uncertainty concerning the attack, will constitute a distinct disadvantage for expedient shelters during the surge period. These problems will be offset by the tension-release, confidence-building, and cohesion-producing consequences of working as a group to finish the shelter. Consequently, no disadvantage in the area of individual/group morale and cohesion is foreseen for upgraded or expedient shelters during the post-surge period.

A group's capacity to manage or solve different types of problems is dependent in part on its past experience; groups of people, like individuals, become more capable with practice. As a consequence, upgrades and expedient shelters have distinct advantages in the problem areas of decision making, conflict resolution and social control, and coordination of efforts during the post-surge period. Group participation in the shelter-construction effort during the surge period serves as a basis for easier and improved management and resolution of these types of problems in the post-surge period. This also results in improved group cohesion and morale during the post-surge period.

Table 3.2 Degree of Problem Variation[a] by Shelter Type

	Shelter Type		
Potential Problems	Preconstructed	Upgrade	Expedient
Decision making	+	-	-
Intra-group conflict resolution and group cohesion:			
Surge period	+	0	-
Post-surge period	0	+	+
Tension management	-	+	+

[a]Key: + = Relative advantage for the social/psychological dynamics of the sheltered population.

- = Relative disadvantage for the social/psychological dynamics of the sheltered population.

0 = No advantage or disadvantage for the social/psychological dynamics of the sheltered population.

Table reflects the expert judgment of an ANL staff sociologist. Consideration of prior FEMA research is included.

None of these advantages is experienced by individuals in the preconstructed shelter. To the disadvantage of their passive, dependent position is added their past history of lower morale and cohesion, producing the one minus in this lower half of Table 3.2.

3.1.4 Concluding Remarks on Organizational and Social-Psychological Aspects of Shelter Evaluation

This discussion has focused on two factors, group size and the presence or absence of coordinated group efforts, as they relate to the four problem areas confronting all occupants of group shelters. Other factors are also probably relevant, which could be established through additional literature review. Two sets of such factors are worth brief mention in closing.

Group homogeneity is likely to prove very important during group shelter occupancy, especially because comfort and personal-space levels are below those to which occupants are normally accustomed. Values, standards, preferences, differences relating to levels of noise, respect for the privacy of others and need for one's own privacy, and sensitivity to odors are likely to be especially important in this context. Other differences, especially those founded on interracial, inter-class, or other inter-group stereotypes and prejudices, will be important in anticipating the organizational and social psychological conditions and dynamics of sheltered population groups. The extent to which group heterogeneity/homogeneity is or should be a matter of concern for shelter managers is a topic worthy of further attention.

A second area is even more closely linked to shelter design: the type of ventilation system and level of ventilation provided for the sheltered population. At least three background or behavioral characteristics of the shelterees can affect the level of ventilation necessary. The age structure of the population is important in this respect, because older and younger individuals have less tolerance for temperature extremes than do others. The level and types of illness present in the sheltered population also affect the need for ventilation; nausea, diarrhea, and fever increase the value of ventilation for reducing odor and body temperature. Finally, physical exercise, which is of great value as a tension release, can increase the need for ventilation.

Ventilation choices are likely to affect the social-psychological and organizational conditions in the shelters in at least three ways. Heat, humidity, and "stuffiness" associated with lower levels of ventilation can exacerbate claustrophobia, tension, hypochondria, and interpersonal conflicts. A manually operated ventilation system could enable shelter occupants to obtain needed exercise and tension release, as well as giving them a needed sense of self-sufficiency and independence. Organization of the ventilation operating shifts and selection of operators (who gets the 1:00-1:30 a.m. shift?) can pose group decision problems. Satisfactory solution to such problems can heighten group cohesion and morale, by giving the sense that "we're all in this together and everyone is pulling a fair share of the weight."

The organizational and social-psychological factors related to group shelters are somewhat less concrete than the "brick and mortar" (or sandbag and plywood) aspects of shelter design and construction. They are at least as important, however. The emotional condition of people as they leave the shelters — whether demoralized, divided, and despairing or confident, cohesive, and mutually concerned — will be determined in large part by organizational and social-psychological factors. Humans are above all a social species. Fallout shelters will house not only individual people, but also social groups of people; such groups will either be pre-existing or newly formed during the surge and post-surge periods. The strength and nature of such groups and the social ties within them will greatly affect the success or failure of the crisis relocation and shelter program, if one measures success by the condition of the popuation in the post-surge period. For that reason, the kinds of issues discussed above should be important considerations in shelter evaluation and planning.

3.2 SURGE-PERIOD RESTRUCTURING OF THE ECONOMIC SYSTEM

Many economic problems would be experienced during the surge and post-crisis periods. The problems would occur in different degrees depending on which shelter options are used. Three problems that warrant special consideration are money and banking, food distribution, and skilled labor allocation. The following paragraphs discuss these problems and the effects on them of the various shelter options.

3.2.1 Money and Banking Considerations

In general, during a surge period the financial system would be disrupted. This disruption would cause a breakdown in normal economic activities. For example, a surge of large numbers of persons into rural host areas would create serious cash-flow problems. There are several reasons for this. First, problems result from the fact that banks operate on a fractional reserve system and thus have relatively little cash on hand at any given time. Second, rural areas are normally served by smaller banks. Thus the cash-on-hand problem is compounded. Third, demand deposits (checks) are the "bulk" of the money supply. Since rural areas normally have conservative banking communities, it is unlikely that checks will be accepted as a medium of exchange (money). Fourth, even if the banks were inclined to accept the checks, they would not be able to send them through the "clearing-house" process, which provides for the collection of checks. The clearing houses would be "in transit" because most of them are currently located in high-risk areas and would have to be moved to host areas so the financial system could be reconstructed in the post crisis period.

Banking problems would vary depending on the shelter option chosen. For example, during the upgrading period it is assumed that certain normal business activities will continue. These include buying of personal and incidental items, some food purchases, and other necessary transactions. It should be noted, however, that these activities would be carried on at a minimal level.

Cash-flow problems would be more severe under the expedient-shelter option, and its many small populations (family size to 60 persons), than under other options, because expedient shelters would constitute many more units needing cash. Also, smaller shelters will probably take longer to construct and require many more "necessity runs." A smaller total demand for cash would be the result under the shelter-upgrade options. Upgrades centralize the surge-period population more than expedient shelters. As a result, the working (supervised) population is larger and more involved in protection tasks. Economies of scale set in because fewer necesssity runs are required. Also, as the population becomes more centralized, the community spirit tends to create fewer personal needs and demands.

The modular upgrading option will create cash flow demands similar to the upgrade options because surge-period population can be similarly centralized. The pre-engineered (256-person) option can be highly centralized if the units are constructed and placed together as groups in fields. Essentially, more centralized groups lessen the surge-period money and banking problems.

All options are subject to the same problems in the post-crisis period. These problems center on reestablishing the financial system in the host areas. It appears that FEMA should more extensively consider in its crisis relocation planning the financial problems created during the surge period. Money and banking plans could be developed between FEMA, the Federal Reserve System, the U.S. comptroller of currency, and various other state and federal regulatory agencies. These plans could be factored into the shelter-option selection process.

3.2.2 Food-Distribution Considerations

Two considerations will be discussed relative to the shelter options: the size of a shelter population and what that implies in terms of food distribution, and the role of rationing. The expedient shelter (family size to 60 people) creates many more supply lines than any other option. Each shelter must be stocked, and only limited "aggregate" feeding can be achieved. As a result, more distribution vehicles, fuel, personnel, and increased communications are necessary under this option. Distribution problems become less of a problem as the population becomes more centralized under the other options. In fact, under the preconstructed-shelter option, there could be relatively few centers and thus few distribution problems. FEMA crisis relocation planning includes a system of rationing coupons and cash payments. This may cause some distribution problems. For example, the plans point out that cash can be paid in certain circumstances (new host-area arrivals, people without coupons, etc.) in lieu of the coupons. This situation would create a dual monetary system including "free" coupons and/or cash payments. The result is that the price system would completely break down and the food-distribution system would become a coupon system; those without coupons would nevertheless have to be fed under the system, a situation that could create havoc in the coupon system. This problem would be magnified in the expedient-shelter option because many more units would be demanding food, and the possibility for "missing coupons" would be increased. The problem would be lessened as the size and hardening of the shelter is increased (from upgrading to preconstructed).

3.2.3 Obtaining Adequately Trained Personnel

Consideration must be taken of the demands for certain types of workers under the various options. In general, demand for construction workers would be extensive during the surge period. Competing demands for these workers would include: industrial hardening, essential industry production, and shelter construction and/or upgrading in host areas. Area coordinators would be increasingly hard-pressed to designate and allocate workers in construction and other trades. Additionally, incentive programs must be devised to encourage 12-hour shifts and the commuting of workers who would be designated to continue to work in risk areas but who would reside in host areas. Other types of workers who should receive particular attention are energy and food-production personnel. These workers should not have their efforts diverted to upgrading or constructing shelters.

Many of the above concerns would vary with the shelter options. For example, small expedient shelters would require fewer skilled construction workers. Thus, these workers would be free for industrial hardening and other jobs, which would require their services in the risk area for 12-hour shifts. The families of skilled workers relocated to rural and small-town host areas would have to prepare their expedient shelters without the help of the most skilled family member for that task. The result may be that the worker would not return to the risk area after his first shift. This problem would be compounded by the previously mentioned money and banking problem. If the normal incentive system of higher pay for harder and longer work breaks down, the worker would have no incentive to return to the risk-area job.

Other options would create different types of competition for workers. The building upgrade, the pre-engineered community shelter, and the modular upgrading system would all require many skilled construction workers. As a result, these workers may be in short supply. The demands for heavy-duty-equipment operators would be especially high if both the upgrading and pre-engineered options are chosen, and the demands would conflict with each other. The community expedient shelter (pre-engineered) option, for example, would create a demand imbalance for heavy-equipment operators and other construction personnel as would the building-upgrade option. The modular upgrading system would reduce this problem. Normally, the market system brings these types of shortages into balance by increasing the wages of scarce personnel and allowing competition for these services. The winner (highest bidder) in this efficient market is assumed to have the greatest need. In a surge period, the pre-engineered and upgrade options would possibly create a shortage of personnel, and the price system would not be available. As a result, these options could create a great deal of pressure on the CRP coordinator. Civil strife could result from the inability of the CRP coordinator to meet the demands for these workers. The preconstructed shelter option would not create much competition for construction workers in a host area because this option does not require many essential construction workers during the surge period. It might therefore be a far more attractive option in the vicinity of key industrial areas.

4 INSTITUTIONAL MECHANISMS TO ENCOURAGE SHELTER PLANNING AND PLAN IMPLEMENTATION

Owners and operators of congregate-care and other shelter-designated facilities should be encouraged to plan and implement programs of upgrading and shelter construction. To the greatest extent possible, these facilities should have a dual-use capability. A dual-use fallout shelter is a shelter having a normal, routine use and occupancy as well as an emergency use as a fallout shelter.[30] There are several advantages to planning and implementing dual-use shelters. First, the number of surviving buildings is increased, and post-attack recovery improved. Second, a larger number of host-area residents (building owners/operators and others) would become involved in shelter-planning prior to a crisis than would be if the program were exclusively based on single-purpose shelters. Third, upgrading and implementation of shelters can easily be made part of a program to provide for other crisis situations. The added structural strength can provide protection against earthquakes, tornadoes, hurricanes, and blast. Back-up generators could provide energy security for natural and other disasters that cause energy system failure. Stored building materials can act as a reservoir for immediate emergency repairs in any disaster. Lastly, planning and implementation can enhance a community's social and emergency services through emphasis on dual-use shelters. The nonshelter use could be encouraged in nonemergency periods and thus increase a community's standard of living prior to a crisis. The emphasis on dual use of facilities may cause less resistence to shelter planning on the part of local agencies (e.g., Greensboro-Guilford County, North Carolina).[43]

Encouraging plans for upgrading buildings to shelter status would best be done by building managers after building-use patterns are established for existing buildings. However, upgrade incentives will be most effectively applied in the design stage of new buildings. Upgrading planning could be required as an alternative to slanting when slanting costs are more than 1-3%. Slanting and upgrading planning and implementation can be promoted by requirements written into public-program funding formulas (new and existing programs) and tax laws at the federal, state, and local levels. Lawmakers should be especially cognizant that the emphasis of these legal changes should be on relatively rural host areas.

A number of institutional considerations will help determine the effectiveness of efforts to encourage construction of dual-use buildings. First, the method of providing incentives can be expected to determine who bears the cost of such construction. Second, the ownership status of dual-use buildings will influence how and with what difficulty the federal government can implement plans to shelter the population. This section will survey some of these issues.

4.1 METHODS OF PROVIDING FEDERAL INCENTIVES

Subsidy and regulation are the two major approaches the federal government can use to directly encourage construction of dual-use buildings. Subsidy programs result, directly or indirectly, in a net flow of taxpayers' dollars to help pay the cost of a desired project. Typical federal subsidy programs take the form of grants-in-aid or tax deductions. Regulation is defined as any law or legally based ruling which, directly or indirectly, requires a person to accomplish a governmental objective, regardless of whether or not that person would choose that objective without government compulsion. Building codes are typical regulations.

The choice between subsidies and regulations to encourage construction of dual-use buldings could have important implications for successfully accomplishing the program. First, the use of regulation as an isolated method places the burden of paying for the added costs of strengthening buildings on the owners. This will provide an incentive to resist the law. Indeed, it may even be a violation of the Fifth Amendment to the U.S. Constitution to require private owners of existing buildings to retrofit their property without compensating them for their expenses. On the other hand, subsidization by itself cannot guarantee that builders who do not want their buildings to become shelters will build them to be shelter-capable; they can simply ignore the subsidy and build as they wish. Moreover, federal subsidy programs are notoriously inefficient because they frequently subsidize those who would take the desired action (in this case, making their buildings dual-purpose) without the subsidy. Thus, both regulations and subsidies have difficulties, and some mix of the two approaches could prove to be the optimal way of encouraging dual-purpose buildings.

4.1.1 Illustrations of Incorporating Incentive Opportunities in Existing Federal Programs

Many federal agencies already sponsor programs that, with slight modification, could be used to encourage planning for upgrading and/or construction of shelters. Those agencies include the Department of Agriculture (USDA), Department of Defense (DOD), Department of Energy (DOE), Department of Housing and Urban Development (HUD), and Department of Interior (DOI). The following paragraphs summarize some of the programs and modifications that could be instituted. This list is only a sample of the many programs that are likely candidates.

4.1.1.1 The Department of Agriculture

The Department of Agriculture represents a particularly attractive federal agency for encouraging shelter programs because of its basically rural orientation.

Farm Home Administration. The Farm Home Administration has a proposed 1983 budget of $210 million. Many of its programs can, with slight modification, encourage shelter awareness, planning, and construction. The FHA irrigation and drainage loan programs provide loans to organizations primarily composed of farmers, ranchers, certain Indian tribes, and other rural residents for projects that include the construction, improvement, or enlargement of facilities for drainage and the control of water generally. This includes loans for soil, water, and conservation districts to purchase heavy earth-moving equipment. Both water and earth-moving equipment are absolutely essential in rural host areas during the surge and crisis periods. Earth-moving equipment will be in especially short supply in host areas during surge periods because there will be multiple demands for this equipment (industrial hardening, expedient shelter construction, upgrading, etc.).

If the program were amended, FEMA could encourage building an inventory of the equipment in certain storage locations and also encourage more equipment purchases with dual-use capabilties. This program could in effect, with little extra expenditure, be used to create an inventory list and stockpile of heavy equipment needed during the surge period. The FHA also provides direct loans for farm homeownership, repair, rental, and farm labor housing. These programs could be modified slightly to require a plan for upgrading buildings or constructing expedient shelters, and they might also be used for disseminating upgrading handbooks for use in surge periods. More extensive modifications and dollars would be required to encourage slanting in farm structures.

Commodity Credit Corporation. The Commodity Credit Corporation (CCC) was created to stabilize, support, and protect farm income and prices; to help maintain balanced and adequate supplies of agricultural commodities, their products, foods, feeds, and fibers; and to help in their orderly distribution (15 U.S.C. 714-724p). The Reagan Administration has recently adopted a program to pay farmers who meet acreage limitations with "in-kind" grain from the CCC surplus. This grain can then be sold on the market and thus reduce the surplus and budget requirements of the CCC. This program could be slightly modified to require a plan for distibution of feeds to farmers for maintenance of their livestock during surge and post-surge periods. This plan could also require farmers to "think about" sheltering their livestock and dispersing the animals, in coordination with local officials, to feed the surge populations. The CCC covers many farm products, including peanuts, cotton, corn, wheat, and rice. Modification of the laws governing the CCC could provide an excellent source of planning information to FEMA at little or no cost to the government. Shelter-training incentives could be readily attached to the payment-in-kind program; by its nature, this program allows farmers to have extra time to devote to other pursuits.

Forestry Service. The Forestry Service conducts research and disseminates information through eight regional forest experimental stations and the Forest Products Laboratory. This information includes basic knowledge about, and improved technology in, the protection of resources from fire. Financial and technical assistance is provided to state forestry organizations for fire protection on nonfederal lands and for properly training and equipping crews for interstate and interagency action during fire emergencies. The crews would be very valuable in a surge period because they would be well trained in basic construction techniques (which are required for fire fighters); they would also have heavy equipment available to them and experience in rapidly deploying it to other areas. Modification of present laws to encourage the planning for use of these capabilities in a surge period would create little or no additional expense and provide a valuable inventory of expertise and equipment.

Rural Electrification Administration. The Rural Electrification Administration, under authority of the Rural Electrification Act of 1936, as amended, makes insured loans and guarantees loans made by other qualified lenders to rural electric and telephone borrowers for the purpose of extending and improving electric and telephone service in rural areas. Riders could easily be attached to these loans requiring borrowers to slant their facilities or plan upgrades in their existing and future construction. Additionally, they could be encouraged to bury their lines, which would serve the dual purpose of providing better service in bad weather and hardening the electrical distribution network for surge and post-surge periods.

Other USDA Programs. Many other Department of Agriculture programs can be used to help improve the shelter capabilities in rural areas. These include, but are not limited to, the agricultural research service, cooperative state research service, and rural clean water programs.

4.1.1.2 The Possibility of a Federal Building Code to Promote Shelters

A similarly bewildering array of regulatory devices could be used by the federal government to require construction of dual-use buildings. The most important choice in designing such a regulatory program is in determining how great a role state governments would play in enforcement. A range of options is available, from a single set of national standards enforced by FEMA or HUD, to a relatively loose requirement for states and local governments to amend their own building codes to mandate dual-use construction methods.

The experience of the Department of Energy (DOE) in proposng federal Building Energy Performance Standards (BEPS) is relevant to evaluating potential obstacles to such regulation. In 1979, DOE proposed regulations pursuant to the Energy Conservation Standards for the New Buildings Act of 1976 to require future new buildings to be built to meet energy-conservation standards. Enforcement was to be through state building codes, with the threat of a cutoff of certain federal grants-in-aid to states failing to enforce the BEPS acting as an incentive to induce state compliance. Since the BEPS are the most recent major federal attempt at regulating building construction, the methods chosen to implement them may provide a useful precedent for any FEMA effort to enact federal dual-use construction requirements.

At the same time, it must be recognized that the BEPS ultimately failed. After the DOE initially proposed them, public response — especially by builders — was so negative that the standards never were implemented. While it is true that a federal dual-use construction requirement might be less costly than maximizing energy efficiency, the historic local nature of the building industry and building codes could be a tremendous obstacle to a national standard. However, the national security implication of a better civil defense capability might overcome this problem.

4.1.1.3 Other Federal Agencies and Programs

Presently, the laws and regulations governing the Department of Defense do require that shelter modifications be made in all defense construction, but there are significant escape clauses that can be employed. The extent of usage of these escape clauses should be evaluated. The inventory of equipment on hand at military bases, Military Reserve locations, and other defense establishments will be very valuable in the construction of expedient shelters and the upgrading of existing facilities. Also, coordination of these resources and training of military personnel in applying them to the upgrading and construction of expedient shelters should take place. At the very least, distribution of the proposed "upgrading handbook" should be planned. Many other DOD activities should be evaluated for shelter planning and construction activities.

The Department of Housing and Urban Development programs are generally aimed at low-rent public housing and community-development grants. With modification, these programs could provide for public housing shelter planning in the host areas that do receive these grants. Many public housing units are of structural types that will accept significant upgrading. With some modification of the laws and regulations governing these grants, shelter planning and construction could be facilitated.

The Department of Interior has facilities in many rural host areas. Additional construction by DOI could include upgrading plans for slanting construction of these facilities. The mine-inspection programs of the DOI Bureau of Mines could be used to collect data on shelter-capable mines and inventory shelter construction equipment at those mines located in host areas.

The Department of Energy programs for local energy independence have encouraged the use of solar energy and alcohol fuels. These programs could provide very useful energy-resource planning for shelters at little cost to the government. DOE's fossil-energy programs could also be encouraged to provide mine information. Many other programs dealing with small engines, alternative engines, and other power sources could also be helpful to shelter back-up power planning and/or independent power system installation. Further research would probably show that several other agencies and programs are also excellent candidates for encouragement of various aspects of a CRP shelter program.

4.1.1.4 Incentives through Federal Programs — A Short Note

Most of the above mentioned programs will indirectly affect state and local laws and programs. Other state and local programs could be aided directly through new federal incentive programs. For example, many northern rural areas have inadequate snow-removal capabilities. These capabilities could be enhanced through programs designed for heavy-equipment purchases. This equipment would have the dual use of snow removal and providing an inventory of heavy equipment available for upgrading buildings and construction of expedient shelters. This equipment could be local or state owned. In an organizational sense, the Radiological Emergency Planning arm of FEMA already provides for exercises to evacuate populations during hypothetical accidents at nuclear electric plants. These exercises include coordinating the efforts of state officials, local officials, and private industry representatives. Many of these exercises are held in semipopulated areas, and the populace is "moved" to rural host areas. These exercises could be expanded to provide for "hypothetical" movement of key-worker personnel and equipment, at additional cost to the government. Many other opportunities for state and local involvement in shelter planning and construction exist.

4.1.2 Creation of Incentives through Rewriting of Federal Tax Laws

Federal and state tax laws could be modified with incentive clauses that apply to planning upgraded shelters or constructing new ones. Changing the laws could involve private enterprise in the process of shelter planning or, at the very least, encourage consideration of shelter options and plans in the free market. The Tax Equity and Fiscal Responsibility Act of 1982 and the Economic Recovery Tax Act of 1981 provide many examples for these modifications. The following paragraphs show a few examples.

4.1.2.1 Public Utility Dividends and the 1981 Act

The Economic Recovery Tax Act of 1981 allows participants in qualified public utility dividend-reinvestment plans to elect to exclude from their income, for federal income tax purposes, up to $750 per year ($1500 for a joint return) of dividends reinvested under the plan. Reinvested dividends will qualify for this exclusion only if the person elects on his federal income tax return to have this benefit apply to such dividends. Shares purchased with qualified reinvested dividends have a zero-cost basis for federal income tax purposes. These shares are not taxed until they are sold or disposed of in some other manner. Gains realized on these shares held for one year or longer will be taxed as long-term capital gains. In 1982, proposed legislation was defeated that would have repealed the tax deferral of dividends reinvested in a qualified dividend reinvestment plan, as permitted under the 1981 Act. Many of the utilities qualifying for this plan have heavily invested in generating stations located in rural areas. Modifications to the act could encourage slanting and/or planning for expedient shelter in these plants. Many of these plants are nuclear-powered plants that already meet strict "hardening" standards; requiring the utility to plan for shelters would not add to the expense of the plants. With these amendments to the 1981 Tax Act, the utility industry could become an active supporter of the shelter program and gain an ally in the fight to continue this provision. Additionally, this act could be modified to require planning for electricity generation and distribution in surge and post-surge periods. It would appear that a national partnership between the FEMA shelter program and public utilities can be forged, using the 1981 Economic Recovery Tax Act as the basis for that partnership.

4.1.2.2 Depreciation Clauses of 1982 Act

The Tax Equity and Fiscal Responsibility Act of 1982 could, with some modification, provide an excellent vehicle for encouraging shelter planning and construction in host areas. This act changes many of the rules that apply to cost-recovery depreciation, allowing an acceleration of that process. Changes in this law to cover real property used for civil defense could significantly encourage private owners of property to construct hardened dual-purpose facilities. Projects that were marginal in the past could now become feasible.

4.1.2.3 Capitalizing-Interest Clause of 1982 Act

Individuals, Sub-chapter S corporations, and personal holding companies are required to capitalize interest and property taxes attributable to the construction period of realty (other than low-income housing) to be used in business or held for investment. The capitalized amounts are amortized generally over 10 years. The 1982 law applies a similar rule to the construction of nonresidential real property by regular corporations. The 1982 Act could easily be modified to require real property owners to submit an upgrading plan for the property in the event of a crisis. Other, more costly changes in the act could encourage shelter construction or design in the property.

4.1.2.4 Target Jobs in 1982 Act

The 1982 Act extends the targeted jobs-credit provisions of previous legislation. The jobs-credit provision provides a special tax credit to employers hiring employees from certain targeted groups. The 1982 Act extended coverage to wages paid to individuals who begin work for the employer on or before December 3, 1984 — the previous cutoff date was December 31, 1982. In addition to extending the credit, the new law makes additional changes in the credit setup relating to summer employees and the general definition of the assistance program. The intent of these provisions is to provide jobs for economically disadvantaged sections of society. Slight expansion of the definitions and work roles of "targeted" employers could significantly encourage companies located in rural host areas to designate key workers and set up shelter plans with targeted workers.

4.1.2.5 Other Observations

A wide variety of excise, corporation, and personal-income tax laws could also have riders attached to them to encourage shelter planning and construction. In many cases, this would be at no additional cost to the government, although it would obviously place an added burden on the taxpayer. An important point to remember is that such legislation must apply primarily to host areas. It therefore would not affect a very large portion of the economy. To the extent that host-area residents are more supportive of civil defense, legislation affecting only them might be far easier to pass.

4.2 STATUS OF BUILDING OWNERSHIP — FEDERAL VERSUS STATE RIGHTS AND RESPONSIBILITIES

An important institutional question that may affect the success of programs designed to encourage construction of dual-use buildings is the ownership of those buildings. While no serious obstacles exist to upgrading federally owned buildings, some problems may be encountered in requiring state and local governments to upgrade their property, and serious difficulties may be encountered with privately owned structures. Moreover, the use of private buildings as shelters will create many additional institutional problems that must be addressed.

4.2.1 Public Buildings

The key to understanding the difficulty of implementing a federal law requiring upgrading or slanting is understanding the basis of our federal system. States (and, by implication, localities) are sovereign units of government with certain immunities to action by the federal government. While the federal government regulates many activities traditionally undertaken by states, there are restrictions on how much the federal government can require state governments to do on behalf of the federal government. Although the answer is by no means clear, it is possible that a federal law instructing states how to build or renovate state-owned buildings to improve their sheltering capabilty would be unconstitutional. A more definitive answer requires additional research.

Of course, no such problems exist with respect to federally owned buildings. The federal government can build its buildings with any sheltering capability it wants. In general, existing laws reflect these patterns. Federal laws and regulations affect federal buildings. Only a few states have laws, and these laws primarily affect public buildings.[22-24]

4.2.2 Private Buildings

As great as the difficulties may be in requiring state and local governments to construct dual-use buildings, similar problems bearing on privately owned buildings probably are greater. The government (federal or state) cannot go beyond a particular, undefined point in requiring building modifications without risking the possibility that a court would hold that its actions contravene the Fifth Amendment to the U.S. Constitution. The Fifth Amendment requires the government to compensate any person whose property is taken for a public use; a court finding that private property has been taken results in an award of money damages to the private owner. Without further research, it is impossible to speculate convincingly about whether a building code requiring dual-use capability in either new or existing privately owned structures would be held to be a public-use taking, but the question bears further investigation. If such a ruling were made, it would mean that the *only* way to implement a broad shelter program in private buildings would be through the use of subsidies.

4.2.3 Related Legal Issues

Restrictions may exist on the ability of the government to place people in a private building during a crisis. As with requirements for constructing or renovating buildings in a certain way, the performance by a private citizen of an essentially public service (sheltering) could be interpreted as being a use of private property by the government and, therefore, something entitling the building owner to compensation. Since the ability to provide compensation during a crisis may be questionable, owners may resist designation of their buildings as shelters or may demand payment in advance. Moreover, private owners in some circumstances may be constitutionally entitled to simply refuse to permit their property to be used for shelters, even if they are compensated. Starting in 1965 with the case of *Griswold v. Connecticut*, the U.S. Supreme Court has ruled that a right to privacy exists that simply excludes the government from entering certain private property. The most obvious kind of building that might be covered by the risk to privacy would be the private home, but further reseach is necessary to determine how far the right of privacy might reach in a nuclear-war situation. It seems apparent that this problem should be addressed before a crisis occurs. A prior resolution of legal problems (very rare in normal legal procedures) would greatly enhance the implementability of a shelter program.

4.3 PROMOTION OF SHELTER CONSTRUCTION AND UPGRADING THROUGH STATES AND LOCALITIES

Many states have laws that support shelter construction, but only three require consideration of the construction of shelters in public buildings. Arizona legislation[22] and Rhode Island legislation[23,24] provide for shelters to be built in all public buildings, with certain reservations. The reservations include: if the shelter increases the cost of building by more than 3% (Arizona), or 3-1/2% (Rhode Island); if the shelter impairs the purpose or effectiveness of the building (Arizona); and if it is impractical to build the shelter (both states). Alabama legislation[44] provides for shelters being built in all public buildings costing more than $50,000; it also includes cost and impracticality reservations. Without additional analysis, it is not possible to determine if these statutes can serve as models for new state laws that would encourage shelter construction under the preconstructed options. At present, state statutes do not consider planning for upgrading or constructing expedient shelters in lieu of slanting. Almost any state law governing the construction of buildings or state and local building codes could provide for planning for upgrade and/or expedient shelter construction in new and renovated buildings located in host areas. This could be done at little or no cost to the government.

Another avenue for encouraging shelter construction, upgrade, and/or planning could be the modification of property taxes at the state and local levels. A property-tax exemption could be granted to those who provide for shelter space and/or upgrading plans in host areas. To entice state and local governments to pass this type of legislation, the federal government might have to guarantee the revenue loss of the community.

5 SUMMARY AND CONCLUSIONS

5.1 SUMMARY

This study has examined the adequacy of existing FEMA approaches in providing congregate-care and fallout-shelter protection under a program of crisis relocation. In this program, much of the U.S. population would be evacuated from urban high-risk areas to rural and small-town host areas. It has been found that the current FEMA approach can theoretically provide shelter for 80-95% of the total U.S. population based on 80% evacuation from urban high-risk areas. Difficulties with the current approach have been found to be confined to certain geographical areas of the U.S. Four new shelter options have been examined for use as possible remedies to shelter shortages in certain areas of the country: (1) a boat option, in which people use existing pleasure and other craft to move away from risk areas; (2) barn shelters, in which people relocate to farms with sturdy, fully enclosed barns with lofts and build shelter space within the barn and/or upgrade the barn itself; (3) the modular upgrading system (MUS), in which an expedient shelter is constructed inside an existing building, eliminating any need to get earth onto the roof of that building; and (4) a buried H-shaped community shelter housing 256 people and including latrine facilities and separate power supplies (protected from electromagnetic pulse effects) for ventilation and minimal lighting. Each of these shelters is found to have unique advantages that would prove desirable in specific sitations. None is superior to the others in all situations, and each can usefully complement upgrading in certain locations.

We have estimated the number of shelter spaces that would be provided by existing and new methods. Compared to total national space needs, the major options could contribute the following maximum percentages:

Boats	9%
Barns	19%
Nonresidential basement upgrades	22%
Host-area homes for host-area residents	30%
Existing NSS shelters with a PF of 40+	33%
Above-ground nonresidential upgrades	90-100%
Outdoor expedient shelters	100%

In terms of cost, as shown in Table 5.1, we found that existing underground spaces (in mines and basements) constitute the least expensive form of shelter. However, as shown above, there are not enough such spaces to satisfy national needs. The upgrading of existing above-ground buildings to shelter status was also found to be relatively inexpensive. Properly constructed above-ground upgrades using presently developed FEMA methods — when combined with existing NSS spaces, mines, and basements — were found to meet the needs

Table 5.1 A Summary of the Characteristics of Shelter Options Receiving Detailed Analysis in This Study

Option	Economy Rank	Cost ($/Space)	Latrine Facility	Positive Ventilation	Largest % of U.S. Need Each Option Can Meet	Size of Shelter	Survival Probability
UNDERGROUND							
Mine	1	0.05	Not in cost	Independent power system	5	Group to community	Excellent
Indoor nonresidential basement, full upgrade	2	0.8	In building	Manual	22	Group to community	Good
Indoor residential basement, lean-to (earth cover)	3	1.5	In house	None	30[a]	Family (4 persons)	Good
Buried pole expedient	7	3.5	Not included	Manual	100[b]	Family	Good
Indoor residential basement, lean-to (sandbag cover)	8	3.6	In house	None	30	Family	Good
Buried house trailer	9	5.1	In trailer; no sewer	Possible	100	Group	Good
Buried H-shaped shelter, preconstructed expedient	10	8.5	In shelter	Independent power system	100	Community (256 persons)	Excellent
ABOVE GROUND							
Modular upgrade (expedient indoor shelter)	4	1.7	In building	Manual	>94	Family to community	Good
Outdoor A-frame (one version semiburied -- same data)	5	2.4	Not included	None	100	Family	Poor
Nonresidential building upgrade	6	3.2	In building	Manual	<94	Group to community	Good
House upgrade	7	3.5	In building	Manual	30[c]	Family to group	Good

[a]Based on the generous assumption that all host-area residents find basement spaces in host-area homes.

[b]Would certainly be lower than this because of areas in which ground water levels are high.

[c]Assumes that only host-area residents are housed in host-area homes. If every host-area resident were willing to share his or her living space with 2.3 risk-area residents, this share would increase to 100%.

of 90-95% of the population. However, to get from 90% up to 100% of national needs it is necessary either to use one or more of the four additional options recommended in this report or to build outdoor expedient shelters.

Constructing good-quality outdoor expedient shelters is as expensive -- i.e., as difficult — as upgrading existing buildings. Expedient shelters also have several undesirable characteristics, which are enumerated in this report. In order to acceptably shelter the entire relocated U.S. population in every geographic region of the country, it is therefore desirable to pursue the development of one or more of the additional options recommended here. Moreover, simply because these shelter options give so much flexibility to local planners, they should be developed to the degree that expedient shelters and upgrading have already been developed. The estimated 95% contribution of national shelter needs of existing FEMA methods may also be overly generous because it assumes that upgrading can readily be accomplished in every building now listed as upgradable. In practice, this is not likely to be the case. Because upgrading represents the keystone of crisis relocation planning, the absolute assurance of upgradability is crucial. The modular upgrading system recommended here both assures the upgradability of existing buildings and does not rule out additional buildings being upgraded.

In addition to technical considerations of shelter adequacy, this study considered issues of managing of shelter construction and operation. We found that sheltering large groups in community-size structures is importantly different from sheltering small groups in family-size structures. A number of technical problems can be more readily solved in large shelters, and the costs per space tend to decline as the size of a shelter increases. At the same time, social, psychological, and organizational problems become more complex and require more active management as shelter size increases. These trade-offs must be considered in crisis relocation planning.

Shelter ventilation was a major concern of the study participants. Present manual systems will be inadequate in the deep South during most of the year and may be inadequate during some of the year in most parts of the U.S. Ventilation systems with their own power supplies, working independently of and electric utility grid, are desirable. The buried H-shelter (Sec. 2.2) includes such a system.

Over a 20-year period, a program of host-area incentives to construct buildings with greater shelter capacity and/or greater upgradability could greatly enhance the effectiveness of crisis relocation planning. This study included several preliminary suggestions about possible incentive programs. The idea of an incentive to improve a building's upgradability was developed. Such a program could also enhance public safety in rural and small-town host areas by causing public buildings to be stronger and more resistant to tornadoes, hurricanes, and earthquakes.

5.2 CONCLUSIONS

The several conclusions reached in this study appear in Vol. 1 of the report and are reiterated here. These conclusions support the general FEMA emphasis on upgrading, but they also demonstrate the site-specific nature of the sheltering problems still to be solved.

5.2.1 Upgrading

1. In a number of cases it would be possible to achieve indoor exposure of less than 50 ERDs even if upgrades do not achieve a PF of 40. In many cases blast closures would not be necessary. In many states it should be possible to eliminate blast-closure problems altogether by moving CRP sites beyond a specified blast overpressure line (a presently unknown value probably somewhat less than 1.0 psi). To accomplish this, FEMA blast-overpressure estimating techniques need to be modified to provide more detailed spatial information on expected blast overpressures. The minimum value presently simulated by FEMA is 1.0 psi. Further study of building survival at blast overpressures up to 2.0 psi is needed to provide information on where damage probabilities decline to zero by structure type.

2. Regions 1 and 9 have the worst problems in providing adequate shelter (see Figs. 1.11 and 1.14). Region 2 and then Region 3 have the next worst problems, in that order. With occasional CRP modifications, the rest of the country appears to have the ability to provide shelter by means of upgrades to a maximum PF of 40 in locations subject to less than 1.0 psi blast overpressure. Put another way, it appears that as much as 83% of the shelter space needed can be provided by upgrading shelters to a maximum PF of 40 in areas subject to less than 1.0 psi blast (see Table 1.3). This assumes a maximum allowable in-shelter exposure of 50 ERDs and 80% evacuation of risk areas. These optimistic results cannot in all cases be achieved by present methods of crisis relocation planning. Specifically, congregate-care facilities measured by the current 40 ft^2/person standard would not be adequate (see Fig. 1.15). However, if this problem is solved by methods suggested later in our conclusions, then adequate shelter could theoretically be provided within every state in Regions 4-8 and 10. In other words, interstate agreements would not be necessary in these regions.

3. The severe problems of Regions 1, 2, 3, and 9 require additional study and analysis of upgrading and alternative sheltering methods. These regions have relatively few upgradable shelter spaces per resident and have few basements for relocating residents (see Fig. 1.13). To make maximum use of upgradable shelters, problems of blast closure must be solved in these regions. (Because of uncertainty over blast problems below 1.0 psi, the existence of some blast-closure problems in other regions cannot be ruled out, even though blast-closure problems should be small in those regions. Future analysis should be directed toward more precise definition of the environment where blast upgrading must occur.) Use of relatively blast-resistant NSS spaces within the 2.0 psi boundary should be considered in these locations. Use of the barn shelter concept should be considered (though it will not be effective in Region 9). Interstate compacts are necessary and already in use in three of the problem regions (1,2,3). Because these are coastal regions, the use of the boat option should be examined. Even if every possibility mentioned above were to be implemented, it is doubtful that adequate shelter can be provided in California. In this single state, congregate care might have to be provided by tents, recreation vehicles, and expedient outdoor shelters. Rapidly erectable, somewhat blast-resistant expedient shelters near urban areas (such as the H-shelter suggested in this report) may prove to be desirable in the four problem regions. At this point, none of the options can be specifically recommended for these regions.

4. Several areas with shelter problems worse than the norm (southern California, Arizona, and Florida) have resident populations consisting of many retired people — populations that may find it difficult to construct shelter spaces. Areas of these states also have severe ventilation requirements, which are made even worse by unusual ventilation requirements to assure survival of the elderly.

5. Crisis relocation planners should pay careful attention to soil conditions in host areas. Soil availability could dictate the relative desirability of sheltering options — some demand more use of soil than others. A high water table could create problems in excavating soil for expedient shelters and affect the techniques used for upgrading. If basements are likely to flood because of

electric pump failure and a high water table, many basement upgrades might be ruled out.

6. Basement upgrades, nationally, could provide less than 30% of needed upgraded shelter space at best. In contrast, potential above-ground upgrades exceed the needed national number of upgrades by almost 100%. Therefore, relatively greater attention should be given to above-ground upgrading.

7. While existing upgrading concepts are generally adequate, feasibility problems under certain circumstances have been identified. The modular upgrading sytem (MUS) suggested in this report can, in principle, solve several problems of upgrading. While there is no reason to abandon existing upgrading concepts that have been demonstrated to be highly workable, it is desirable to pursue the MUS concept to the design stage in order to augment upgrading methods. The advantages and disadvantages of the MUS relative to existing upgrading methods should be carefully assessed.

8. The biggest technical problem in a majority of shelters will be ventilation. A 12-volt ventilation system is suggested in this report. It would have the advantages of safety and of the ability to accept parts and power sources (batteries) scavenged from automobiles. This concept should be pursued further. Existing manual ventilation systems should be more extensively tested under conditons that will exist in shelters -- i.e., with human occupancy and operated over a period several days. If these devices work in such conditions, then they may be used in the majority of shelter spaces (those not subject to blast problems). If not, then power ventilation methods must be provided or shelter space standards (and thus the whole CRP process) revised.

5.2.2 Congregate Care

In a significant number of states, there is a sufficient number of theoretically acceptable upgradable shelter spaces but an insufficient number of congregate-care spaces to house each ultimate occupant of the shelter spaces (see Figs. 1.10 and 1.15). In such states, some revision of standard CRP procedures may be helpful. Space allowable per congregate care space might be reduced. Alternatively, plans to bring to the host areas recreation vehicles, tents, and/or mobile homes might be developed.

5.2.3 Advance Preparation

A program to encourage new-construction slanting and slanting-for-upgrading could greatly enhance the ability of host areas to provide shelter in the long run. Not only should institutional-legal methods be developed to encourage slanting and upgrading planning but institutional-legal methods should be pursued to prevent the discouragement of such measures. For example, instead of fixed property-tax deductions for shelter-capable space (Nevada, Rhode Island) there should be legislation to prevent property tax assessments on the proportion of property that will be used for the provision of shelter. Methods of encouraging shelter planning in host areas (but not in risk areas) should be developed. In some areas of the country, the adequacy of the CRP program could be greatly enhanced if host-area residents were able to shelter themselves in the residential structures of their community. Thus, selective encouragement of residential shelter programs for local residents of some host areas deserves consideration.

5.2.4 Organizational, Social-Psychological, and Economic Management Considerations

1. Upgrading of existing buildings to shelter status differs significantly from having each family build an expedient shelter. While upgrading of buildings uses far less material per space provided, it demands greater skill by those managing the construction process (Table 1.1). The high skills of those managing shelter upgrading for large numbers of other people offer the opportunity for a high degree of quality control in construction (especially in terms of achieving a standardized PF) and operation of the shelter at the expense of a far more difficult group management situation.

2. Shelter management studies should be reviewed to determine the adequacy of existing training methods for the kinds of problems that may be anticipated in large groups requiring 10 ft^2 per person for two weeks. The complexity of group shelter management problems will depend in large part on the homogeneity and characteristics of a group of occupants. Groups containing above-average percentages of children, elderly people, and those whose behavior is likely to be unacceptable to an average group of shelter occupants may present special problems to shelter managers. Deficiencies in current training methods should be assessed and a program developed for redressing those deficiencies.

3. This study has focused almost exclusively on shelter characteristics. It has assumed that other aspects of CRP would adequately support the shelter population. While that is a useful assumption for the purposes of this study, many of the recommendations made here could not be implemented without dropping this assumption and considering necessary adjustments in other CRP areas. Such areas as money and banking (or coupon rationing), supplies distribution, and population-relocation choices would all have to be reexamined in light of changed shelter policies. While upgrading methods clearly offer the potential for an adequate fallout shelter program when compared to the old expedient-shelter methods, they just as clearly demand more careful management within and without the shelter.

5.2.5 General Conclusion

In summary, there appear to be great benefits in moving away from a standard national approach to a more site-specific appoach. Existing FEMA research provides a solid foundation for successful crisis relocation planning, but the program can be refined by suitable modifications made in its locational, engineering, and institutionally specific elements.

5.2.6 Recommendations

The study has clearly shown that the current reliance of FEMA on upgrading is warranted. Current efforts to compile an upgrading manual that incorporates methods of accomplishing blast closure are appropriate. Since upgrading cannot fulfill all of the needs for shelter space in host areas, development of additional shelter options is desirable. The boat option, barn option, modular upgrading system, and buried H-shelter all appear to be worthy of further evaluation and possible development. The buried H-shelter and modular upgrading system both could be developed to the detailed design stage. The ventilation system of the buried H-shelter is of special interest for other applications. The barn and boat options might both benefit from further conceptual analysis before proceeding to the design stage. Each of the four options should receive further analysis of the conditions under which they might become superior alternatives to existing upgrading methods. Such analysis should be conducted jointly for the recommended four alternatives because they are, in a sense, competitors with one another for the position as the next best alternative to upgrading. It is doubtful that a consistent winner would result from such study. Instead, the best alternative would be a function of local conditions including building (or boat) availability, materials availability, expected blast, and expected fallout levels.

To improve the in-place shelter capability of the building stock in host areas, new slanting-incentive programs, including slanting-for-upgrading, should be developed.

In addition to instruction manuals on how to assemble talent to construct shelters, FEMA should also work toward development of instruction manuals on how to assemble and quickly train talented people to operate shelters. In addition to traditional physical management techniques (radiation monitoring, occupant rotation, dose estimation, water and food rationing, etc.), FEMA should assemble knowledge on techniques and skills needed to meet the social and psychological needs of a sheltered population.

Finally, although congregate-care space shortages have been identified as a problem for certain states, this study does not recommend that the congregate-care situation be reevaluated until the new shelter options are more completely developed. Because it is necessary to have congregate-care facilities in the immediate vicinity of shelter spaces, the ultimate congregate-care solution will be very much a function of the shelter option adopted.

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APPENDIX:

VENTILATION OF SHELTERS

VENTILATION OF SHELTERS

A study of ventilation in fallout and blast shelters has been made by Scientific Service, Inc.[32] One conclusion of this study is that natural ventilation of large shelters, either above or below grade, cannot be relied upon except in unusual cases. It has also been established that the criterion of minimum ventilation, three cubic feet of air per minute per person, has been superseded. The latest criteria are in the FEMA publication "Natural Shelter Survey Instructions," TR-84 (May 1982). These criteria are based on climatic conditions in various parts of the country, and vary from eight cubic ft/minute per person (minimum) to 40 cubic ft/minute per person (maximum).

Each modular component of the H-type, underground, four-module shelter described in Sec. 2.2 would house 64 people. The air required by each module would thus vary from 512 to 2560 cubic ft/minute. Two types of manually operated air movers have been investigated for use in shelter ventilation. These are the Kearny air pump (KAP) and the packaged ventilation kit (PVK). A discussion of both of these types is given in Ref. 32. However, there is confusion and disagreement in regard to how much air can be moved by units of various sizes.

The amount of power (human power, in this case) required to move air in one 64-person module can be calculated. The equation needed for this calculation is:

$$hp = \frac{cfm\ (\Delta p)}{6356\eta_t}$$

where the units are

hp = horsepower

cfm = cubic feet per minute

Δp = differential pressure, measured in inches water gage (in. wg)

η_t = total efficiency

The differential pressure required depends on the filters used (if any) and the geometry of the shelter. No data are given in regard to the efficiency of either the KAP or the PVK. However, it obviously will not be 100%. There will be friction losses, air slippage, and eddy-current loses in these units.

The power requirements are:

cfm	Δp, assumed (in. water gage)	Hp Required, by Efficiency				
		$0.9\eta_t$	$0.8\eta_t$	$0.7\eta_t$	$0.6\eta_t$	$0.5\eta_t$
512	0.5	0.045	0.050	0.058	0.067	0.081
2560	0.5	0.224	0.252	0.288	0.336	0.403

As the above values show, the horsepower required is very low if mechanically powered units are used. However, if human power is used, this should be looked at in terms of foot-pounds/minute. Then we have:

cfm	Δp, assumed (in. water gage)	Ft-lb/min, by Efficiency				
		$0.9\eta_t$	$0.8\eta_t$	$0.7\eta_t$	$0.6\eta_t$	$0.5\eta_t$
512	0.5	1485	1650	1914	221	2673
2560	0.5	7392	8315	9504	11088	13299

It would require a large group of strong people to supply this energy 24 hours/day for, say, 14 days.

Small centifugal-type blowers, which can be driven by 12-volt direct current, are available. One such unit driven by a 12-volt dc, 1725-rpm motor will move 400 cfm against a differential pressure of 0.875" on the water gage. Each of the four modules would require two such blowers for the minimum case and eight for the maximum.

Larger blowers are also available. A blower with a 1-1/2 hp motor will move 1545 cfm with a differential pressure of 0.875" wg. Two such blowers per module would be more than adequate for the maximum case. Manual crank-type, centrifugal back-up blowers should be provided.

The 12-volt dc motors may be run for a short time in an emergency with automotive batteries. For normal operation, an engine/generator set would be used. These are available with diesel engine drives from 3-kW capacity. The fuel consumption for these units is:

3 kW: 1/3 gal/h
6 kW: 2/3 gal/h
12 kW: 1.05 gal/h

For the H-type, underground, four-module shelter, which would house 256 people, the following equipment items would be needed.

Blowers	Minimum Case (2048 cfm)	Maximum Case (10,240 cfm)
Buffalo Baby Vent (or equivalent)		
Size D, 1/4 hp	8	-
Size G, 1-1/2 hp	-	8
Engine/generator sets* (diesel engine)		
3-kW diesel engine	1 + spare	
12-kW diesel engine		1 + spare

*This equipment would provide power for lighting.

A 12-volt dc power system is preferable to a 120-volt ac system for two reasons:

1. It is inherently safer, even when installed by people with little electrical knowledge.

2. It may be backed up with automobile batteries.