PAGES _____

ARE

MISSING

IN

ORIGINAL

DOCUMENT

OPERATIONS RESEARCH, *Incorporated*
SILVER SPRING, MARYLAND

EVALUATION OF CIVIL DEFENSE SYSTEMS

Shelter Utilization Policies in Montgomery County, Maryland

by

S. R. Parent and R. D. Lipps

January 1964

Prepared Under Contract OCD-OS-62-187
for Department of Defense
Office of Civil Defense
Systems Evaluation Directorate
Washington 25, D. C.

PREFACE

This report documents the application of a flexible procedure to evaluate the relative effectiveness of proposed Civil Defense shelter policies. The primary effort is directed toward the study of shelter-utilization policies in Montgomery County, i.e., how the county shelter resources (both present and proposed) would fill with respect to time. The initial objective of this study is the trial application of a method that has the propensity to examine complex policies of shelter utilization whose predicted outcome may well be beyond the bounds of experienced conjecture.

The evaluation method used herein was applied to a study made by Stanford Research Institute (SRI) to develop a civil defense plan for Montgomery County, Maryland. Although the SRI plan is being refined by local officials, the use of the preliminary plan will demonstrate the applicability of the method developed.

Special appreciation is due to Dr. R. I. Condit and Mr. L. H. Towle of Stanford Research Institute whose timely response to our queries for data and information concerning the proposed policies in Montgomery County allowed the compatible parallel development of our separate studies.

Finally, gratitude is expressed for the guidance and support of Mr. John F. Devaney, Director, and Mr. Lloyd A. Woodward, Project Coordinator, of the Systems Evaluation Directorate, Office of Civil Defense.

SUMMARY

SCOPE OF CONTRACT

1. The contractor, in consultation and cooperation with the government, is furnishing the necessary personnel, facilities, and other services as may be required to:

a. Perform modification of an earlier model developed by Operations Research Incorporated (ORI)[1] for shelter-utilization testing to allow solution, programming, test running, and proof-testing on the IBM 1620 Data Processing System.

b. Further develop and apply to selected local areas the computerized model in a manner to allow the evaluation of shelter-utilization policies.

c. Perform a trial operation with Montgomery County, Maryland, as a selected local area, in conjunction with Stanford Research Institute (SRI) to identify and solve any operating problems that may exist.

APPROACH

2. In the course of earlier research, ORI developed a series of mathematical models[2] that determined the time required for a highly responsive city population to reach available fallout shelter in reasonably

[1] W.A. Hamberg, A.M. Salee, and R.H. Watkins, Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, Operations Research Incorporated Technical Report 210, 1963.

[2] Ibid.

ideal conditions. These earlier models have been computerized and serve as the basis of a method for evaluating with respect to required sheltering time, various policies concerning the movement to shelter and/or the availability of shelter spaces.

3. By using the computerized models to provide a calculation of the number of Montgomery County people sheltered each minute by various policies, a series of policy-representing curves displaying people sheltered vs time after alert was acquired. The examination of these curves, along with investigation of their behavior pattern, allowed a relative evaluation of the policies themselves.

4. The following general policies were evaluated:

   a. The assignment (depending on available spaces) of persons within one mile (30 minutes travel time) from shelter.

   b. The planned use of shelter spaces in:

      1. Facilities with marked and available spaces,
      2. Facilities with existing but currently unused shelter spaces,
      3. Facilities with possible but unimproved shelter spaces,
      4. Projected new construction of commercial buildings, and
      5. Schools, both projected and existing.

   c. Overcrowding of shelter facilities as a means of increasing capacity.

5. The policies were evaluated both for now (1962-63) and for conditions predicted for 1968.

6. This report serves as the evaluation of the shelter-utilization (assignment and improvement) plans for Montgomery County, Maryland, as presented by SRI.[3/]

FINDINGS

7. The modification, computerization, and trial application were successful, and the overall approach was determined to be adaptable for the evaluation of various shelter-utilization policies. The evaluation findings are briefly described as follows:

[3/] Stanford Research Institute, Toward Effective Civil Defense in Montgomery County and Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

a. Assignment Planning

The primary advantage of shelter assignment under current conditions is to minimize the on-street population because only persons who can be sheltered leave their homes.

Owing to the low (20 to 25 percent) shelter to population ratio, current assignment planning is of little value in speeding the fill of shelters even though relocations are avoided.

As long as there is an inadequate number of shelters, a disadvantage of assignment planning is a slightly slower filling rate (a lag of 2 to 5 minutes in Montgomery County) of shelters. This is true because, in restricting the number of people in the movement to shelter, the assignment planning bars a small proportion of the population that can actually reach shelter quicker than those assigned.

b. Use of Additional Facilities

Only a limited proportion of the additional commercial facilities with unused or unimproved shelter capacity are conveniently located with respect to the population so as to increase the number of people sheltered without requiring additional time to complete the movement. Clearly, the most important source of future shelter facilities considered in the public schools that may be utilized in conjunction with the conveniently located commercial facilities now available but unused or unimproved. This policy would allow the projected 1968 county daytime population (435,000) to be sheltered in approximately 50 minutes, as shown in Table 2.

c. Overcrowding

A policy of overcrowding current and projected facilities would allow a low-cost increase in shelter capacity, but would require considerable additional time to utilize the newly created capacity. As shown in Table 2, a 1968 sheltering policy not using public school facilities, allowing a maximum of 100 percent overcrowding, would provide complete shelter for the county population in 1968, and would require approximately 95 minutes to complete.

d. Policy Effectiveness in General

It has been noted during the course of this study that the effectiveness of different shelter-utilization plans varies markedly, depending on the number and location of available shelter spaces in respect to the population. For instance, the advantage of assignment planning changes from a reduction in on-street population for a low-shelter-ratio, to a faster shelter filling time for a high-ratio and adequately sheltered area. The various zones of advantage, disadvantage, or no effect along the scale of shelter-to-population ratio is not known at this time. However, this knowledge would be vital to the proper phasing and planning of shelter utilization for the future.

RECOMMENDATION FOR CONTINUED STUDY

8. To make full use of the evaluation model, it is essential that the overall sensitivity of the resultant evaluation to the various determinants or factors that affect the shelter-utilization problem be determined. Also, further study should be undertaken to find the advantages and disadvantages of various shelter-utilization policies relative to the current or projected shelter-to-population ratio for any typical area of interest.

9. In Montgomery County as in many other localities, final plans are being developed and refined by local officials. The further evaluation of final plans, when available, would serve to determine the effectiveness for Montgomery County and add to the knowledge concerning various shelter-utilization policies used alone or in combination.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

BACKGROUND

1.1 The vulnerability of this country's population to nuclear attack is steadily being reduced through the efforts of the Office of Civil Defense and local Civil Defense organizations in locating, marking, and provisioning fallout shelter spaces. Reduction of expected warning time has increased the requirements for prior planning to obtain efficient sheltering movements and utilization. Recently, significant effort has been directed toward the field of shelter-utilization planning and policy making. However, these efforts, as those in any new field, are of relatively unmeasured value until methods of testing or evaluating them are available and put to use.

1.2 When a preliminary civil defense planning study[1/] was conducted in Montgomery County, Maryland, the need for evaluating and testing the recommended policies was recognized. The evaluation concept[2/] developed by Operations Research Incorporated was selected as a tool to be used in evaluating the relative effectiveness of the recommended policies.

1/ Stanford Research Institute, Toward Effective Civil Defense in Montgomery County and Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

2/ W. A. Hamberg, A. M. Salee, and R. H. Watkins, Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, Operations Research Incorporated Technical Report 210, 1963.

OBJECTIVE OF STUDY

1.3 This study serves two objectives. The first is to complete a trial application of the evaluation method. The second is to provide a quantative evaluation of the proposed shelter-utilization policies as presented by the Stanford Research Institute.[3/] Additional goals of refinement and computerization were achieved and utilized in the policy evaluations.

SCOPE OF STUDY

1.4 The policies to be evaluated in this report are those proposed by SRI in their preliminary planning study for Montgomery County. The SRI study was presented in two distinct parts: (1) general planning aspects, and (2) shelter-utilization plans. These parts are briefly described as follows:

General Planning Aspects

1.5 The general planning aspects of the preliminary study primarily contain advisory information to be used in the formation of operating civil defense plans. The value of this information is immediately apparent, but such information does not lend itself to quantitative testing. The authors of the SRI study have provided a qualitative critique of their own work, and it is felt that any further evaluation of this portion of their report would be inconsequential.

Shelter-Utilization Plans

1.6 Shelter-utilization plans, on the other hand, are definite and therefore more amenable to evaluation. This report, then, is oriented toward their evaluation. SRI separates their shelter-utilization plans and recommendations into Operational (current) Planning and Developmental (future) Planning. The technical scope of the evaluation presented in this report is consistent with these divisions.

1.7 The physical scope of this evaluation lies within the confines of Montgomery County. Geographical boundary effects, other than those considered in the SRI study, are ignored.

1.8 It was not considered to be within the scope of this report to evaluate or discuss in detail any political implications that may arise from policy recommendations contained in the preliminary study. Also, no attempt is made to argue the basic assumptions underlying the complete SRI shelter-utilization planning study.

3/ Stanford Research Institute, op.cit.

APPROACH TO THE PROBLEM

1.9 With the previously cited objectives and scope in mind, the shelter-utilization policies recommended by SRI were evaluated by accomplishing the following tasks:

a. Program, test, and implement selected mathematical models for the IBM 1620.

b. Obtain physical data concerning Montgomery County, such as population, land use, and fallout shelter location.

c. Determine the proposed policies for Operational Planning to be evaluated for Montgomery County.

d. Determine the mathematical description of the proposed policies and provide for compatibility with the computerized evaluation model.

e. Calculate the time required to reach shelter for each policy, utilizing the evaluation model.

f. Analyze the shelter utilization of each policy to determine its relative effectiveness.

g. Repeat tasks (a) through (f) for the policies recommended in Developmental Planning.

FORMAT OF REPORT

1.10 This report is presented in four additional sections and one appendix. These sections are organized to provide a logical description of the evaluation procedure, results, and conclusions.

1.11 A brief description of the evaluation method and procedure, including data requirements, is presented in Section II. Also shown in this section are predicted population characteristics for Montgomery County.

1.12 Section III describes the Operational Plan policies, their evaluation, and the results of these evaluations. The Developmental Plan policies are handled in a similar manner in Section IV.

1.13 The specific conclusions drawn from the evaluation of the Operational Plan and Developmental Plan policies concerning Montgomery County are presented along with certain general conclusions applicable to other locations in Section V.

1.14 The detailed data used in the Montgomery County evaluation are tabulated and documented in Appendix A.

II. METHOD OF EVALUATION

INTRODUCTION

2.1 The purpose of this section is to describe briefly the overall character of the evaluation method. The analytical model, used as the primary evaluation tool, is documented in detail in a previous ORI report.[1/]

INTERNAL STRUCTURE

2.2 The overall model consists of three separate submodels operating in series (i.e., the output of one becomes the input to the next). These three models in order of use are the:

a. Population analysis,
b. Starting-time analysis, and
c. Movement-time-to-shelter analysis.

2.3 Figure 1 shows the relationship of the three submodels. The first two are primarily supporting analyses that supply compatible data for use in the last and most useful submodel. These submodels are described briefly in the following paragraphs.

1/ W. A. Hamberg, A. M. Salee, and R. H. Watkins, Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, Operations Research Incorporated Technical Report 210, 1963.

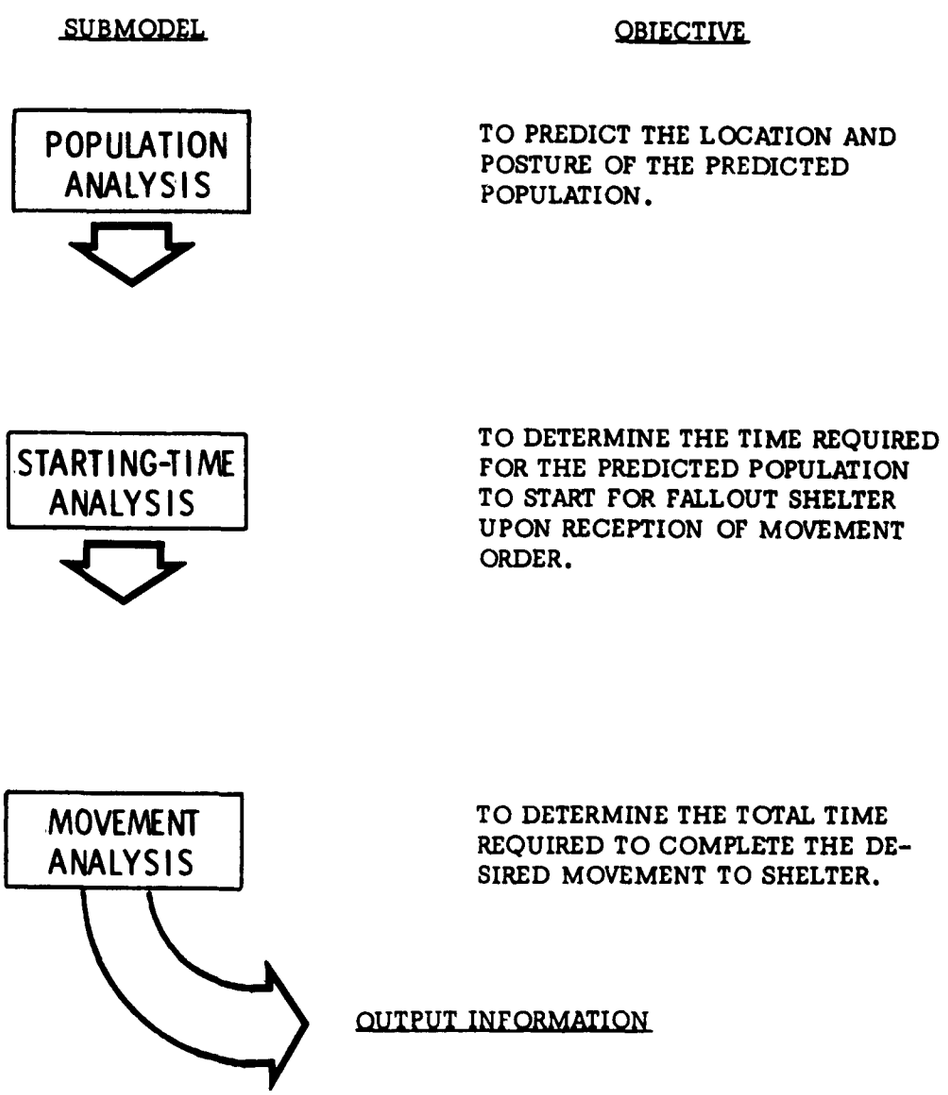

FIGURE 1. INTERNAL STRUCTURE OF THE EVALUATION MODEL

2.8 Figure 3 shows the overall starting-time histogram for the entire county. Again the daytime and nighttime characteristics vary. The concentration of the nighttime population in the at-home, asleep posture (which has a relatively slow starting-time distribution) is reflected by the large portion of population in the later starting times. The distribution for the daytime population is more uniform because the population is more evenly divided into all postures.

Movement Analysis

2.9 The last analysis in the series takes the output of the previous submodel as primary input, along with shelter locations, shelter capacities, and movement velocities, and calculates the time required to complete the movement to shelter under suitable conditions and provides a curve representing population-reaching-shelter vs time.

2.10 The evaluation model computes the time required to reach the door of the shelter. Movement time to this point is referred to as the sheltering time, and the people are referred to as being sheltered. This time does not, however, include additional time for entering and processing within the shelter. The movement time is, in fact, an assumption of instantaneous sheltering at arrival.

INPUT

2.11 Primary input is data pertaining specifically to Montgomery County, Maryland, its physical characteristics, and its population. The population data used in the evaluation of the Operational Planning was the 1962 residential population. These data are described and listed in Appendix A of this report. The 1968 population projected by SRI is used as the input for the Developmental Planning. The fallout shelter availability data are taken directly from the SRI report and are the Phase II National Fallout Shelter Survey listing with some updating by SRI on information from the Corps of Engineers.

VARIATIONS OF USAGE

2.12 Owing to the cellular structure of this evaluation method, the overall model may be employed in many different ways to provide variations about the standard usage just described. Various aspects of the movement may be changed to conform to various policies of interest. For instance, in testing the effect of a particular shelter-assignment policy, the population was assigned to strict destinations in accordance with the preliminary assignment plan, while the unassigned portion of the population was restricted from entering the movement to shelter.

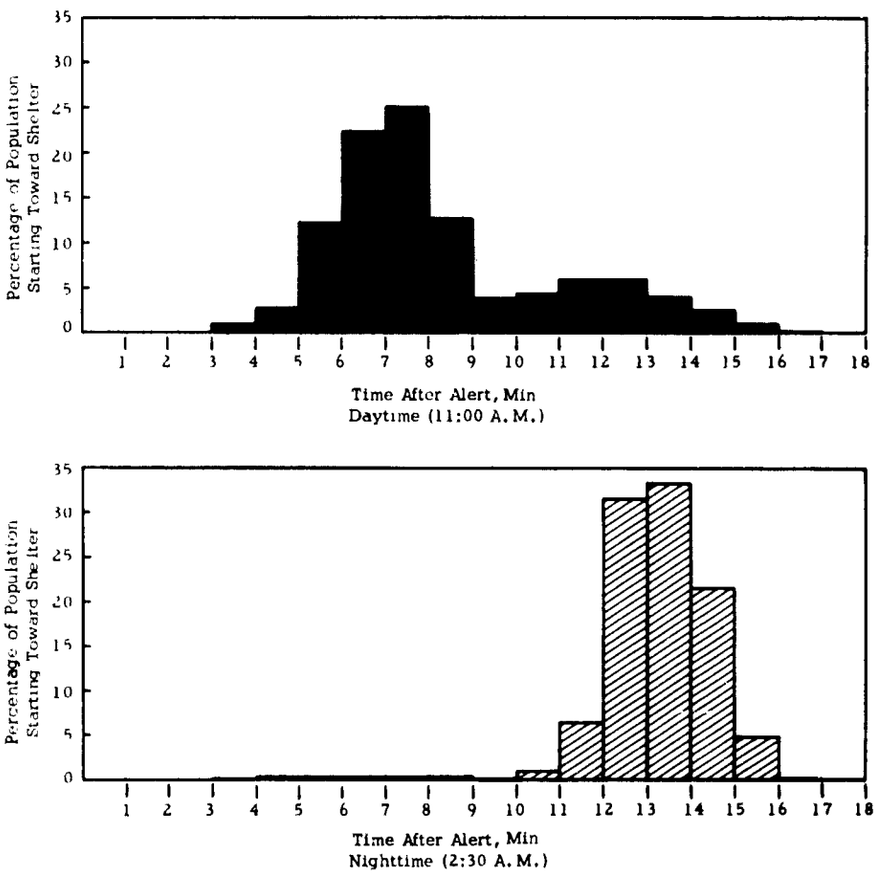

FIGURE 3. COMPARISON OF DAYTIME AND NIGHTTIME STARTING TIME DISTRIBUTIONS

2.13 Any or all of the major input parameters may be varied to examine the effect of:

a. Various movement policies,
b. Various shelter acquisition policies,
c. Weather or environment on movement,
d. Shelter overcrowding, and
e. Degradation or improvement in human response time.

This is certainly not an exclusive list of variations, but it serves to illustrate the different uses of the current model.

III. OPERATIONAL PLAN EVALUATION

INTRODUCTION

3.1 The Operational Plan, as presented in the SRI shelter-utilization study, deals with actions to be taken immediately in relation to current or imminently available resources. The primary recommendation is the adoption of shelter-assignment planning for the county.

3.2 The assignment policy, as proposed by the SRI planning study, can be summed up briefly as follows:

a. Primary Policy. People who are located within assigned areas go to their assigned public shelter.

b. Secondary Policy. People who are not located within any assigned area do one of the following: (1) fill excess public shelter spaces, (2) seek refuge in their own or neighbor's basement, or (3) seek refuge in up-county basements.

In Montgomery County, where the population exceeds the current shelter capacity, many people are not assigned to any shelter and must be considered under the secondary policy. Emphasis, however, is placed on the evaluation of the primary policy.

3.3 The status of public fallout shelters available in Montgomery County is at three levels. These are used in this report as defined and enumerated in the SRI planning study. The three levels are as follows:

a. Marked spaces are licensed shelter facilities that are, or that soon will be, stocked with federally provided fallout shelter supplies. They are available for public use.

b. Existing spaces are spaces identified in Phase II of the National Fallout Shelter Survey as those meeting local marking and stocking criteria. However, only marked spaces are currently available for public use.

c. Possible spaces are those spaces identified in the Phase II Survey as meeting the marking criteria plus those that through improvements can be made to meet the criteria.

3.4 The assignment planning is based on access to the currently available (marked) shelter spaces. However, in addition to the basic policy of utilizing "marked" shelters, the authors of the SRI study present assignment data pretaining to the utilization of "existing" and "possible shelters as well. These are evaluated individually in this report.

3.5 The assignment plans proposed for the county must be tested in relation to a basis of measurement so that improvement or degradation may be measured meaningfully. For this purpose, the various "assignment-movement" policies are compared against the best estimate of an "unassigned movement." These terms are defined as follows:

a. Assigned movement. This is movement to shelter in a pattern directly determined by the assignment plan. The origin and destination of the moving population is scheduled in such a manner as to avoid wasted movement, i.e., people initially start for the shelter in which they are to be sheltered. However, only that portion of the population located within acceptable distance of a shelter is assigned to shelter. The remaining persons are not considered in the movement to public shelter.

b. Unassigned movement. This is movement to shelter by people not assigned to shelter, but who are presumed to have adequate knowledge to start for the nearest shelter regardless of whether or not they can be accommodated there. Three assumptions are made to provide an unassigned policy:

(1) starting times remain the same as in the assigned movement, (2) people initially start to the nearest shelter, and (3) if the shelter at which a person first arrives is filled, he is directed back to his place of origin unless it is possible for him to reach a shelter with excess capacity before it is filled, in which case he is directed there.

3.6 A series of proposed operational policies has been evaluated utilizing people sheltered with respect to time as the major criterion. To keep the evaluations meaningful, only the shelter and assignment-data characteristics of the policies are varied. Other input data, such as population distributions, starting-time distribution, velocities, etc., remain unchanged. Time-to-shelter calculations have been made for:

a. Assigned movement to marked shelter spaces,
b. Unassigned movement to marked shelter spaces,
c. Assigned movement to existing shelter spaces,
d. Assigned movement to possible shelter spaces,
e. Unassigned movement to possible shelter spaces,
f. Overcrowding of marked shelter spaces by (1) 50 percent and (2) 100 percent in unassigned movements, and
g. Overcrowding of possible shelter spaces by (1) 50 percent and (2) 100 percent in unassigned movements.

RESULTS OF ANALYSES

Assigned Movement to Marked Shelters

3.7 The first policy to be evaluated is the SRI-proposed assignment utilizing only "marked" shelters. The results of such a movement to shelter are shown in Figure 4 by a plot of the number of people sheltered as a function of time for both the daytime and nighttime population configurations. As could be anticipated, the slower nighttime starting times (paragraph 2.8) have resulted in a slower filling of shelters at night. Also contributing to this slower rate of sheltering is the poorer nighttime distribution of the population with respect to the shelters, i.e., the shelters remain concentrated in the business districts, whereas the population has shifted to the outlying residential areas.

3.8 Even with the deficiency of shelter spaces, the proposed assignments result in the utilization of only 76 and 66 percent of the marked spaces in the daytime and nighttime movements, respectively. The reason for this is that the assignment plan assigns people to a shelter only when they are located within a maximum acceptable travel time or

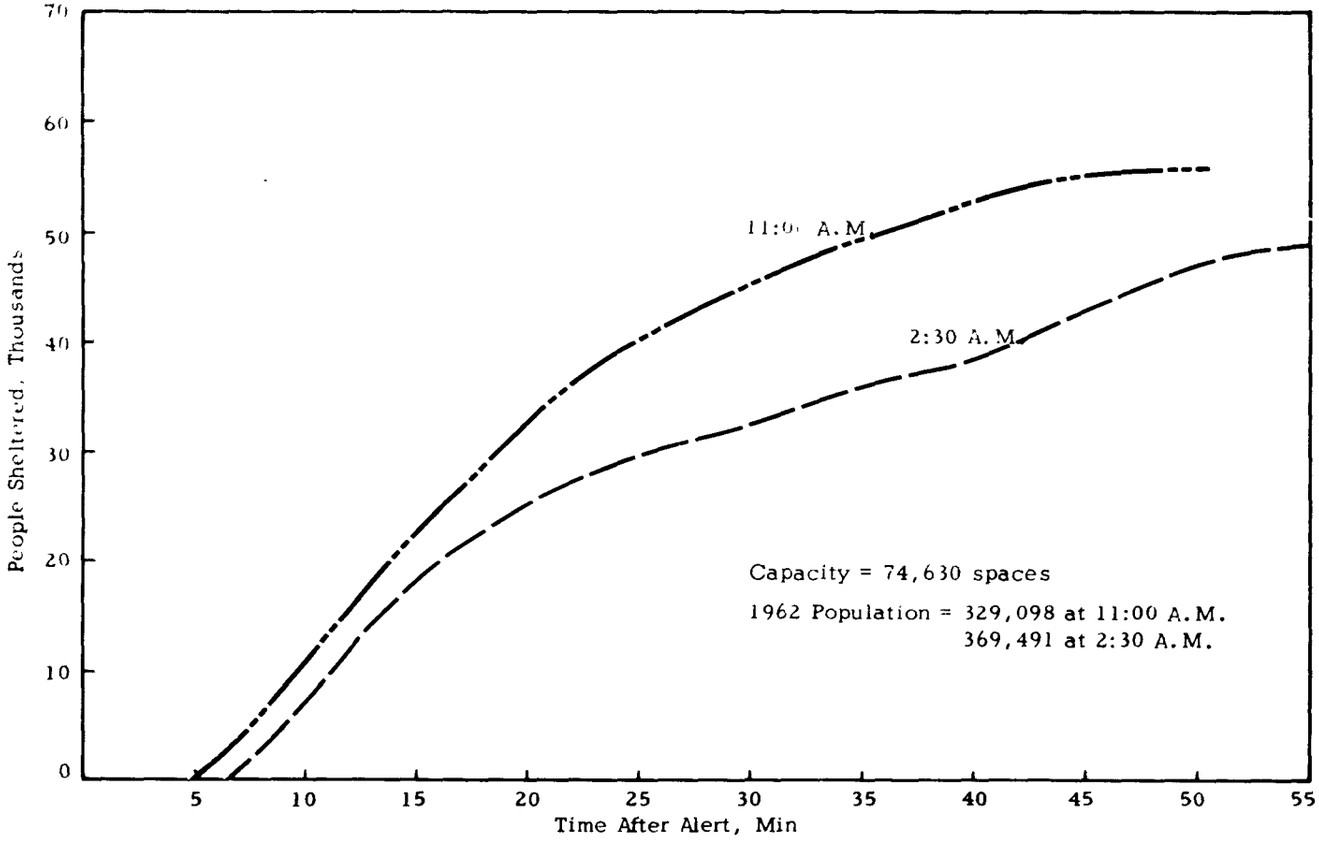

FIGURE 4. NUMBER OF PEOPLE SHELTERED IN ASSIGNED MOVEMENTS TO MARKED SPACES FOR 1962 POPULATION

distance.[1] At night when people are removed from the shelter centers, certain shelters, namely the National Institutes of Health (NIH) and the Naval Ordnance Laboratory (NOL) cannot be filled on the basis of the criteria used because a sufficient number of persons are not located within the maximum distance or travel time to shelters. Therefore, some of the spaces are not filled. During the day people are more concentrated around the shelter centers, and all spaces can be filled except some at NIH. These criteria result in the sheltering of 17 percent of the daytime and 13 percent of the nighttime population.

3.9 The time required to complete the movement, (i.e., the time at which all assigned people reach shelter) is about 50 minutes during the day and about 55 minutes at night. This exceeds the maximum allowable combined starting, traveling, and shelter-queing time (30 minutes) on which the SRI assignment plan is based. There are two reasons for the increased time. First, about 10 minutes of this additional time results from using a nonparametric starting time distribution (as shown in Figure 3) in the starting-time model to provide a realistic approach to the prediction of overall shelter time. (The basis for the SRI assignment plan is a uniform 10-minute starting and shelter-queing time. Earlier studies and a previously noted publication[2] discuss the structure of the nonparametric starting time in detail.) Secondly, the remaining source of additional time comes from the method used in the movement model to compute the travel time of persons initially located in one census tract and sheltered in an adjoining tract. The actual travel time would often be less than that computed in the model. These effects are significant only when people-sheltered vs time are compared directly with the shelter-time data generated within the SRI assignment plan study. All curves calculated in this report are acted on equally by these effects and therefore do not alter any relative evaluation.

Unassigned Movement to Marked Shelters

3.10 Unassigned or free movement, which would take place in the absence of an assignment plan, was analyzed to obtain a comparison with the assigned movement. The results of the unassigned movements during the day and at night are shown in Figure 5. The curves are similar in shape to the assigned movement curves for the early times after alert. However, because the number of persons seeking shelter was not limited

---

[1] In the SRI plan, a total of 10 minutes starting and shelter-queing time plus 20 minutes travel time was the maximum sheltering time; one mile from shelter was the maximum acceptable distance to travel.

[2] W. A. Hamberg, A. M. Salee, and R. H. Watkins, Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, Operations Research Incorporated Technical Report 210, 1963.

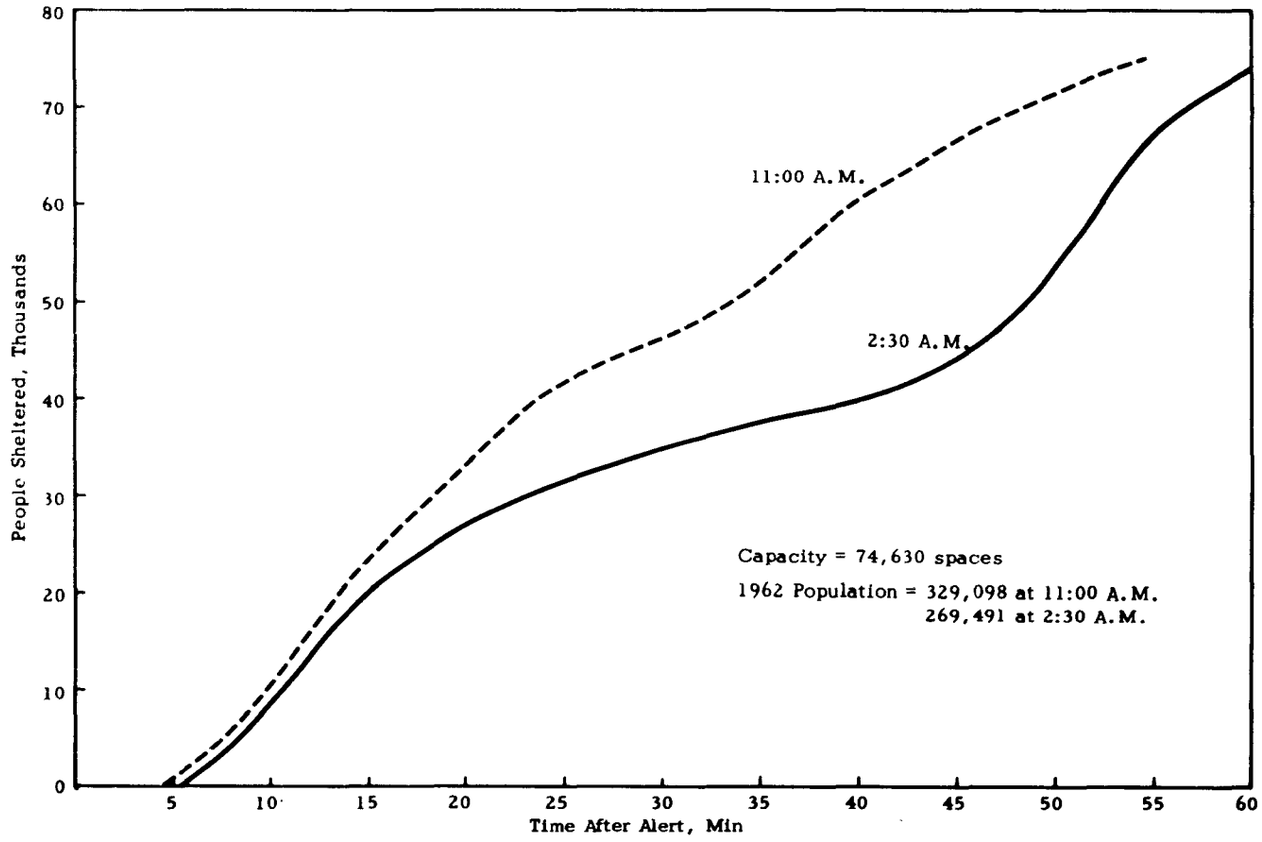

FIGURE 5. NUMBER OF PEOPLE SHELTERED IN UNASSIGNED MOVEMENTS TO MARKED SPACES FOR 1962 POPULATION

by an assignment, all marked shelter spaces were utilized at both the daytime and nighttime. The curves therefore continue to increase until all of the spaces are filled. Even though all marked spaces are filled, only 23 percent of the daytime population and 20 percent of the nighttime population can be sheltered. The time required to complete the daytime and nighttime movements is approximately 55 minutes and 60 minutes, respectively.

3.11 The nighttime movement curve lags the daytime curve because of the reasons discussed previously. Since this lag is obviously not a reflection of a policy and will remain nearly constant for all policies analyzed in this report, there is no need to further investigate these policies at both times of the day. The remaining policies are evaluated for their effect on the 11:00 A.M. or daytime movement only.

Comparison of Assigned and Unassigned Movements

3.12 Figure 6 compares the assigned and unassigned movements during the day and at night. The sets of curves are roughly similar until the shelters are about 60 percent filled. At this point the unassigned curves continue with a relatively rapid sheltering rate whereas the assigned curves taper off because most of the assigned people have been sheltered.

3.13 It should not be disconcerting that the assigned movement curve lags the unassigned movement curve. This is the direct result of the assignment plan, which restricts a portion of the population from joining the movement to public shelter. The assignment plan reserves a space for the slowest starting person located within the assigned area. In the unassigned movement, however, this space is filled more quickly by a person who starts sooner, but is located outside the assigned area.

3.14 As an illustration, consider an assignment rule that assigns people to shelter only if they are located within 20 minutes travel time of a shelter with adequate capacity. For the population, the starting-time-to-shelter distribution will be assumed to coincide with the Montgomery County histogram shown below (which is Figure 3 in tabular form).

Time after Alert, Min	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Percent Starting Toward Shelter (Daytime)	0	1	3**	11	21	24	12	4	5	6	6	4*	2	1	0

3.15 Consider those persons just inside the perimeter of the assigned area, (i.e., with 20 minutes travel time): 4 percent (*) of them will experience a 13-minute starting time for an overall time to shelter of 33 minutes.

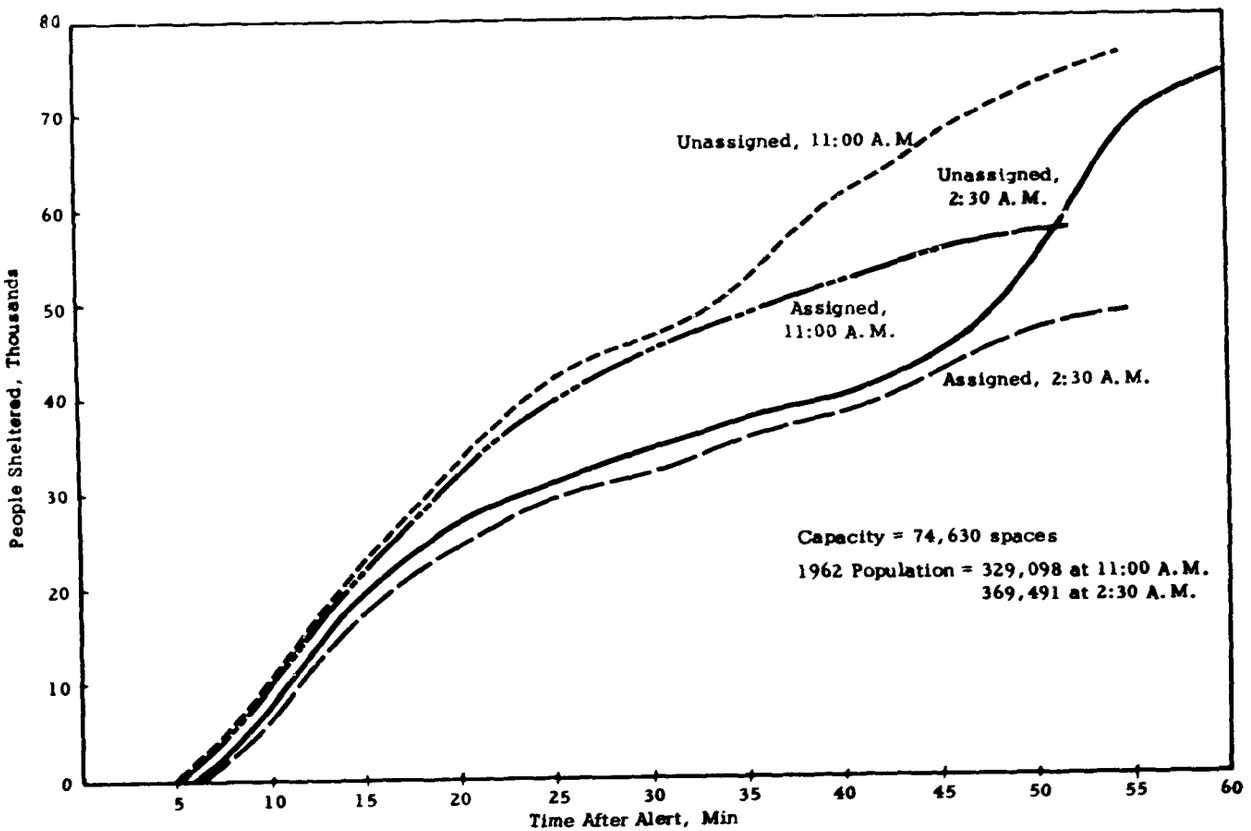

FIGURE 6. COMPARISON OF PEOPLE SHELTERED IN ASSIGNED AND UNASSIGNED MOVEMENTS TO MARKED SPACES

3.16 However, for a group of people even farther away than the assignment rule considers (say, 24 minutes travel time), 3 percent (**) require a starting time of only 4 minutes for an overall time to reach shelter of 28 minutes. This, of course, denotes earlier arrival at shelter for that portion of the unassigned group. Likewise, some percentage of all people with traveling times of between 20 and 34 minutes can also be sheltered sooner unless they are restricted from initiating their movement—as in the preliminary assignment plan.

3.17 At one point (about 30 minutes) on the daytime curves and twice (at about 23 minutes and 38 minutes) on the nighttime curves, the assigned curve nearly overtakes the unassigned curve. This effect can be explained by considering the definition of the two movement types. In the assignment plan all persons are directed to the shelter to which they were assigned and would be sheltered. However, in the unassigned movement people initially start toward the nearest shelter (even though it may fill before their arrival), and many have to be redirected to the location at which they eventually were sheltered. The time required for the relocation slows down the unassigned movement curve sufficiently at the points mentioned to allow the assigned curve to approach it.

3.18 A final characteristic of the two curve sets is that unassigned movement requires only a slightly longer time (5 minutes) to fill <u>all</u> the marked spaces (74,000) than assigned movement requires to fill <u>only those spaces to which people had been assigned</u> (57,000, daytime).

3.19 This, difference is again the result of an assignment plan restricting that proportion of the population which may have the capability to gain shelter more quickly than the average shelter seeker. In an area of shelter deficit (Montgomery County has about 25-percent shelter capacity), the limited capacity is filled first by that small proportion of the population capable of quick reaction and the shortest overall shelter time. Of course, this small proportion of the entire population (moving in an unassigned manner) is a larger number of people than an identical proportion of the assigned population (which is equivalent to the assigned shelter capacity only). Again, this denotes a higher sheltering rate for the unassigned movement than for assigned movement to shelter. At this stage it is well to point out that it should not be assumed that the entire population could be sheltered in approximately the same time, even if sufficient shelter space were available. Present shelter locations preclude this possibility.

3.20 In view of the previous evaluation of the people sheltered as a function of time, it might be concluded that there is no advantage in using an assignment policy. However, to give a broader picture, the evaluation is carried out a step further. Using the assumptions previously stated,

the number of people on the street as a function of time is computed for a movement to shelter and shown in Figure 7 for both the 11:00 A.M. assigned and unassigned movements. The advantage of the assignment policy becomes more apparent. In the assigned movement, the number of people on street at the peak is considerably less than for the unassigned movement because only those people assigned to shelter initiate movement. Also, the time at which the streets are clear of people is sooner in the assigned movement because the last person to be sheltered is also the last person on the street, and as soon as he reaches shelter the streets are cleared. In the unassigned movement, however, when the last person is sheltered, large numbers of people are still on street seeking public shelter, and considerably more time is required for them to return home.

3.21 The people on street versus time curves (Figure 7) are presented to show that when there is a large shelter deficit, the number of unprotected people can be reduced by an assignment plan such as the one recommended in the Montgomery County preliminary planning study. If there were sufficient shelters for the entire population to be assigned to shelter, an assignment plan would not reduce the number of people on street unless it could shorten the required sheltering time. It is able to do this by assuring that every person initially starts for and travels directly to the shelter where he can be sheltered. Thus, ultimately, the real advantage in an assignment plan will be to reduce the required sheltering time.

3.22 Overcrowding of Marked Shelters. The deficiency of shelter capacity in Montgomery County, when only marked spaces are considered, brings forth the question of whether the marked shelter areas could be more efficiently utilized. Without analyzing the effects on shelter living conditions, an attempt has been made to answer this question by evaluating two arbitrary levels of overcrowding: 50 percent and 100 percent. This, in effect, reduces the unit area of all spaces to 2/3 and 1/2 the original unit area. Although this policy was not recommended by the preliminary planning study, its possibilities should be considered.

3.23 Since overcrowding would raise the shelter capacities throughout the county, the original assignment data based on lower capacity are somewhat meaningless. The investigation into the overcrowding policy is based entirely on unassigned movement criteria because the exercise of producing an overcrowded assignment plan for marked shelters as input data is not within the scope of this report.

3.24 Unassigned movements to 50-percent and 100-percent overcrowded and normal-capacity marked spaces are compared in Figure 8.

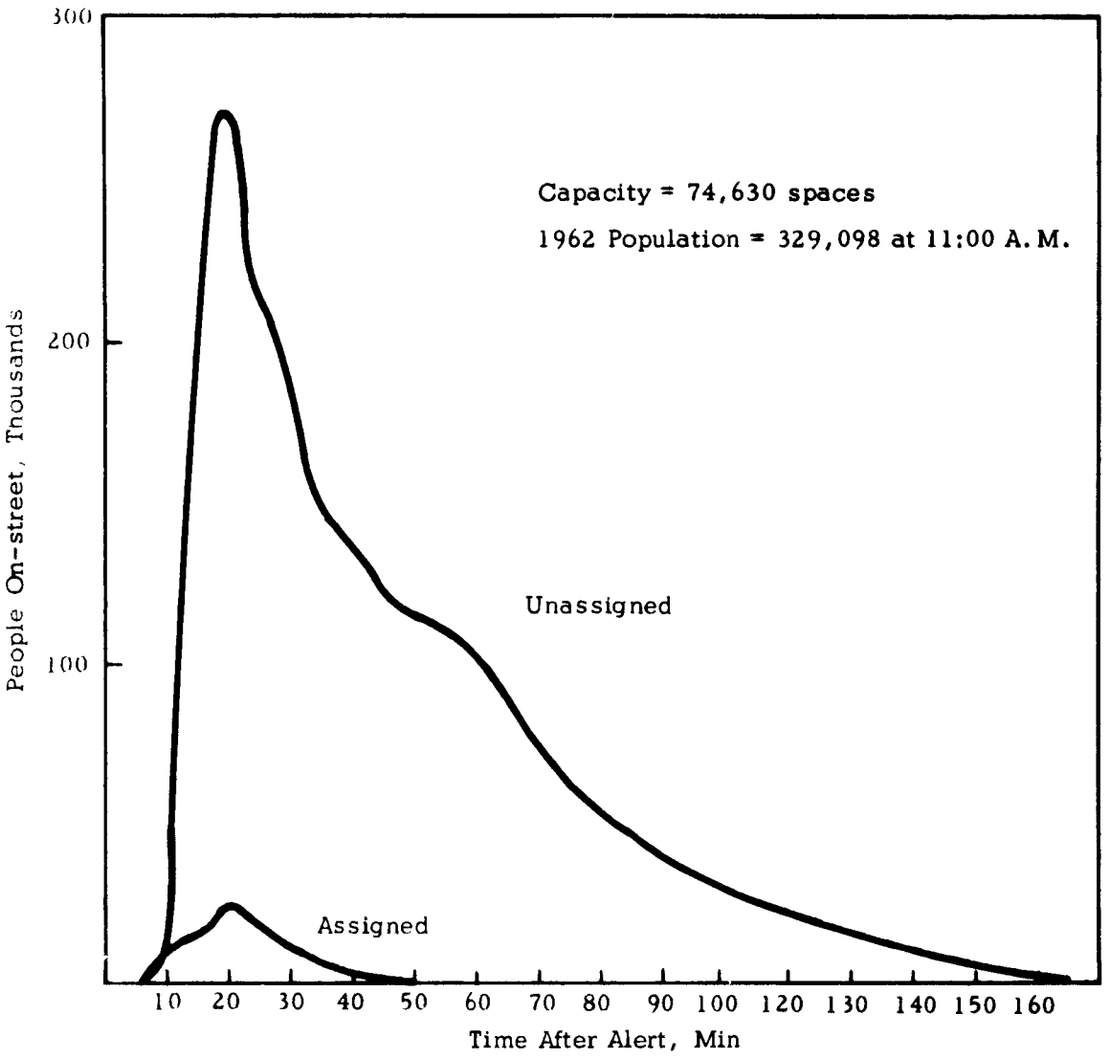

FIGURE 7. COMPARISON OF NUMBER OF PEOPLE ON-STREET DURING ASSIGNED AND UNASSIGNED MOVEMENTS TO MARKED SPACES (1962 DAYTIME)

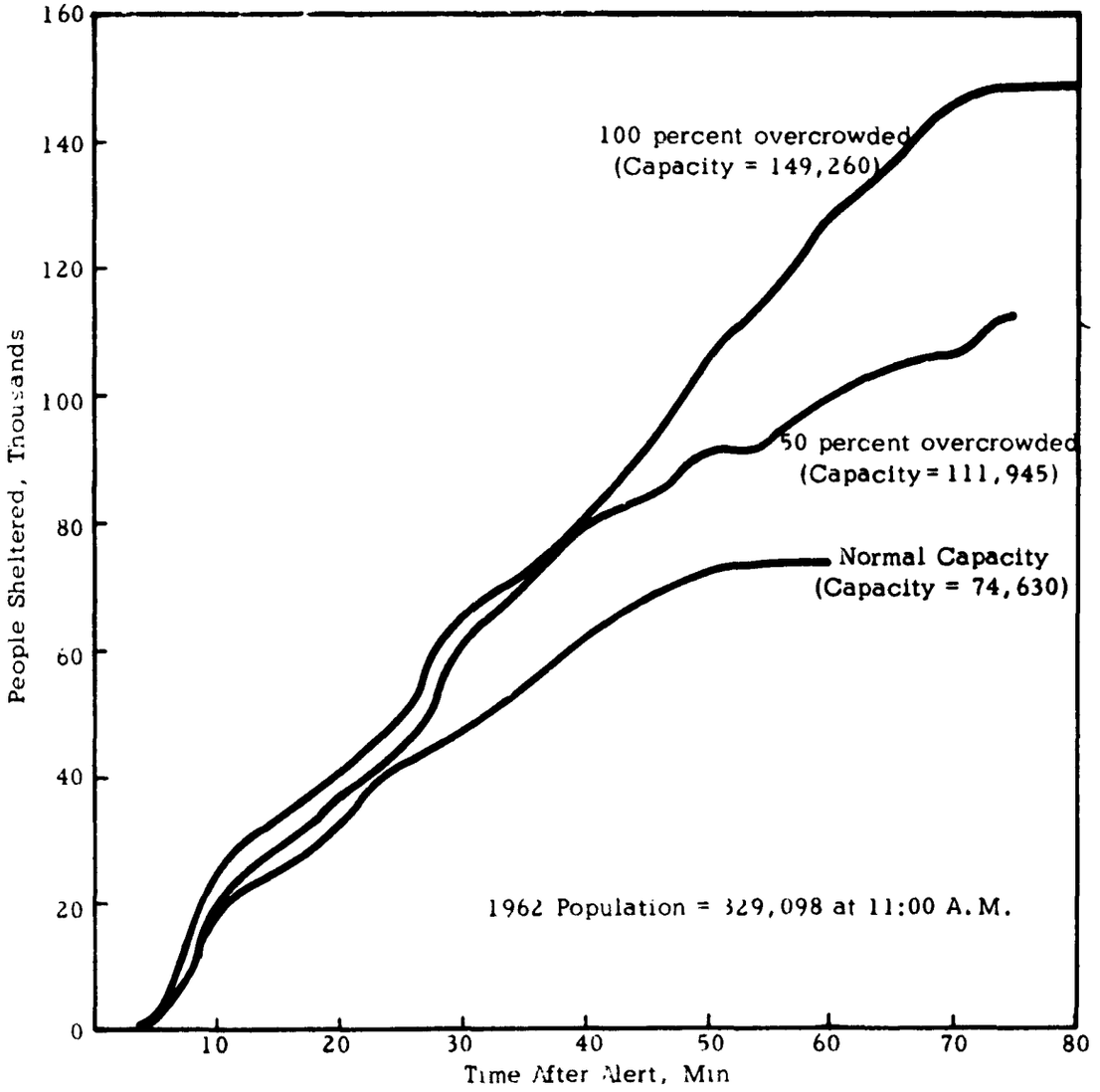

FIGURE 8. COMPARISON OF PEOPLE SHELTERED IN OVERCROWDED, UNASSIGNED MOVEMENTS TO MARKED SPACES (1962) DAYTIME

3.25 The increase in the number of people sheltered versus time for the overcrowding policies is due entirely to increased capacity. The overcrowding provides no improvement in shelter distribution. Although the two overcrowding policies result in more people being sheltered at all values of time, more time must be available if the movements are to be completed. The movement to the shelters overcrowded by 50 percent requires approximately 75 minutes to complete the sheltering of 34 percent of the daytime population. About 46 percent of the daytime population can be sheltered if the shelters are overcrowded by 100 percent, and approximately 80 minutes are required for completion. The increment of time required to obtain the additional 50-percent overcrowding is small because a large shelter deficiency still exists even when overcrowding is considered. The number of persons arriving at the large shelter complexes from the surrounding areas is of such magnitude that the additional shelter spaces are filled in very little additional time.

Utilization of Existing and Possible Shelters

3.26 In addition to the proposed assignment policy utilizing marked shelters only, the SRI study presents planning information on which assignment policies utilizing additional existing and possible shelter spaces could be based. The people sheltered versus time curves for these policies are shown in Figure 9, along with a curve for the assigned movement to marked shelters only.

3.27 The increase in the number of people sheltered when all the existing and possible shelters are included is due to both increased capacity and better shelter distribution. Under the assigned movement to existing shelters, 63 percent of the spaces are utilized and 32 percent of the daytime population is sheltered; if only the possible shelters are utilized, 59 percent of the available spaces is used, and only 41 percent of the daytime population can be sheltered. This lack of 100-percent shelter utilization does not denote inefficiency or error in the assignment, but illustrates the problems of shelter distribution in most areas of the county. A large number of the additional spaces made available in the existing or possible categories are in or adjacent to areas currently having adequate or excess marked spaces. Preparation of these additional spaces for use would be wasted effort under the assignment plan criteria because not enough people are located within the maximum distance of shelter. This is true even though a countywide shelter deficit exists.

3.28 The time required to complete the movement to existing shelters and the movement to possible shelters is approximately 60 minutes and 65 minutes, respectively. Both times are slightly longer than the time required for movement to marked spaces only. The additional spaces that are used, therefore, can be utilized with minimum requirements for

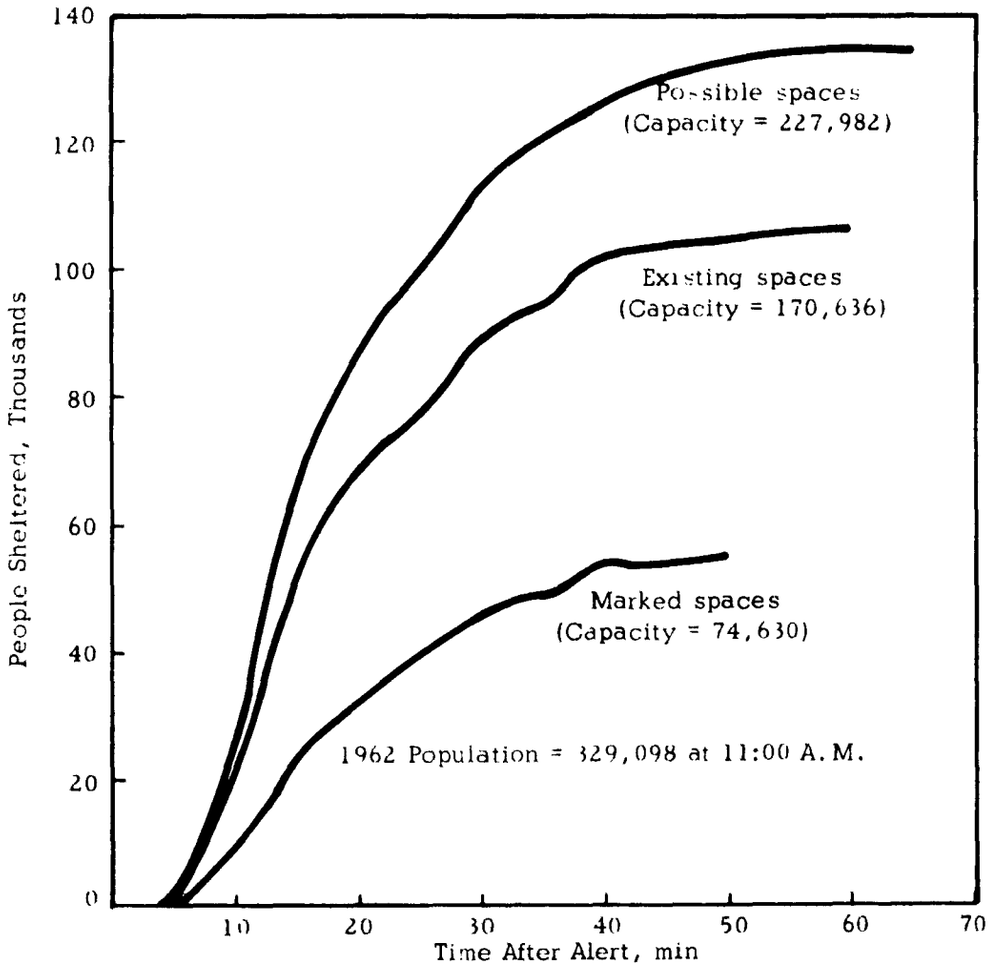

FIGURE 9. COMPARISON OF NUMBER OF PEOPLE SHELTERED IN ASSIGNED MOVEMENTS TO MARKED EXISTING AND POSSIBLE SPACES (1962 DAYTIME)

additional time. This is a direct result of the use of only the conveniently located existing and possible shelters.

Unassigned Movement to Possible Shelters

3.29 Thus far, all the proposed and alternative policies investigated have shown a deficiency of fallout shelter capacity. In an attempt to provide shelter for more of the population, a greater utilization of all possible shelters has been considered. All possible shelters can be filled in an unassigned movement, and more capacity can be obtained by overcrowding these spaces. Figure 10 shows the result of: (1) unassigned movement to possible shelters (normal capacity), (2) unassigned movement to possible shelters overcrowded by 50 percent, and (3) unassigned movement to possible spaces overcrowded by 100 percent.

3.30 In the normal-capacity unassigned movement to possible facilities, 70 percent of the daytime population can be sheltered in a total time of 95 minutes. This movement requires about 50 percent more time than unassigned movement to marked shelters to utilize the additional capacity gained.

3.31 The 50-percent overcrowded, possible shelters are filled in unassigned movement in about 125 minutes and provide shelter for 100 percent of the county's daytime population. The time required is considerably more than the time required for the non-overcrowded movements and again is the result of increased capacity without improved distribution. This policy does not, however, provide shelter for the entire nighttime population; it leaves about 8 percent still unsheltered.

3.32 An unassigned movement to 100-percent overcrowded possible spaces likewise shelters 100 percent of the daytime population, but can also shelter the entire nighttime population as well. The daytime movement can be completed in 120 minutes, which is only slightly less than the movement to the 50-percent overcrowded shelters. The reason is, of course, that while both situations are capable of sheltering the daytime population, 100-percent overcrowding is only slightly more effective in reducing sheltering time because although it allows shelters in areas of deficiency to be overcrowded by 100 percent, shelters in some areas of excess may not be overcrowded by 100 percent.

Secondary Protection Policies

3.33 Up to this point, this section has concentrated on primary policies concerning the segment of population that moves to public shelter. It is now necessary to consider the secondary policies, recommended by SRI and summarized in paragraph 3.2, which deal with persons not assigned to shelter.

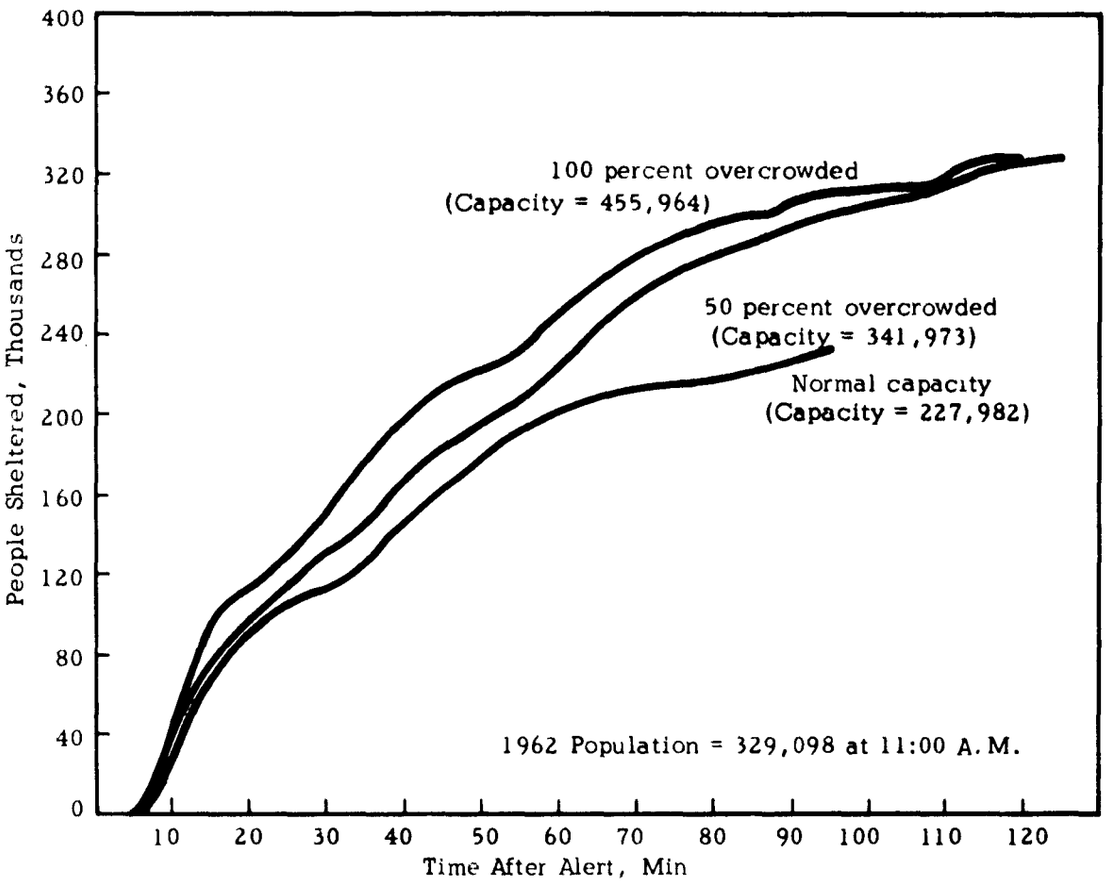

FIGURE 10. COMPARISON OF PEOPLE SHELTERED IN UNASSIGNED MOVEMENTS TO POSSIBLE SPACES (1962 DAYTIME)

3.34 The first alternative policy is to try to fill excess shelter space, i.e., shelter spaces to which no one has been assigned. In the daytime, the only facility having an excess of spaces over the number of people assigned to it (when only marked spaces are considered) is NIH. At night, excess spaces are available at both NIH and NOL. As explained in paragraph 3.20, the advantage of the preliminary assignment plan is the reduction of the number of persons on street, many of whom cannot be sheltered because of the large shelter deficit. However, this plan leaves about 17,000 marked shelter spaces unfilled at NIH during the day. The policy proposed by this report calls for the filling of these spaces by unassigned people who are near to NIH. If people were to follow this policy, however, it is possible that more than 17,000 people would attempt to fill the excess NIH spaces. For example, assume that two out of every three persons, presently unassigned but living within a 2-mile radius of NIH, attempted to fill these excess spaces. Approximately 33,000 persons would be competing for 17,000 excess spaces. The result would be that all marked spaces would be filled, which eliminates one of the disadvantages of the assignment plan, but approximately 16,000 people who cannot be sheltered would be left on street, which somewhat negates the advantage of the plan. It seems logical, therefore, that either the 17,000 people closest to NIH should be included in the preliminary assigned plan or be encouraged to stay home.

3.35 The second recommended policy for those unassigned to shelter is to occupy their own or a neighbor's basement. Perhaps this is the most acceptable policy for unassigned people since many have already considered this eventuality and have made some preparations. It is a policy that can be carried out quickly. The only question left unanswered is if sufficient protection will be provided.

3.36 The final recommended policy for unassigned people is for them to move to an up-county area and seek shelter in someone's basement. Such a movement would require a minimum of five hours[3/] to complete, which is not within the range of anticipated warning times. The policy also requires the up-county residents to accept a large number of strangers into their homes. Even if these requirements can be met, advantage has been gained only if the up-county area is less affected by damage and fallout than the remainder of the county. All things considered, this final policy does not appear to be feasible.

3/ Stanford Research Institute, Toward Effective Civil Defense in Montgomery County and Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

SUMMARY OF FINDINGS

3.37 The findings from evaluation of the Operational Plan are summarized in Table 1 and Figure 11. Conclusions based on these findings are presented in Section V.

TABLE 1

SUMMARY OF THE RESULTS OF THE EVALUATION OF THE OPERATIONAL PLAN POLICIES FOR MONTGOMERY COUNTY, MARYLAND

Movement (to)	Time of Day	Shelter Capacity	Time Required to Complete Movement, Min	Utilization of Shelter Capacity, Percent	Percentage of Population Sheltered									
					Total	Time After Alert, Min								
						15	30	45	60	75	90	105	120	135
Marked Spaces (Assigned)	11:00 a.m.	74,630	50	76	17	6	13	16	17					
Marked Spaces (Assigned)	2:30 a.m.	74,630	55	66	13	4	9	10	13					
Existing Spaces (Assigned)	11:00 a.m.	170,636	60	63	32	6	7	31	32					
Possible Spaces (Assigned)	11:00 a.m.	227,982	65	59	41	20	34	39	40	41				
Marked Spaces (Unassigned)	11:00 a.m.	74,630	55	100	23	6	14	21	23					
Marked Spaces (Unassigned)	2:30 a.m.	74,630	60	100	20	4	10	11	20					
Possible Spaces (Unassigned)	11:00 a.m.	227,982	95	100	70	21	35	49	62	65	69	70		
50 Percent Overcrowded Marked Spaces (Unassigned)	11:00 a.m.	111,945	75	100	34	9	18	25	30	34				
100 Percent Overcrowded Marked Spaces (Unassigned)	11:00 a.m.	149,260	80	100	46	10	20	28	39	44	46			
50 Percent Overcrowded Possible Spaces (Unassigned)	11:00 a.m.	341,973	125	96	100	24	39	56	69	83	89	95	99	100
100 Percent Overcrowded Possible Spaces (Unassigned)	11:00 a.m.	455,964	120	72	100	30	46	64	76	89	94	97	100	

1962 Population = 329,098 at 11:00 a.m.
369,491 at 2:30 a.m.

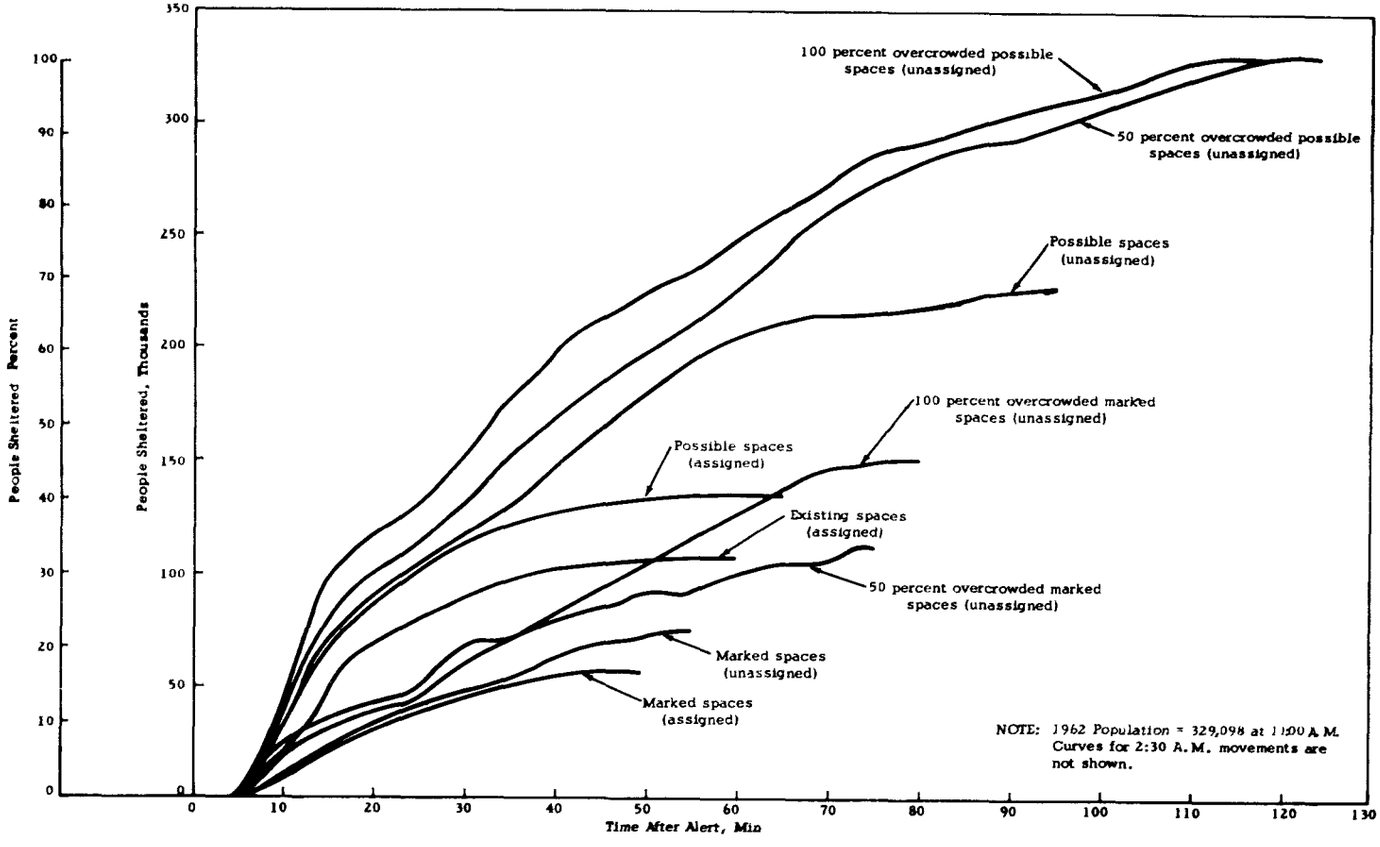

FIGURE 11. SUMMARY OF SHELTERING CURVES FOR THE OPERATIONAL PLAN POLICIES AT 11:00 A.M.

IV. DEVELOPMENTAL PLAN EVALUATION

INTRODUCTION

4.1 In contrast to the Operational Plan, the Developmental Plan is concerned with future and longer term shelter improvements. The policies recommending these improvements are of significant importance for a continuing increase in survival capability.

4.2 This section is devoted to evaluating shelter utilization proposed in SRI's Developmental Plan.

4.3 The preliminary planning study selected 1968 as the year for completion of the Development Plan in Montgomery County, and the ORI evaluation is based on the estimated population and projected possible public fallout shelter for this date. The residential population and fallout shelter inputs to the evaluation model are taken directly from the SRI study. Anticipated land usage is projected from the current land usage with the aid of the Maryland National Capital Park and Planning Commission general plan for the regional area.[1/] Employment data are projected from the 1960 census figures, based on anticipated population changes. All other inputs remain the same as in the Operational Plan Evaluation.

4.4 The basic population characteristics are expected to apply to the 1968 population. Again, only the daytime evaluations are used, and nighttime movements may be assumed to lag the daytime movements the same as shown in Figures 4 and 5.

1/ Maryland National Capital Park and Planning Commission, On Wedges and Corridors, 1962.

4.5 The SRI Developmental Plan portion of the Montgomery County study proposes that additional shelter capacity be obtained through the following policies:

a. Mark existing shelters that are not presently marked,

b. Improve and mark the possible facilities that are advantageously located,

c. Incorporate shelters in certain buildings expected to be built between now and 1968,

d. Incorporate shelters in existing and planned public buildings, particularly schools, in areas of shelter deficit, and

e. Construct shelters in tract housing and individual homes.

The policy of building shelters in tract housing and individual homes is listed, but since estimates of the number of such shelters expected to be built by 1968 have not been made, no evaluation of this policy is undertaken.

4.6 The proposed policies are not alternative policies. All have been recommended, and each has been considered a necessary step in the anticipated future fallout shelter program. Evaluation is made, however, at various steps to illustrate incrementally the effects of each policy on the movement to shelter. In addition, some additional policies, not proposed in the SRI Developmental Plan, are discussed.

4.7 The Developmental Plan did not include an assignment of persons to specific shelters, and since it is beyond the scope of this study to formulate an assignment, all policies are evaluated on the basis of an unassigned movement. This is beneficial to the evaluation because it eliminates possible interactions between assignment itself and the shelter-improvement policies under evaluation.

4.8 The Developmental Plan provides for the sheltering of the peak daytime and nighttime population of each census tract. Since many people may be included in the peak population of more than one census tract, total shelter capacity will exceed the number of persons in the county at any particular time. The advantage of this excess is that shelter capacity may be distributed in a manner that more closely coincides with all possible daily population configurations; it represents, however, an increased demand on resources. When the policies based on the peak population estimates are evaluated for 11:00 A.M., some of the proposed shelter capacity may not be utilized because of the instantaneous nature of the prediction of county population used in the evaluation model.

RESULTS OF ANALYSES

4.9 As a base curve for the policy evaluations, the movement of the projected 1968 population to currently marked shelters has been calculated, and the results are shown in Figure 12. This would be the resulting movement if no shelter improvements are made prior to 1968. The movement requires 50 minutes to complete, which is about 5 minutes faster than the unassigned movement of the 1962 population to these same shelters. The shorter sheltering time is due to increased growth and density in the population around the shelters, which are filled by persons who have a relatively short traveling time. Except for the slightly more rapid sheltering, the shape of the curve is almost identical to the 1962 curve, and all other characteristics are similar. A 100-percent utilization of the shelters is obtained by the unassigned movement in which the entire population seeks shelter. Although the shelters can be more rapidly filled by the 1968 population, the situation is more critical because only 17 percent of the daytime population can be sheltered, whereas these facilities would shelter 23 percent of the 1962 daytime population in an unassigned movement.

Marking Existing Shelters

4.10 The first policy to be considered is the securing, marking, and stocking of all existing shelters. This is the most feasible method of obtaining additional spaces and also one of the least expensive. The resultant curve, indicating the number of people sheltered versus time in the movement to existing shelters, is shown in Figure 13, along with the base or "do nothing" curve. The merits of making these existing spaces available, which would result in both increased capacity and improved shelter distribution, is apparent. The time required to complete the movement is 70 minutes, which is 20 minutes longer than the movement to marked shelters. Additional time is required to utilize all of the additional shelters. However, if additional time is not available, this policy provides sufficient capacity and location improvement to shelter twice the number of people as when only marked shelters are considered. Thirty-nine percent of the daytime population can be sheltered in the existing spaces.

Improving Possible Shelters

4.11 The next most obvious policy to consider is improvement of the possible shelters. However, since these shelters are generally distributed in the same manner as the existing and marked shelters, i.e., concentrated in the commercial centers, many spaces have not been recommended for improvements in the SRI planning study. The study neglects these spaces only because it recommends sufficient shelters in other policies for the sheltering of the entire population. The evaluation, then, considers only the addition of those possible spaces recommended for improvement by the SRI Developmental Plan.

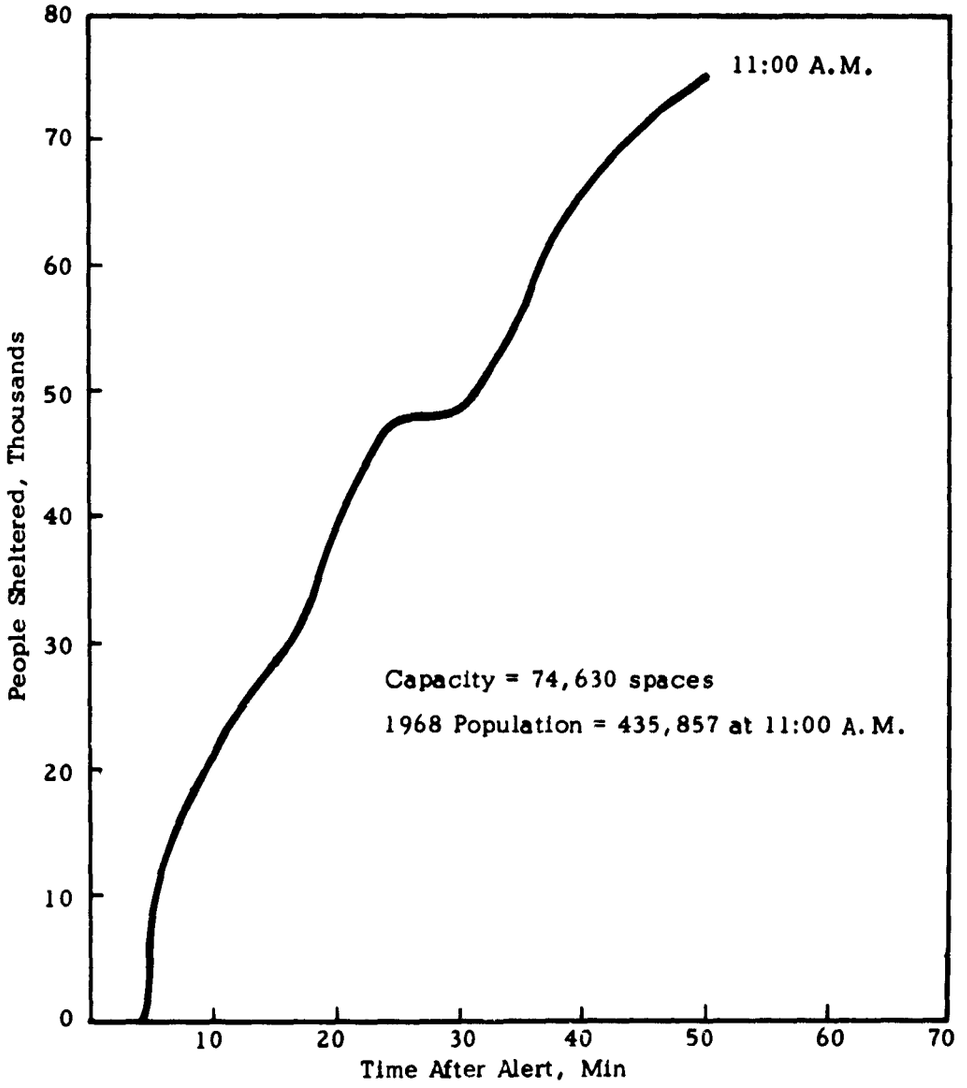

FIGURE 12. NUMBER OF PEOPLE SHELTERED IN AN UNASSIGNED MOVEMENT TO MARKED SPACES (1968 DAYTIME)

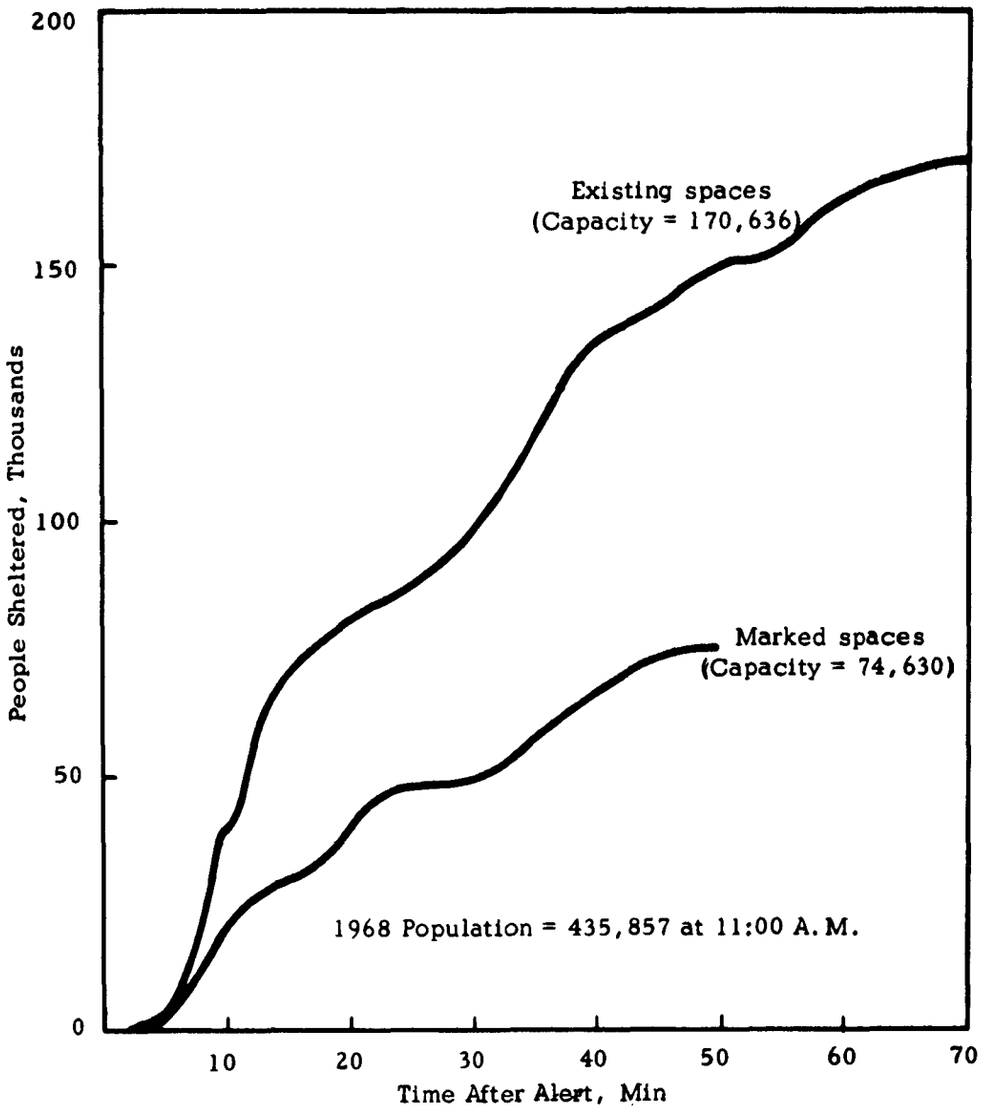

FIGURE 13. COMPARISON OF PEOPLE SHELTERED IN UNASSIGNED MOVEMENTS TO MARKED AND EXISTING SPACES (1968 DAYTIME)

4.12 The people sheltered versus time curve for a daytime movement when the possible spaces recommended for improvement are included is presented in Figure 14. The curve for the movement prior to the inclusion of these spaces is also shown as a comparison. Note that the new curve represents a better sheltering situation and requires only slightly longer completion time than for existing spaces. All of the possible spaces recommended for improvement can be utilized if a small additional time is available. This is primarily due to selecting possible shelters only when they are conveniently located. The total movement requires 75 minutes and shelters 43 percent of the daytime population.

Shelters in New Construction

4.13 The next recommended policy is the incorporation of fallout shelters in buildings to be constructed within the Developmental Plan completion period. The estimates for the location and capacity of these shelters are projected in the SRI report from anticipated building construction and are used in the evaluation model without alteration. The shelters provided by this policy are not considered by themselves, but rather as an addition to the previous policy (calling for the improvement of certain possible facilities) because it is assumed that the improvement and marking of present possible shelters will be completed first.

4.14 The movement to shelter resulting from the addition of these new shelters is shown by the sheltering curve in Figure 15, where it is compared with a movement to the possible spaces proposed for improvement. The improvement in the sheltering curve is the result of both increased capacity and improved distribution. The movement is completed in 85 minutes, which is slightly longer than the previously evaluated movement. However, the curve indicates that a large portion of the shelters incorporated in the new commercial construction can be utilized without an increase in time required to complete the movement. Under this policy, 64 percent of the daytime county population can be sheltered in the 85 minutes.

Construction of Shelters in Schools

4.15 Up to this point, all shelter-improvement policies have been characterized by the noticeable concentration of shelters in the business and commercial centers of the county. To provide a greatly improved distribution of shelters, which is a prime requisite for increased sheltering rates, the SRI Developmental Plan recommends construction of fallout shelters at public schools located in areas of shelter deficiency and in sufficient capacity to provide shelter for projected peak population.

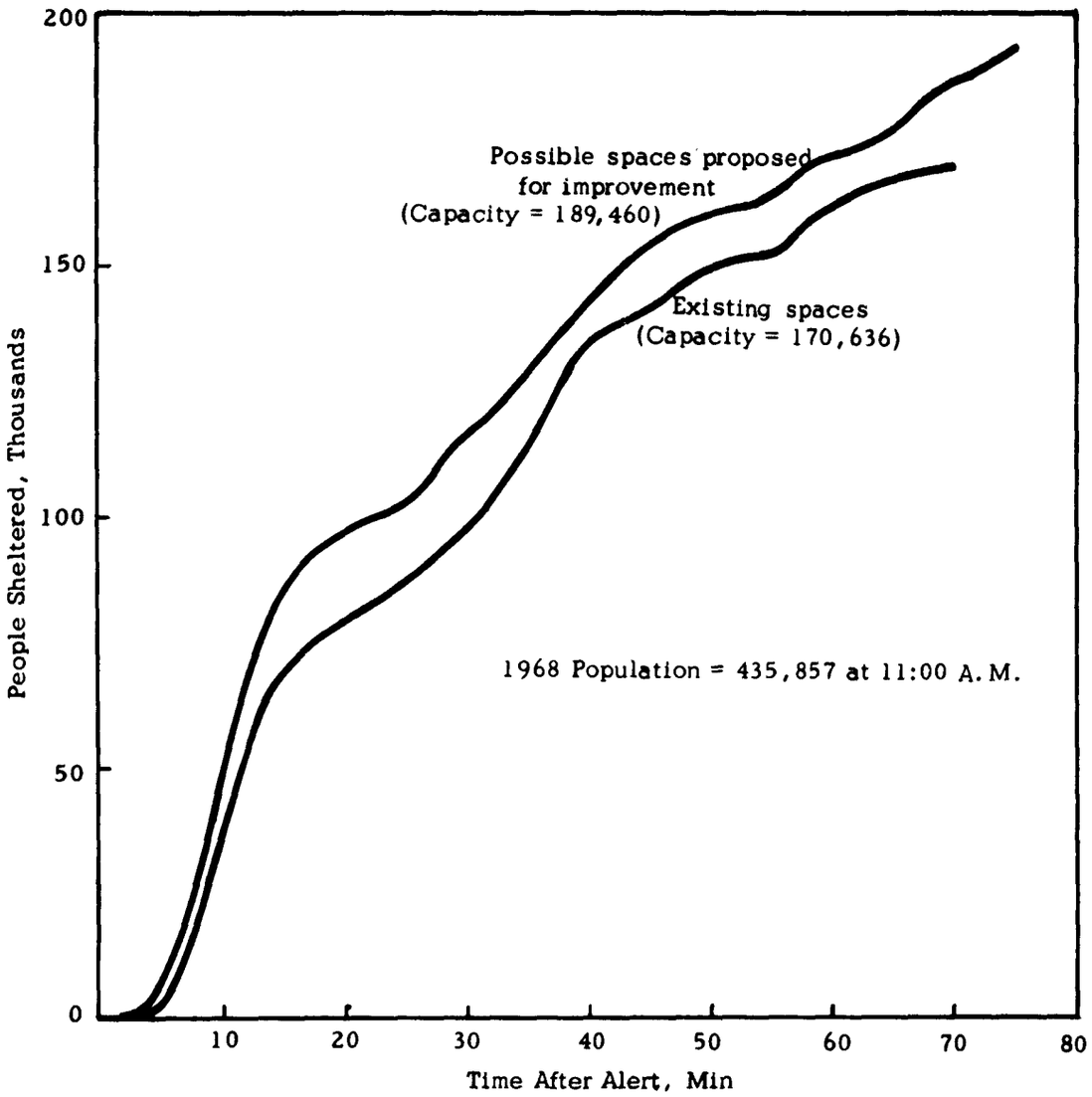

FIGURE 14. COMPARISON OF PEOPLE SHELTERED IN UNASSIGNED MOVEMENT TO EXISTING AND POSSIBLE SPACES PROPOSED FOR IMPROVEMENT (1968 DAYTIME)

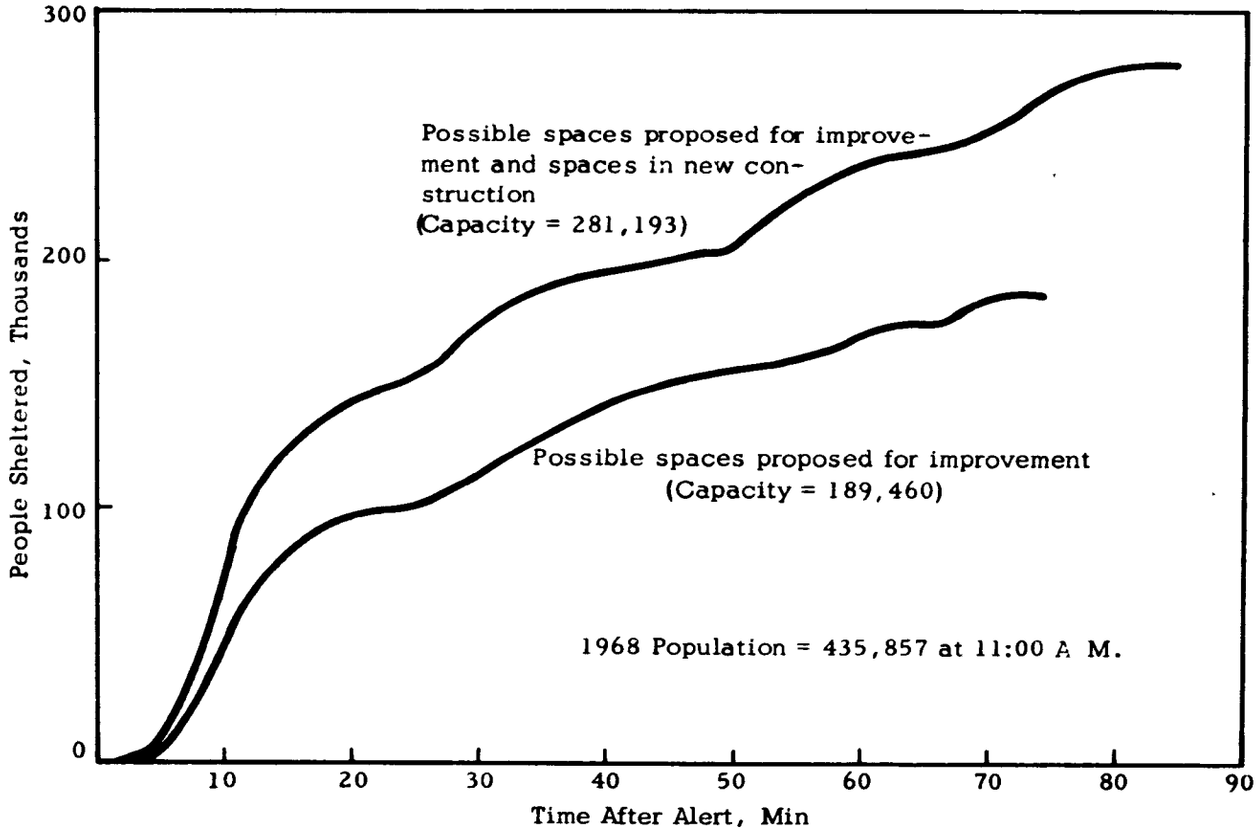

FIGURE 15. COMPARISON OF PEOPLE SHELTERED IN UNASSIGNED MOVEMENTS PRIOR TO AND AFTER THE ADDITION OF SPACES IN NEW CONSTRUCTION (1968 DAYTIME)

4.16 Figure 16 shows the resultant daytime movements both before and after the proposed school shelters are added to the spaces provided in the previous policies. In this case, the entire population is sheltered and the movement requires 50 minutes, which is a notable reduction from the time required to complete the movement prior to the addition of these shelters. Not only can the additional shelters be utilized without requiring additional time, but they actually reduce the overall time required to protect more people. This is true because with the addition of these spaces all people would be located nearer shelter. Without these spaces, many people would have to seek shelter in other census tracts. The distances, both average and maximum, to adequate shelter are therefore greatly reduced.

4.17 Since shelter-improvement policies in the SRI Developmental Plan are based on peak population estimates, some shelter spaces would not be utilized in daytime (11:00 A.M.) movement. A lesser number would not be utilized in nighttime (2:30 A.M.) movement. However, it is possible that the spaces not utilized at 11:00 A.M. and 2:30 A.M. may be utilized at some other time of the day, and, conversely, some of the spaces utilized at 11:00 A.M. and 2:30 A.M. may not be utilized at other times. By providing shelter for the peak population, a more rapid movement is possible, but a larger number of spaces must be provided.

4.18 The people sheltered versus time curve for the movement to (a) possible shelters recommended for improvements, plus (b) shelters incorporated in new construction, plus (c) shelters proposed to be built at schools, represents an incremental evaluation of the proposed shelter improvement program presented by SRI. The order in which each portion is evaluated was chosen according to the logical sequence in which the policies may be completed, although it is recognized that the portions may be in various stages of completion.

Overcrowding of Shelters

4.19 As in the Operational Plan, the Developmental Plan portion of the planning study does not consider the possibility of shelter overcrowding. However, until all of the proposed policies are nearly completed, the entire 1968 county population cannot be sheltered at normal capacity. Therefore, as an interim policy, overcrowding of the available shelters should be considered. Two overcrowding policies are evaluated:

a. 100-percent overcrowding of those possible shelters presently available and proposed for improvement in the Developmental Plan.

b. 100-percent overcrowding of those shelters included in new construction, in addition to the shelters of (a) above.

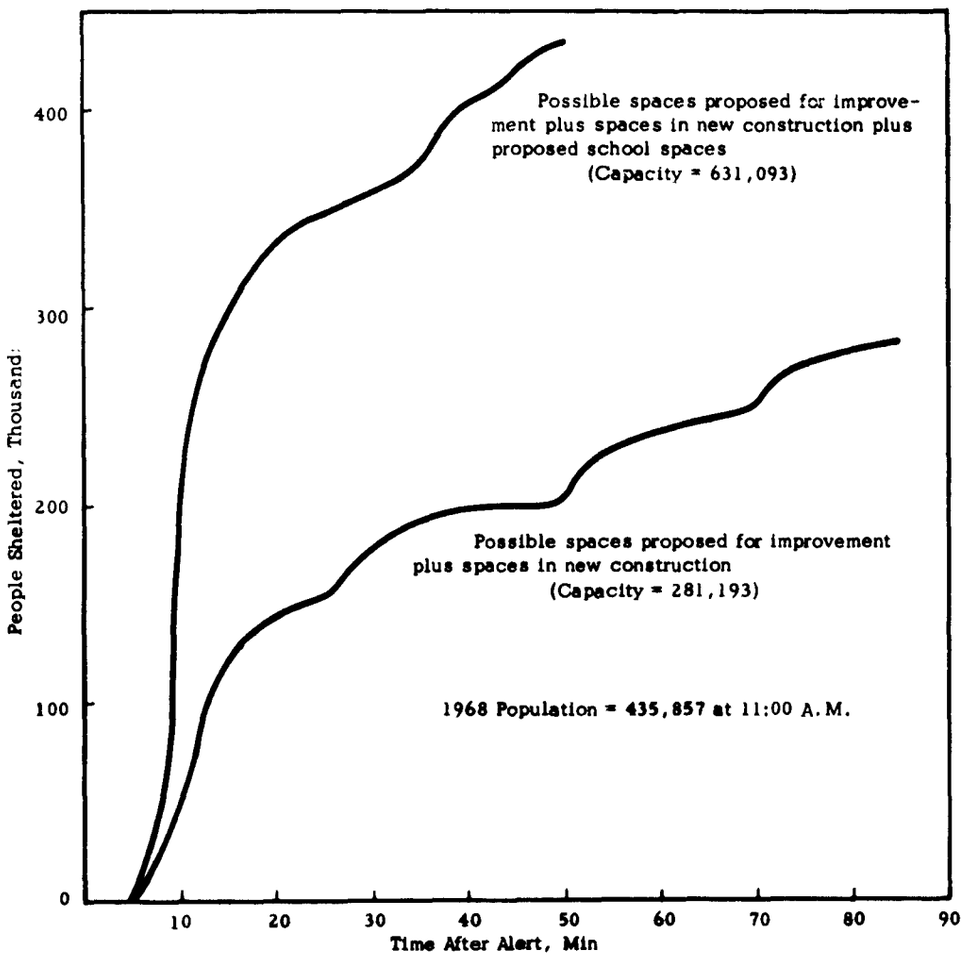

FIGURE 16. COMPARISON OF PEOPLE SHELTERED IN UNASSIGNED MOVEMENTS PRIOR TO AND AFTER THE ADDITION OF PROPOSED SCHOOL SPACES (1968 DAYTIME)

4.20 The sheltering curves for both of the overcrowded movements are shown in Figure 17, along with the movements to the same shelters at normal capacity, i.e., without overcrowding. The first overcrowding policy shelters 87 percent of the daytime population in 120 minutes. Although additional time is required to complete the overcrowded movement, some improvement in the sheltering curve at practically any time during the movement may be noted. The second overcrowding policy requires 95 minutes to shelter the entire daytime population. Again, the completion time is greater than for the normal capacity movement, but more people are sheltered throughout the entire curve.

4.21 The second overcrowding policy curve is compared with the completed-shelter improvement program in Figure 18. Both policies shelter the entire population. However, the overcrowding policy utilizing possible and new construction capacity requires 95 minutes for completion of the movement, whereas the completed shelter improvement program, including the school shelters, requires only 50 minutes. This further illustrates the effects not only of sufficient capacity, but also adequate distribution of this capacity.

SUMMARY OF FINDINGS

4.22 The findings from evaluation of the Developmental Plan are summarized in Table 2 and Figure 19. Conclusions based on these findings are presented in Section V.

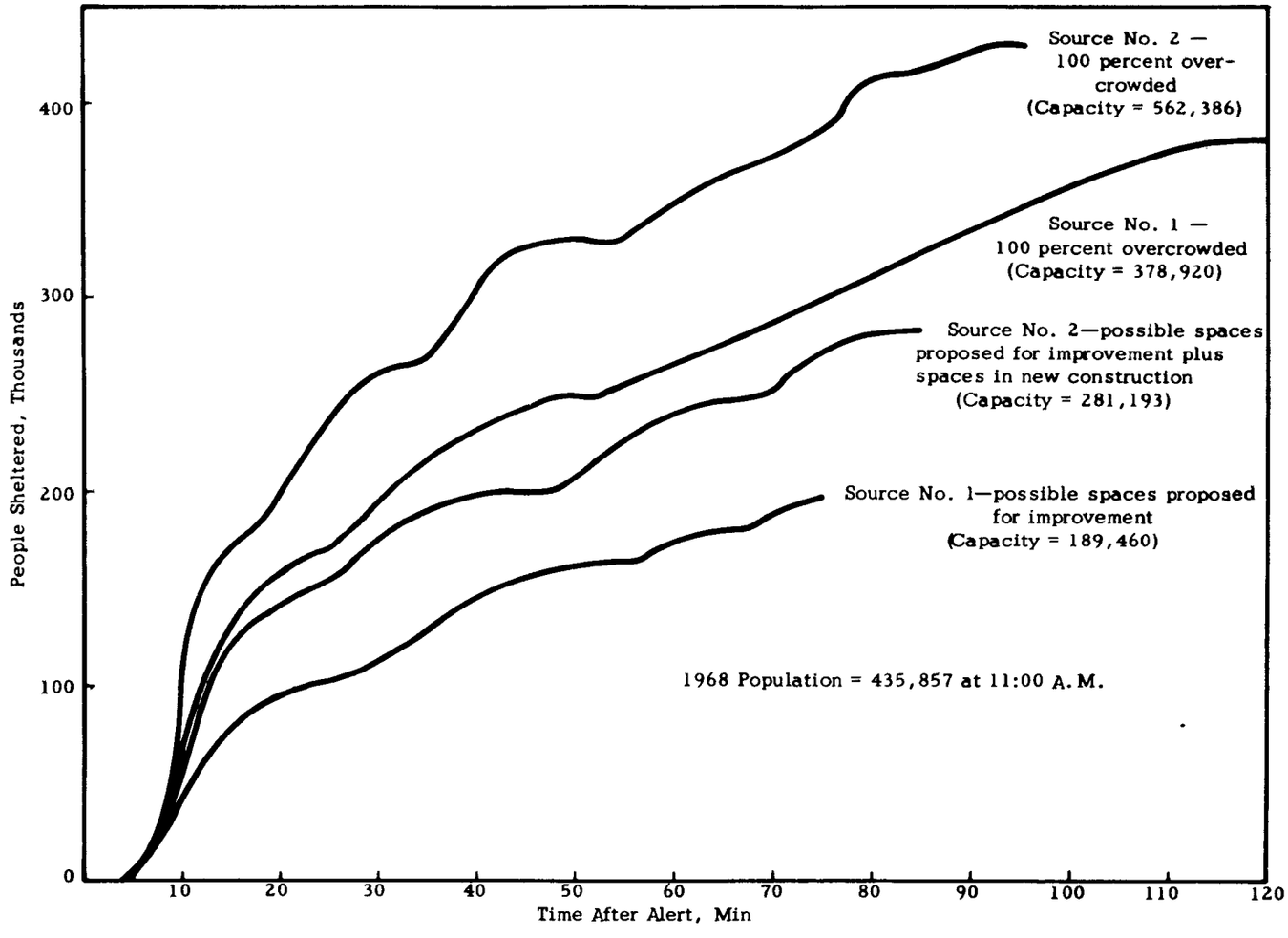

FIGURE 17. COMPARISON OF PEOPLE SHELTERED WITH OVERCROWDING IN UNASSIGNED MOVEMENTS PRIOR TO AND AFTER THE ADDITION OF SPACES IN NEW CONSTRUCTION (1968 DAYTIME)

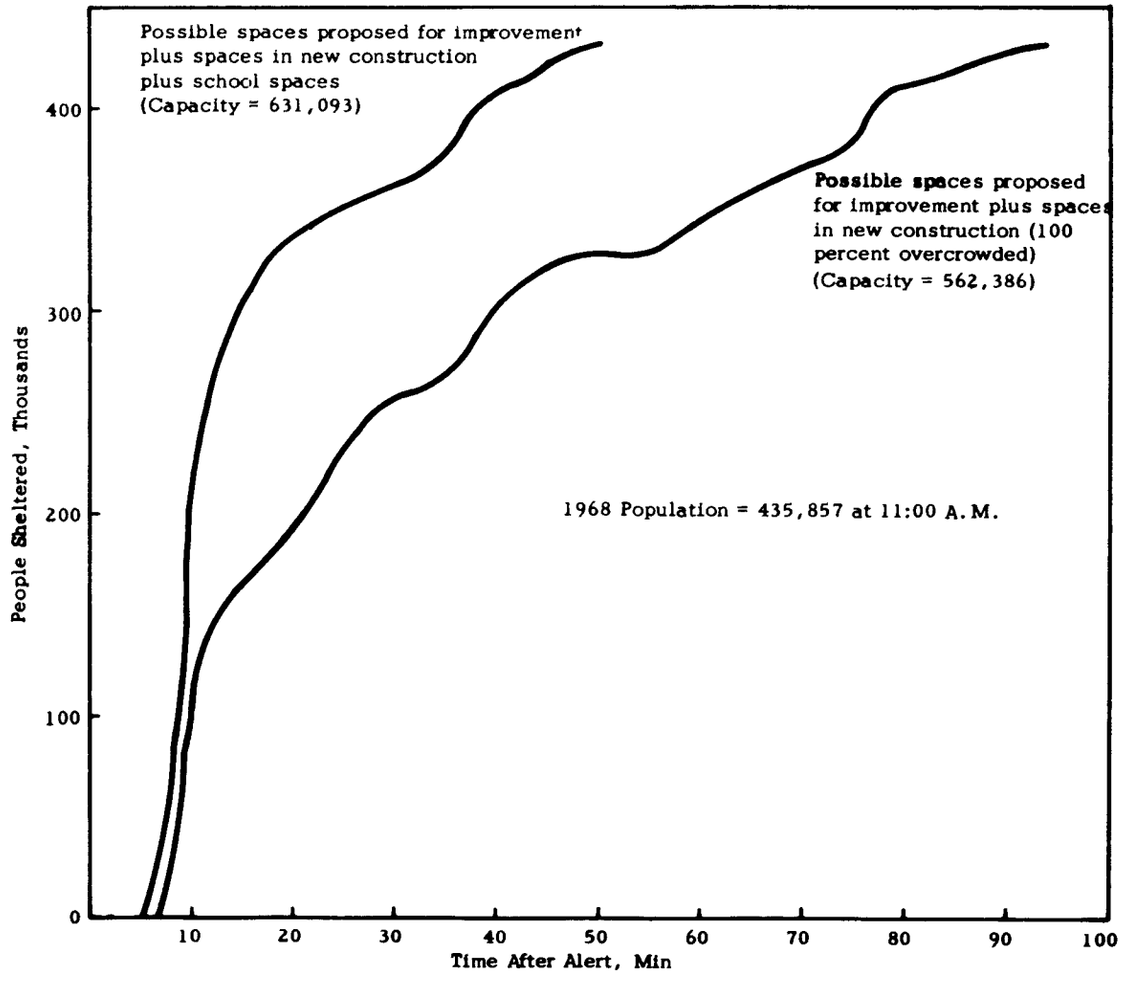

FIGURE 18. COMPARISON OF TWO PLANS FOR FULLY SHELTERING THE 1968 DAYTIME POPULATION

TABLE 2

SUMMARY OF THE RESULTS OF THE EVALUATION OF THE DEVELOPMENTAL PLAN POLICIES FOR MONTGOMERY COUNTY, MARYLAND

Movement * (to)	Shelter Capacity, Spaces	Time Required to Complete Movement, Min	Utilization of Shelter Capacity, Percent	Percentage of Population Sheltered									
				Total	Time After Alert, Min								
					15	30	45	60	75	90	105	120	135
Marked Spaces	74,630	50	100	17	7	11	16	17					
Existing Spaces	170,636	70	100	39	15	23	32	38	39				
Proposed Possible Spaces	189,460	75	100	43	19	26	35	39	43				
Proposed Possible Spaces plus Spaces in New Construction	281,193	85	100	64	23	42	46	54	62	64			
Proposed Possible Spaces plus Spaces in New Construction plus Proposed School Spaces	631,093	50	69	100	69	83	97	100					
100-Percent Overcrowded Proposed Possible Spaces	378,920	120	100	87	26	45	55	62	69	77	84	87	
100-Percent Overcrowded (Proposed Possible Spaces plus Spaces in New Construction)	562,386	95	77	100	40	59	73	78	88	98	100		

* All movements are unassigned at 11:00 a.m.

Note: 1968 Population = 435,857 at 11:00 a.m.
469,120 at 2:30 a.m.

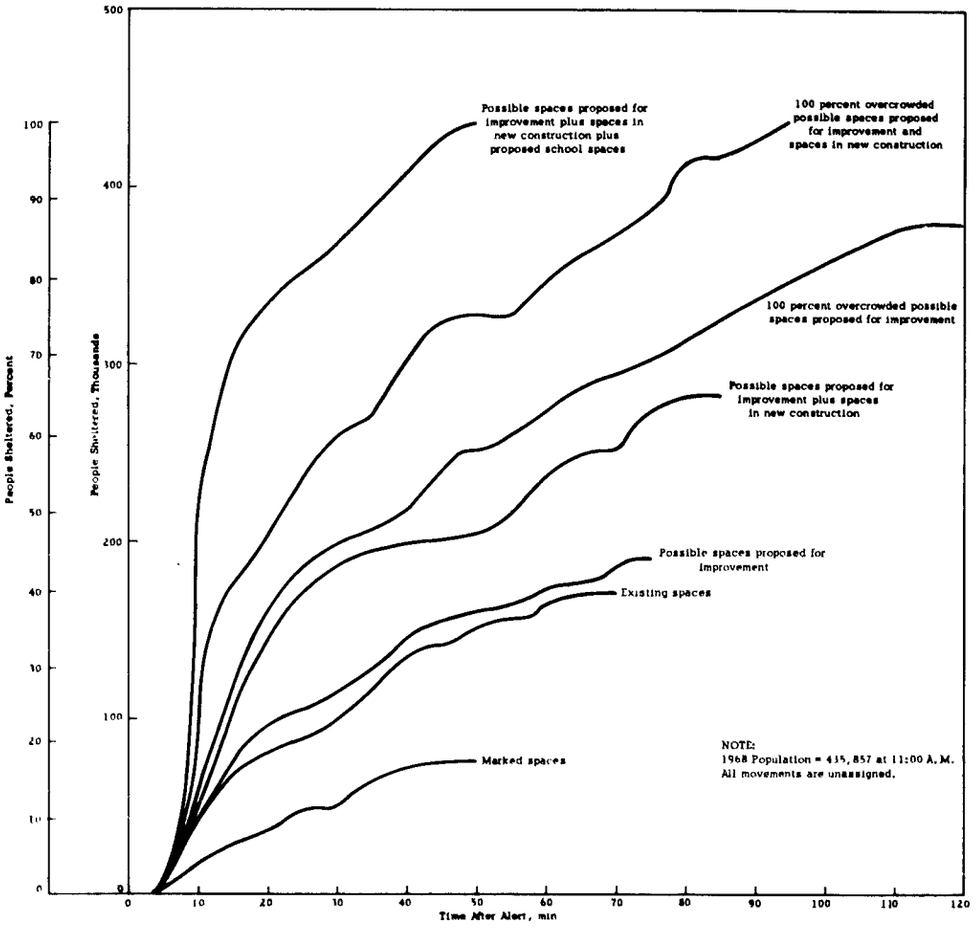

FIGURE 19. SUMMARY OF SHELTERING CURVES FOR THE DEVELOPMENTAL PLAN POLICIES AT 11:00 A.M.

V. CONCLUSIONS

INTRODUCTION

5.1 This section examines the information derived in the preceeding sections. Advantages and disadvantages of the various planning policies are listed, and conclusions concerning the relative merits of these policies are drawn. Conclusions are presented in regard to specific Montgomery County results and results that are more general and which may be true in any area.

MONTGOMERY COUNTY

5.2 The following conclusions concern policies as they apply to Montgomery County.

Assignment

5.3 Assignment, as considered here, refers to the predetermination of the movement to shelter pattern, as presented by SRI in their Montgomery County Planning Report. Specific assignments are made only in the Operational Plan portion of the SRI report, and the conclusions, therefore, also refer only to this portion.

5.4 Advantages. Assigned movement results in fewer people on street during the movement to shelter than in the unassigned movement. The peak on-street population is less, and the time required to clear the streets is less during assigned movement. This advantage is brought about by allowing only those people assigned to shelter to initiate movement.

5.5 Assignment results in the faster completion of movement to shelter. In all cases analyzed, assigned movement was completed in less time than was a similar unassigned movement.

5.6 Disadvantages. Assignment results in the use of only a portion of the available shelter space, even though a large shelter deficiency exists in Montgomery County. This leads directly to fewer people being sheltered than can be sheltered in unassigned movement. The shelter utilization under assignment planning averages only 66 percent, whereas it is always 100 percent for unassigned movement. This is the major reason (and penalty) associated with the more rapid completion of assigned movement noted above as advantageous.

5.7 Assignment results in a slightly lower shelter filling rate than for unassigned movement. More people can be sheltered under the unassigned movements than under the corresponding assigned movement for any point in time during the moves. This is due to the capability of persons located just outside an assigned area to start to shelter sooner than some persons within the assigned area. The result, of course, is that they reach shelter in less time, even though they had a greater travel time.

5.8 Summary. An assigned movement can be completed in less time than an unassigned movement, but results in poorer shelter utilization, lower sheltering rates, and fewer persons being sheltered. Assignment also results in a significant reduction of peak on-street population during the movement and a faster clearing of the streets. In considering the advantages and disadvantages, it is concluded that the assignment plans for Montgomery County are of limited value at this time, with the only true advantage being reduction of the on-street population.

Utilization of Additional Public Shelter Space

5.9 Additional public shelter space refers to all public shelter space not presently marked and available to the public. Under the Operational Plan, SRI proposes the addition of those spaces identified by Phase II of the National Fallout Shelter Survey as existing and possible. Under the Developmental Plan, when more long-term shelter improvements can be considered, SRI proposes the addition of (1) existing spaces, (2) possible spaces that are properly located, (3) spaces incorporated in new building construction, (4) spaces to be constructed in public schools, and (5) spaces incorporated in developments and new individual homes. Owing lack of data presented, the final policy (5) in the Developmental Plan is not evaluated.

5.10 Advantages. The inclusion of all existing and possible spaces in the Operational Plan results in an increase in the sheltering rate and the number of people that can be sheltered. This is true for both assigned and unassigned movement plans.

5.11 The inclusion of the existing and the properly located possible spaces in the Developmental Plan also results in an increase in the sheltering rate and the people who can be sheltered. The addition of only the properly located possible spaces on a selective basis allows located spaces to be added in other policies for better overall utilization.

5.12 The incorporation of spaces in new construction also results in an increase in the sheltering rate and the number of persons who can be sheltered. Fortunately, in Montgomery County a large portion of new construction is expected to take place in the areas that will also receive a large proportion of the population increase. These new spaces, therefore, are relatively well located.

5.13 The construction of spaces at public schools, when added to the spaces obtainable in the other policies, allows the projected 1968 population to be fully sheltered in public shelters. Further, the distribution of these spaces in areas of shelter deficiency increases the sheltering rate to such an extent that the time required to complete the movement is considerably less than the time required to complete movement without the addition of these spaces.

5.14 Disadvantages. In considering the large shelter deficiency existing in Montgomery County at the present time, any addition of shelter spaces cannot have important disadvantages. It might be pointed out that many of the available additional spaces can be utilized only if additional time is available to complete movement because these spaces, like marked spaces, are concentrated in the business and commercial centers of the county.

5.15 A point which could be disadvantageous if ignored is the requirement for compatibility between the Operational and Developmental planning in relation to the improvement of possible shelter facilities. If all of the possible facilities are currently improved to provide an immediate effect on shelter space inadequacy, then the future policies, which intend to use only the conveniently located possible shelters in the overall developmental plan, will duplicate the spaces from other more suitably located sources, and resources expended in the initial improvements will be lost if the original shelters are abandoned.

5.16 Summary. The addition of the existing and possible spaces in the Operational and Developmental Plans will provide shelter for additional people and increase the sheltering rate. However, additional time will be required for a portion of these additional people to be sheltered. If only a certain portion of the possible spaces is utilized in the Developmental Plan, then either the remaining possible spaces will not be available in the Operational Plan, or the resources expended in improving these spaces will have been used only to be abandoned later.

5.17 In considering the advantages and disadvantages of the policies in relation to sources of additional space, it is concluded that:

a. The Developmental Plan, particularly in relation to school facilities as a source, is highly satisfactory.

b. The Operational Plan is sufficient primarily because it offers the only alternatives for sheltering the maximum (but not entire) population under existing space criteria. The proposed use of all possible capacity is a disadvantage in two ways:

1. Because of poor facility location, the time required to shelter 70 percent of the total population is high (on the order of 95 minutes).

2. Since the Developmental Plan utilizes only the suitably located portion of all the improved shelters, the unused, but improved, shelters represent a drain on current resources that should be minimized. Judicious and accurate planning is required in this area to prevent undue costs due to future abandonment of currently improved shelters.

Overcrowding

5.18 Overcrowding is the filling of fallout shelters in excess of their recommended capacity. Overcrowding is not preposed by SRI in their planning study, but is included in this evaluation report because of its possible interest and also to serve as an additional practical application for the computerized evaluation technique. This evaluation does not consider the discomfort or personal problems inherent at the levels of overcrowding studied. Fifty-percent and 100-percent overcrowding were chosen to bracket a probably level of acceptability.

5.19 Advantages. In the Operational Plan, the advantages gained by overcrowding are an increase in the number of people who can be sheltered and an increase in the sheltering rate. These advantages exist regardless of what shelters are available for overcrowding, i.e., these advantages are gained if marked, existing, or possible shelters are overcrowded. However, the possible spaces are required, under the levels of overcrowding examined, to provide public shelter for the entire population.

5.20 In the Developmental Plan, the advantages of overcrowding are also increases in the number of people who can be sheltered and in the sheltering rate. Although overcrowding should not be needed when the shelter improvement program is completed, it can be an economical interim

policy as portions of the program are being completed. Prior to the full incorporation of the spaces in public schools, the projected 1968 population can be fully sheltered by overcrowding spaces provided by the other increments of the Developmental Plan.

5.21 Disadvantages. The disadvantage in all of the overcrowding situations considered is that many of the additional spaces created by the overcrowding can be utilized only by an increase in the movement time required. This is the result of increasing capacity without improving the distribution of spaces.

5.22 Summary. In both the Operational Plan and the Developmental Plan, overcrowding results in an increase in the number of people who can be sheltered and an increase in the sheltering rate. However, additional time is required to utilize many of these additional spaces. In both plans interim overcrowding permits the entire population to be sheltered. In considering the advantages and disadvantages, it is concluded that overcrowding should be given consideration in the transition period between the Operational and Developmental Plans for Montgomery County.

GENERAL CONCLUSIONS

5.23 Although the evaluations are made on the policies applying specifically to Montgomery County, some general conclusions may be made regarding the application of the policies and their probable effects in any area.

5.24 An overriding interaction, which is evident at this point, is that generally the acquisition of additional suitable shelter space increases the advantages of assignment planning and decreases the advantages of overcrowding.

5.25 Table 3 presents these general conclusions in the form of a binary "good or bad." Also presented with the conclusions are several brief statements regarding the decisions and considerations as they are now understood. In some cases, general knowledge is not sufficient to support a conclusion; this is to be expected in initial studies of this nature. However, it is felt that these conclusions serve a heuristic purpose and may be a foundation for more universal policy evaluation.

RECOMMENDATIONS FOR CONTINUED STUDY

5.26 The ultimate goal of protection concepts, policies, and procedures is to enhance survival by providing a high degree of shelter utilization in minimum time. Procedures that determine the number of people sheltered versus time have been originated, trial tested, and subjected to rigorous practical application by Operations Research Incorporated. These procedures currently evaluate the relative merits of

TABLE 3

SHELTER POLICIES - GENERAL CONCLUSIONS

PLANNING POLICY	TIME FRAMES OF PUBLIC SHELTER UTILIZATION PLANNING			
	OPERATIONAL PLANNING Goal: Best Utilization of Current Resources		TRANSITION PERIOD (Developmental Planning)	DEVELOPMENT OBJECTIVE Goal: 100 Percent Capacity, Minimum Movement Time
	In Areas of Large Shelter Deficiency	In Areas of Small Shelter Deficiency		
ASSIGNMENT - To Shelter Only	GOOD Except On-Street Population and Street Clearing Time is Unnecessarily High	BETTER On-Street Population is High Anyway	GETTING EVEN BETTER	If Capacity is 100 Percent and Well Distributed-BOTH ARE EQUALLY ADVANTAGEOUS
- To Shelter by Maximum Time and Distance Criteria	BAD Shelters Not Fully Utilized Slower Filling Time	- Depends on Shelter Locations Relative to Population Desirable Shelter Location: ? Slower Filling Time A Few Shelters Not Fully Utilized Undesirable Shelter Location: BAD Shelters Not Fully Utilized	BAD GETTING BETTER Depending on: - Population Growth and Degree of Location Improvement With Capacity Improvement	
OVERCROWDING	GOOD May Not Shelter 100 Percent, But Will Shelter More Than Present Criteria Will Require Additional Time But, At Least, Maintains Original Filling Rate	GOOD Will Probably Shelter 100 Percent Will Require Additional Time, But Will, At Least, Maintain Original Filling Rate	GOOD ONLY IN INTERIM USE Should Not Be Permanently Relied On Other More Efficient Plans Should Be Replacing Need for Overcrowding, Resulting in Faster Sheltering	BAD Is Not An Efficient Policy For Achieving Development Objectives Considers Only Shelter Capacity - Location is More Improtant in Achieving Development Objectives
ACQUISITION OF ADDITIONAL SPACE	GOOD - The Only Ethical Policy Choice Important Considerations: - Weigh Overall Value and Possible Phasing of Current Acquisitions Into Developmental Planning - Evaluate Overcrowding as an Additional Primary Source of Spaces	GOOD Important Jonsiderations: - Selective Acquisition of Best Located Spaces - Evaluate Possibilities of Overcrowding as a Secondary Source of Spaces	GOOD Important Considerations: Maintain Selectivity and Monitor New Commercial Building for Incorporation of Spaces. Include Shelter Spaces in School Improvements and Construction	GOOD - Adjustments and Selective Expansion Required to Maintain and Update Spaces in Relation to Population Changes

alternative shelter-utilization policies by considering the effects of many factors or determinants (such as the area, population, and shelter locations) inherent to populous areas. At this time, the effects of these determinants are known only in a cumulative manner, and the additional effects of independent variations among them is not well understood. Knowledge concerning sensitivity toward specific factors is of prime use in assessing the most rewarding areas of policy study and factors that must be represented by highly reliable data to avoid distortion of the evaluation.

5.27 Therefore, an essential step must be taken to acquire maximum use of the evaluation model. This step is the determination of the overall sensitivity of the resultant evaluation to the various determinants or factors that affect the shelter-utilization problem. Also, further study must be undertaken to find the advantages and disadvantages of various shelter-utilization policies relative to the current or projected shelter-to-population ratio for any area of interest. In addition, a study must be made to determine the interaction of various proposed shelter-utilization policies to find if there is an advantageous combination of effects that may be employed.

5.28 In relation to Montgomery County, as in many other localities, final plans are being developed and refined by local officials. The further evaluation of final plans, when available, would serve to determine the local effectiveness for Montgomery County, and also add to the general knowledge, described above, concerning various shelter-utilization policies used alone or in combination.

APPENDIX A

MONTGOMERY COUNTY DATA

A.1 This appendix contains specific input data for Montgomery County, Maryland. General input data are not presented here, but can be found in Appendix C of Operations Research Incorporated Technical Report 210.[1/]

A.2 Basic Population Data. Table A.1 contains basic population data for each census tract for 1962.

A.3 Area and Land-Use Data. Table A.2 contains basic area and land-use data for each census tract for 1962.

A.4 Fallout Shelter Data. Table A.3 contains fallout shelter data for each census tract for 1962.

A.5 Resident and County Working Force by Occupations. Table A.4 contains a breakdown into occupational categories of the employed residents and available jobs in Montgomery County for 1962.

A.6 SRI Daytime Assignment Data. Table A.5 contains SRI daytime assignment data for each census tract for 1962.

A.7 SRI Nighttime Assignment Data. Table A.6 contains SRI nighttime assignment data for each census tract for 1962.

1/ W. A. Hamberg, A. M. Salee, and R. H. Watkins, Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, Operations Research Incorporated Technical Report 210, 1963.

A.8 Basic Population Data. Table A.7 contains basic population data for each census tract for 1968.

A.9 Area and Land-Use Data. Table A.8 contains basic area and land-use data for each census tract for 1968.

A.10 Fallout Shelter Data. Table A.9 contains fallout shelter data for each census tract for 1968.

A.11 Resident and County Working Force by Occupations. Table A.10 contains a breakdown into occupational categories of the employed residents and available jobs in Montgomery County for 1968.

A.12 Intratract Movement Velocities. Table A.11 contains data showing the velocity of movement to shelter within each census tract.

A.13 Intertract Distances and Movement Velocities. Table A.12 contains data showing the travel distances and velocities for census tracts between which there was intertract movement.

A.14 Relationship Between Census Tracts and Standard Locations. Table A.13 contains data showing the relationship between the census tract numbers used in this report, the census tract numbers used by the U. S. Bureau of the Census, and the standard location numbers used in the SRI report for Montgomery County.

TABLE A.1

MONTGOMERY COUNTY, BASIC POPULATION DATA (1962)

Census Tract	Resident Population [1]	School Population [2]	Employed Population [3]	School Enrollment [4]
1	2,327	697	728	362
2	4,689	1391	1691	1572
3	3,413	1009	1137	694
4	2,109	629	727	434
5	1,958	520	692	841
6	3,693	1026	1292	591
7	4,748	812	1708	1587
8	4,519	1375	1642	1415
9	6,659	1813	2222	726
10	7,525	1587	2586	3989
11	15,298	4078	4218	4075
12	10,018	2321	4109	1326
13	5,719	1582	1944	2405
14	7,076	1949	2445	1409
15	9,244	2987	3040	3133
16	6,184	1452	2043	445
17	7,805	550	4006	--
18	4,350	721	1746	3962
19	3,366	603	1770	--
20	4,740	1004	2042	909
21	7,486	1593	2612	2221
22	5,208	1180	2036	564
23	6,824	703	2879	458
24	6,547	809	2863	502
25	1,638	300	875	--
26	8,595	548	2966	--
27	5,185	1886	1723	1172
28	3,652	656	1306	2033
29	5,171	234	1953	2513
30	3,645	773	1392	378
31	5,535	1330	1795	1071
32	3,657	1041	4085	1214
33	10,264	2864	2678	1732
34	16,614	4702	5276	5420
35	9,344	2822	2929	2503

TABLE A.1 (CONT)

Census Tract	Resident Population	School Population	Employed Population	School Enrollment
36	8,181	2152	2809	2221
37	8,807	2540	3083	1739
38	1,594	538	541	342
39	8,531	2172	2861	3209
40	6,014	1265	2314	1277
41	4,294	1114	1612	1113
42	2,349	522	851	570
43	5,282	1237	1758	622
44	7,038	1659	2220	805
45	11,042	3026	3007	3417
46	4,564	824	1698	604
47	4,701	896	1744	592
48	6,980	387	3593	2192
49	1,103	210	86	--
50	4,326	777	1669	360
51	5,057	710	1783	426
52	4,113	690	1465	378
53	2,405	362	773	--
54	3,475	1191	1291	1815
55	4,640	849	1543	594
56	4,250	812	1677	605
57	8,477	1655	2340	2368
58	5,313	1183	2141	750
59	11,198	2955	3520	2027
60	4,889	1078	1560	431
61	3,842	1083	4109	2277
62	6,100	1735	4085	2428
63	6,100	1735	4085	2428
64	1 670	312	1612	742

1. Source: The Maryland National Capital Park and Planning Commission, Comparative Data, 1960-1962 for Census Tracts, Montgomery and Prince Georges Counties, Maryland, Information Bulletin No. 5, July, 1962.

2. Number of residents of census tract attending school. Source: Montgomery County (Maryland) Board of Education.

3. Source: Total Employed (1960) x Resident Population (1962) ÷ Resident Population (1960) - 1960 Data from U. S. Bureau of the Census, U. S. Censuses of Population and Housing: 1960, Final Report PHC (1)-166, 1961.

4. Number of students attending school in census tract. Source: Montgomery County (Maryland) Board of Education.

TABLE A.2

AREA AND LAND-USE DATA, 1962,
MONTGOMERY COUNTY

Census Tract	Area, sq mi			
	Total[1]	Business and Commercial[2]	Industrial[2]	Local Business and Shopping[2]
1	42.80	.0038	--	.0054
2	31.90	.0008	.0156	--
3	37.90	.0006	--	.0084
4	36.90	.0004	--	.0032
5	62.50	.0005	.0017	.0010
6	45.40	.0022	.0092	.0036
7	1.61	.0117	--	.0351
8	29.99	.0010	--	.0499
9	1.53	.0192	.1624	.0577
10	3.72	.0211	--	.0092
11	1.75	.0049	.0117	.0148
12	4.91	.0092	.0234	.0367
13	45.50	.0188	.0046	.0188
14	29.76	.0122	.0103	.0031
15	9.35	.1047	.0038	.0039
16	0.86	--	.0019	.0017
17	0.61	.0074	.0089	.0104
18	0.57	--	.0042	.0006
19	0.18	--	.0005	.0020
20	0.35	--	.0005	.0023
21	1.27	--	.0014	.0044
22	0.74	--	--	.0079
23	0.49	.0008	--	.0075
24	0.76	.0042	--	.0042
25	0.43	.1740	.2166	.1484
26	0.32	--	--	.0195
27	0.80	.0020	.0023	.0020
28	0.71	.0056	.0037	.0014
29	0.80	.0094	--	.0094
30	0.64	--	.0005	.0047
31	0.70	.0038	--	.0038
32	1.59	.0040	.0040	.0040
33	1.22	.0027	.0005	.0077
34	1.88	.0009	--	.0037
35	1.45	--	--	.0176

TABLE A. 2 (CONT)

Census Tract	Area, sq mi			
	Total[1]	Business and Commercial[2]	Industrial[2]	Local Business and Shopping[2]
36	1.12	--	--	.0059
37	0.91	.0009	--	.0038
38	0.47	.1331	.0099	.1286
39	1.30	--	--	.0031
40	0.78	.0017	.0131	--
41	1.40	.0009	.0018	--
42	0.46	--	.0222	.0161
43	0.79	--	.0114	.0055
44	2.79	--	.0019	.0137
45	1.87	.0007	--	.0007
46	0.72	.0003	--	.0003
47	0.76	.0007	.0005	.0029
48	0.63	.0711	.0328	.1149
49	0.89	.2168	--	--
50	0.89	.0031	--	.0094
51	1.32	--	.0119	.0094
52	0.70	--	--	.0063
53	0.36	--	--	.0016
54	0.77	--	--	.0031
55	1.06	--	.0192	.0017
56	0.71	.0020	.1222	.0167
57	1.76	.0020	.0061	.0022
58[3]	1.14	--	.0192	.0317
59	4.66	.0006	--	--
60	25.40	.0042	.0112	.0169
61	22.09	.0132	.0316	.0132
62	7.94	.0010	.0010	.0010
63	6.35	.0011	.0011	.0011
64	0.59	.0050	.0015	--

[illegible]

[illegible]

TABLE A.3

FALLOUT SHELTER DATA, 1962,
MONTGOMERY COUNTY

Census Tract	Facilities[1]					
	Marked		Existing[2]		Possible[3]	
	Number	Capacity	Number	Capacity	Number	Capacity
1			2	1010	2	1010
2			1	27	1	172
3						
4						
5						
6						
7	1	450	1	551	1	551
8	1	510	1	510	1	510
9	4	710	8	1054	8	2713
10	2	195	2	254	2	754
11						
12						
13			1	30	1	180
14						
15	2	7165	1	12430	1	13180
16						
17	8	1710	10	2327	10	2349
18	2	1020	4	1840	4	2176
19			6	339	6	627
20			1	67	1	138
21						
22	1	95	1	96	1	96
23	4	780	15	3893	15	4567
24	5	765	9	1256	9	1506
25	14	2985	31	14036	31	27140
26	20	9350	22	13759	22	15592
27	1	130	1	130	1	130
28						
29	2	370	2	372	2	919
30						
31						
32						
33						
34	1	315	1	316	1	639
35						
36						
37						

TABLE A.3 (CONT)

Census Tract	Facilities[1]					
	Marked		Existing[2]		Possible[3]	
	Number	Capacity	Number	Capacity	Number	Capacity
38	2	375	4	13945	4	15748
39						
40						
41						
42						
43						
44	1	60	1	76	1	76
45						
46	3	2030	3	2347	3	3021
47						
48	9	2085	22	3873	22	9221
49	1	38365	2	71235	2	93645
50						
51						
52						
53						
54						
55			2	407	2	646
56	2	1140	3	3968	3	4011
57	1	120	2	696	2	1148
58			2	14697	2	14697
59						
60	4	3735	2	4639	5	10258
61						
62						
63						
64	1	170	1	506	1	562

[1] Source: Stanford Research Institute, Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 1963. Originally derived for Phase II of the National Fallout Shelter Survey.

[2] Existing spaces include marked spaces.

[3] Possible spaces include existing and marked spaces.

TABLE A.4

MONTGOMERY COUNTY, RESIDENT AND COUNTY WORKING FORCE BY OCCUPATIONS (1962)

Occupation	Resident Wk. Force[1]	County Wk. Force[2]
Mining	86	47
Construction	8,815	4,839
Manufacturing	11,797	6,405
Railroad and Railway express services	686	372
Other transportation	1,951	1,059
Community, utility, and sanitary services	3,461	1,879
Wholesale trade	4,309	2,338
Eating and drinking places	2,070	1,123
Other retail trade	17,385	9,436
Business and repair services	5,029	2,729
Private households	4,040	2,193
Other personal services	2,771	1,504
Hospitals	3,412	1,852
Educational services	9,415	5,110
Other professional and related services	15,389	8,352
Public administration	32,326	17,545
Other industries	17,932	9,733

[1] The total number of county residents that are employed in each occupational category. Source: Resident Working Force (1960) x Resident Population (1962) ÷ Resident Population (1960)...1960 Data from U.S. Bureau of the Census, U.S. Censuses of Population and Housing: 1960, Final Report PHC(1)-166, 1961.

[2] The total number of positions, in each occupational category, held in Montgomery County. Source: 0.543 x (Resident Working Force). The number 0.543 = No. of jobs held in Montgomery County (1960) ÷ Total Resident Working Force (1960)...1960 Data from U. S. Bureau of the Census, ibid.

TABLE A.5

SRI DAYTIME ASSIGNMENT DATA, 1962,*
MONTGOMERY COUNTY

Census Tract	Number of Residents Assigned to Shelter		
	Marked Spaces	Existing Spaces	Possible Spaces
1		572	572
2		27	172
3			
4			
5			
6	22	22	600
7	450	550	550
8	548	845	845
9	693	1037	1677
10	212	271	1817
11			
12			
13			321
14			
15	6430	6430	6430
16	743	743	743
17	2304	2752	2774
18	564	1646	3703
19		339	627
20		67	138
21			
22	96	96	96
23	780	3890	4418
24	765	1268	3025
25	4090	18172	21698
26	3970	4141	4503
27	2247	2351	2708
28	2058	2115	3800
29	370	1467	4584
30	18	18	18
31			
32			400
33			
34	315	316	639
35			
36		1049	1049
37		104	924
38	375	12275	12275

TABLE A.5 (CONT)

Census Tract	Number of Residents Assigned to Shelter		
	Marked Spaces	Existing Spaces	Possible Spaces
39		578	831
40			278
41			
42			
43			
44	1350	1366	1366
45	1265	1265	2199
46	2808	2814	2812
47	263	349	349
48	6277	7679	10760
49	11666	11666	11666
50	1327	1669	1694
51		18	18
52			
53			
54	47	47	52
55	33	440	665
56	1140	3968	4011
57	120	2326	2707
58		4103	5737
59			2552
60	3708	5705	4700
61			
62			
63			
64	170	506	562

*Source: Stanford Research Institute, Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

TABLE A.6

SRI NIGHTTIME ASSIGNMENT DATA, 1962,*
MONTGOMERY COUNTY

Census Tract	Number of Residents Assigned to Shelter		
	Marked Spaces	Existing Spaces	Possible Spaces
1		514	514
2		27	172
3			
4			
5			
6		28	540
7	458	550	550
8	534	883	883
9	231	570	1228
10	685	743	2282
11			
12			
13		202	350
14			
15	4930	4930	4930
16		748	748
17	1932	2499	2587
18	798	2447	4877
19		340	627
20		67	138
21			
22	317	97	97
23	530	3893	4420
24	1009	4827	6325
25	3068	6717	9114
26	6577	7712	7875
27	130	2669	3269
28		2521	3625
29	276	4257	5400
30		27	27
31			
32			72
33			
34	315	315	639
35			
36		1251	1400
37		162	853

TABLE A.6 (CONT)

Census Tract	Number of Residents Assigned to Shelter		
	Marked Spaces	Existing Spaces	Possible Spaces
38	378	11963	12125
39		572	694
40			207
41			
42			
43			
44	2694	2710	2710
45		1922	1959
46	4100	4140	4140
47		333	816
48	4105	5206	7220
49	3070	3070	3070
50		2729	3270
51		32	32
52			
53		274	274
54		196	521
55		460	700
56	500	3392	3427
57	120	4497	4838
58		4007	4441
59			3084
60	2327	3081	4758
61			
62			
63			
64	170	506	562

*Source: Stanford Research Institute, Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

TABLE A.7

MONTGOMERY COUNTY, BASIC POPULATION DATA (1968)

Census Tract	Resident 1/ Population	School 2/ Population	Employed 3/ Population	School 4/ Enrollment
1	3,705	1123	1252	928
2	6,079	1775	2280	1573
3	6,990	2153	2525	1469
4	3,569	1056	1244	367
5	3,511	923	1257	1496
6	5,857	1599	2132	502
7	6,513	1133	2504	2002
8	10,587	3091	3996	2110
9	11,636	3351	4374	1113
10	15,366	2797	5756	4538
11	13,958	4006	4336	3382
12	15,743	3763	5469	4071
13	8,519	2368	3102	6111
14	9,636	2360	3476	2721
15	12,476	3816	4519	6431
16	7,153	1724	2513	394
17	8,486	560	4402	--
18	5,214	928	2360	3401
19	3,733	679	1972	--
20	5,070	1034	2172	765
21	10,323	2364	4060	1751
22	9,812	2335	4099	478
23	7,425	765	3357	371
24	7,180	890	3276	417
25	1,845	345	975	--
26	8,182	736	4079	--
27	6,340	2530	2448	904
28	4,405	793	1661	1561
29	6,185	1497	2366	1894
30	3,830	797	1454	301
31	7,090	1730	2464	881
32	4,681	1498	1582	1515
33	10,506	1902	3189	1368
34	16,900	4664	5449	4638
35	9,579	2864	3120	2157
36	9,123	2326	3222	3015

TABLE A.7 (CONT)

Census Tract	Resident[1] Population	School[2] Population	Employed[3] Population	School[4] Enrollment
37	9,103	1,720	3,176	1,368
38	2,722	969	1,197	301
39	10,478	3,731	3,538	2,605
40	7,744	1,611	3,066	1,020
41	4,788	891	1,622	1,268
42	2,488	508	965	464
43	5,484	1,223	1,815	487
44	11,658	2,798	3,973	1,326
45	14,167	4,066	4,300	2,864
46	6,629	1,100	2,452	487
47	4,934	957	1,935	487
48	10,229	532	5,411	1,488
49	1,103	210	86	--
50	5,627	962	2,162	278
51	7,063	975	2,561	394
52	4,072	668	1,482	278
53	2,483	365	791	--
54	3,508	1,210	1,303	1,245
55	4,992	973	1,835	487
56	5,186	996	2,063	510
57	10,773	2,262	3,340	1,503
58	8,190	1,810	3,435	657
59	16,112	4,576	5,719	5,102
60	12,817	2,986	4,701	5,535
61	10,559	3,263	3,664	8,472
62	9,135	2,914	3,097	6,252
63	9,136	2,914	3,097	6,252
64	789	379	258	--

[1] Source: SRI estimates, Stanford Research Institute, Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

[2] Number of residents of census tract attending school. Source: School Population (1962) x Resident Population (1968) ÷ Resident Population (1962)...1962 Data from Table A.1.

[3] Employed Population (1962) x Resident Population (1968) ÷ Resident Population (1962)...1962 Data from Table A.1.

[4] Number of students attending school in census tract. Source: School Enrollment (1962) x Resident Population (1968) ÷ Resident Population (1962)...1962 Data from Table A.1.

TABLE A.8

AREA AND LAND-USE DATA, 1968,
MONTGOMERY COUNTY

Census Tract	Area, sq mi			
	Total[1]	Business and Commercial[2]	Industrial[2]	Local Business and Shopping
1	42.80	.0038	--	.0054
2	31.90	.0008	.0156	.0113
3	37.90	.0006	--	.0084
4	36.90	.0004	--	.0032
5	62.50	.0005	.0017	.0010
6	45.40	.0022	.0092	.0036
7	1.61	.0117	.0134	.0577
8	29.99	.0160	.0134	.0612
9	1.53	.0192	.1758	.0690
10	3.72	.0211	--	.0092
11	1.75	.0049	.0117	.0148
12	4.91	.0392	.0368	.0593
13	45.50	.0188	.0046	.0188
14	29.76	.0122	.0371	.0031
15	9.35	.1047	.0038	.0039
16	0.86	--	.0019	.0017
17	0.61	.0074	.0089	.0104
18	0.57	--	.0042	.0006
19	0.18	--	.0005	.0020
20	0.35	--	.0005	.0023
21	1.27	--	.0014	.0044
22	0.74	--	--	.0079
23	0.49	.0008	--	.0075
24	0.76	.0192	--	.0042
25	0.43	.2040	.2300	.1710
26	0.32	--	--	.0195
27	0.80	.0020	.0023	.0020
28	0.71	.0056	.0037	.0014
29	0.80	.0094	--	.0094
30	0.64	--	.0005	.0047
31	0.70	.0038	--	.0038
32	1.59	.0040	.0040	.0040
33	1.22	.0027	.0005	.0077
34	1.88	.0009	--	.0037
35	1.45	--	--	.0176
36	1.12	--	--	.0059
37	0.91	.0009	--	.0038

TABLE A.8 (CONT)

Census Tract	Area, sq mi			
	Total[1]	Business and Commercial[2]	Industrial[2]	Local Business and Shopping[2]
38	0.47	.1481	.0233	.1399
39	1.30	--	--	.0031
40	0.78	.0017	.0131	--
41	1.40	.0009	.0018	--
42	0.46	--	.0222	.0161
43	0.79	--	.0114	.0055
44	2.79	--	.0019	.0137
45	1.87	.0007	--	.0007
46	0.72	.0003	--	.0003
47	0.76	.0007	.0005	.0029
48	0.63	.1011	.0462	.1262
49	0.89	.2168	--	--
50	0.89	.0031	--	.0094
51	1.32	--	.0119	.0094
52	0.70	--	--	.0063
53	0.36	--	--	.0016
54	0.77	.0150	--	.0144
55	1.06	--	.0192	.0317
56	0.71	.0020	.1222	.0167
57	1.76	.0170	.0195	.0022
58[3]	1.14	--	.0192	.0317
59	4.66	.0006	--	--
60	25.40	..0042	.0112	.0169
61	22.09	.0132	.0316	.0132
62	7.94	.0010	.0010	.0010
63	6.35	.0011	.0011	.0011
64	0.59	.0050	.0015	--

[1] Source: The Maryland-National Capital Park and Planning Commission, Comparative Data, 1950-1960 for Census Tracts, Montgomery and Prince George's Counties, Maryland, Information Bulletin No. 4, 1961.

[2] Business and commercial, industrial, and local business and shopping areas were projected from current land usage with the aid of the general plan for the regional area, On Wedges and Corridors, Maryland-National Capital Park and Planning Commission, 1962.

[3] The total area of Census Tract 58 was reduced by 50 percent from that given in the Maryland National Capital Park and Planning Commission bulletin because about half of the area is taken up by the Potomac River.

TABLE A.9

FALLOUT SHELTER DATA, 1968, MONTGOMERY COUNTY

Census Tract	Facilities[1]									
	Marked		Existing[2]		Possible Proposed for Improvement[3]		Incorporated in New Construction		Proposed to be Built at Public Schools	
	Number	Capacity	Number	Capacity	Number	Capacity	Number[4]	Capacity	Number	Capacity
1			2	1010	2	1010	2	1000	2	3800
2			1	27	1	172	1	335	4	4700
3							2	1000	3	4500
4									2	1900
5									3	5600
6									2	1900
7	1	450	1	551	1	551	3	1300		
8	1	510	1	510	1	510	56	28200		
9	4	710	8	1054	8	2713	2	841	2	5700
10	2	195	2	254	2	754	2	800	5	19600
11									4	14700
12							5	2300	7	13000
13			1	30	1	180	1	350	7	15300
14							1	500	6	9800
15	2	7165	1	12430	1	13180	1	550	8	11500
16									1	2000
17	8	1710	10	2327	10	2327				
18	2	1020	4	1840	4	2176	1	164	2	6400
19			6	339	6	339				
20			1	67	1	67			2	3800
21									3	8900
22	1	95	1	96	1	96	22	11000	1	2500
23	4	780	15	3893	15	3893				
24	5	765	9	1256	9	1506	2	750	1	2000
25	14	2985	31	14036	31	17136				

TABLE A.9 (CONT.)

Census Tract	Facilities[1]									
	Marked		Existing[2]		Possible Proposed for Improvement[3]		Incorporated in New Construction		Proposed to be Built at Public Schools	
	Number	Capacity	Number	Capacity	Number	Capacity	Number[4]	Capacity	Number	Capacity
26	20	9350	22	13759	22	15592	8	3967		
27	1	130	1	130	3	1049	12	5900		
28										
29	2	370	2	372					1	8000
30										
31									2	4500
32							4	1800	3	5000
33									2	5400
34	1	315	1	316	1	376			5	16800
35									3	10700
36									3	8000
37									2	5800
38	2	375	4	13945	4	15748	9	4397		
39									4	11000
40							4	2175	2	5200
41									2	6500
42							5	2300	1	2400
43									1	2500
44	1	60	1	76	1	76			3	4300
45									6	13700
46	3	2030	3	2347	3	2847			1	1000
47									1	2500
48	9	2085	22	3873	22	9221	11	5552	1	7700
49	1	38365	2	71235	2	71235				
50										
51							8	3750	1	2000
52									1	1400
53										
54									2	6400

TABLE A.9 (CONT.)

Census Tract	Facilities[1]									
	Marked		Existing[2]		Possible Proposed for Improvement[3]		Incorporated in New Construction		Proposed to be Built at Public Schools	
	Number	Capacity	Number	Capacity	Number	Capacity	Number[4]	Capacity	Number	Capacity
55			2	407	2	407			1	2500
56	2	1140	3	3968	3	4011	8	3957	1	2600
57	1	120	2	696	2	696			2	7700
58			2	14697	2	14697	3	1500		
59							1	450	7	16000
60	4	3735	5	4639	5	6389			5	5500
61							9	4250	7	14700
62							3	1412	8	16250
63							3	1412	9	16250
64	1	170	1	506	1	506				

[1] Source: Stanford Research Institute, Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 30 June 1963.

[2] Existing spaces include marked spaces.

[3] Considers only the possible spaces proposed by SRI for improvement and includes existing and marked spaces.

[4] Owing to lack of data, the number of facilities was taken to be the Capacity ÷ 500, taken to the nearer whole integer.

TABLE A.10

MONTGOMERY COUNTY, RESIDENT AND COUNTY WORKING FORCE BY OCCUPATIONS (1968)

Occupation	Resident Wk. Force[1]	County Wk. Force[2]
Mining	111	65
Construction	11,487	6,790
Manufacturing	15,202	8,985
Railroad and Railway express services	886	524
Other transportation	2,514	1,486
Community, utility, and sanitary services	4,459	2,636
Wholesale trade	5,553	3,282
Eating and drinking places	2,667	1,576
Other retail trade	22,403	13,243
Business and repair services	6,480	3,830
Private households	5,206	3,078
Other personal services	3,570	2,110
Hospitals	4,397	2,599
Educational services	12,133	7,172
Other professional and related services	19,830	11,722
Public administration	41,657	24,624
Other industries	23,107	13,659

[1] The total number of county residents that are employed in each occupational category.
Source: Resident Working Force (1960) x Resident Population (1968) ÷ Resident Population (1960) - 1960 Data from U. S. Bureau of Census.

[2] The total number of positions, in each occupational category, held in Montgomery County.
Source: 0.543 x (Resident Working Force) - 0.543 from Table A.5.

TABLE A.11

INTRATRACT MOVEMENT VELOCITIES,
MONTGOMERY COUNTY

Census Tract	Movement Velocity, mph[1]	Census Tract	Movement Velocity, mph[1]
1	20	33	4
2	20	34	4
3	20	35	4
4	20	36	4
5	20	37	4
6	20	38	4
7	20	39	4
8	20	40	4
9	8	41	4
10	8	42	4
11	8	43	4
12	8	44	4
13	8	45	4
14	4	46	4
15	4	47	4
16	4	48	4
17	4	49	4
18	4	50	4
19	4	51	4
20	4	52	4
21	4	53	4
22	4	54	4
23	4	55	4
24	4	56	4
25	4	57	4
26	4	58	4
27	4	59	4
28	4	60	8
29	4	61	8
30	4	62	4
31	4	63	4
32	4	64	4

[1] Velocity of the movement to shelter within census tract.
Source: assumed.

TABLE A.12

INTERTRACT DISTANCES AND MOVEMENT VELOCITIES, MONTGOMERY COUNTY

Census Tract		Distance, 1/ miles	Velocity, 2/ mph
Origin	Destination		
3	2	8.01	20
4	2	15.0	20
5	2	22.5	20
6	8	8.8	20
6	60	10.69	14
10	9	1.89	8
11	10	3.46	8
11	9	1.89	8
12	34	7.39	6
14	13	9.9	6
16	15	2.8	4
17	18	1.1	4
17	26	3.14	4
19	17	1.1	4
20	23	1.57	4
21	22	.95	4
23	26	2.2	4
24	25	.94	4
24	26	1.73	4
25	26	.78	4
27	26	1.41	4
28	26	1.41	4
28	25	2.2	4
29	24	1.41	4
30	29	1.1	4
31	29	2.12	4
32	34	2.51	4
33	34	1.57	4
34	49	6.29	4
35	34	2.04	4
36	38	1.06	4
37	38	1.41	4
38	49	4.87	4
39	38	1.57	4
40	38	1.73	4
41	38	2.54	4
42	38	1.89	4

TABLE A.12 (CONT)

Census Tract		Distance,[1] miles	Velocity,[2] mph
Origin	Destination		
43	49	2.2	4
43	44	1.57	4
43	48	3.69	4
44	49	1.57	4
45	46	1.89	4
45	49	2.99	4
46	49	1.41	4
47	48	.94	4
47	49	1.73	4
48	49	1.57	4
48	54	1.18	4
50	49	1.41	4
51	49	2.20	4
52	49	3.14	4
53	56	1.87	4
54	48	1.18	4
55	56	1.26	4
55	49	2.83	4
56	57	1.33	4
56	49	4.08	4
57	58	1.57	4
57	49	4.24	4
58	49	4.64	4
59	58	2.67	4
59	57	3.62	4
61	10	3.4	8
62	13	8.17	6
63	15	6.92	4

[1] Distances are geographic center-to-center distances, except when destination is one particular shelter or shelter complex, in which case the measurement is made from the geographic center of the census tract of origin to the specific shelter. The measurements were made from a Maryland National Capital Park and Planning Commission street map. Distances are given only for those census tracts between which there was travel during any of the analyzed movements.

[2] Velocities are given only for those census tracts between which there was travel during any of the analyzed movements. Source: Average of the intratract movement velocities of the origin and destination.

TABLE A.13

RELATIONSHIP BETWEEN CENSUS TRACTS AND STANDARD LOCATIONS, MONTGOMERY COUNTY

Census Tract Number (Used in this report)	Census Tract Number[1]	Standard Location Number[2]
1	1	36
2	2	37
3	3	38
4	4	39
5	5	40
6	6	41
7	7	42
8	8	43
9	9	1
10	10	2
11	11	3,4,44
12	12A	45
13	13	47
14	14	48
15	15	49
16	16	50
17	17	51
18	18	52
19	19	53
20	20	54
21	21	5
22	22	6
23	23	7
24	24	8
25	25	9
26	26	10
27	27	55,11
28	28	12
29	29	13
30	30	14
31[3]	31	15
32	32	29
33	33	30
34	34	31
35	35	32
36	36	33
37	37	34
38	38	35

TABLE A.13 (CONT)

Census Tract Number (Used in this report)	Census Tract Number[1]	Standard Location Number[2]
39	39	16
40	40	17
41[4]	41	57
42	42	58
43	43	39
44	44	60,19
45	45	20,61
46	46	21
47	47	22
48	48	23
49	49	24
50	50	62
51	51	63
52	52	64
53	53	65
54	54	66
55	55	67,25
56	56	68,26
57	57	27
58	58	69
59	59	28
60	60	70
61	12B	46
62[5]	32	56A
63[6]	32	56B
64[7]	41	18

[1] U.S. Bureau of Census, U.S. Censuses of Population and Housing: 1960, Final Report PHC(1)-166, 1961.

[2] Stanford Research Institute, Shelter Utilization Planning in Montgomery County, Maryland, Menlo Park, California, 1963.

[3] Area = 10 percent of area of No. 32; population = 23 percent of population of No. 32.

[4] Area = 70 percent of area of No. 41; population = 72 percent of population of No. 41.

[5] Area = 50 percent of area of No. 32; population = 38.5 percent of population of No. 32.

[6] Area = 40 percent of area of No. 32; population = 38.5 percent of population of No. 32.

[7] Area = 30 percent of area of No. 41; population = 28 percent of population of No. 41.