

Cost-Effective Housing Systems for Disaster Relief

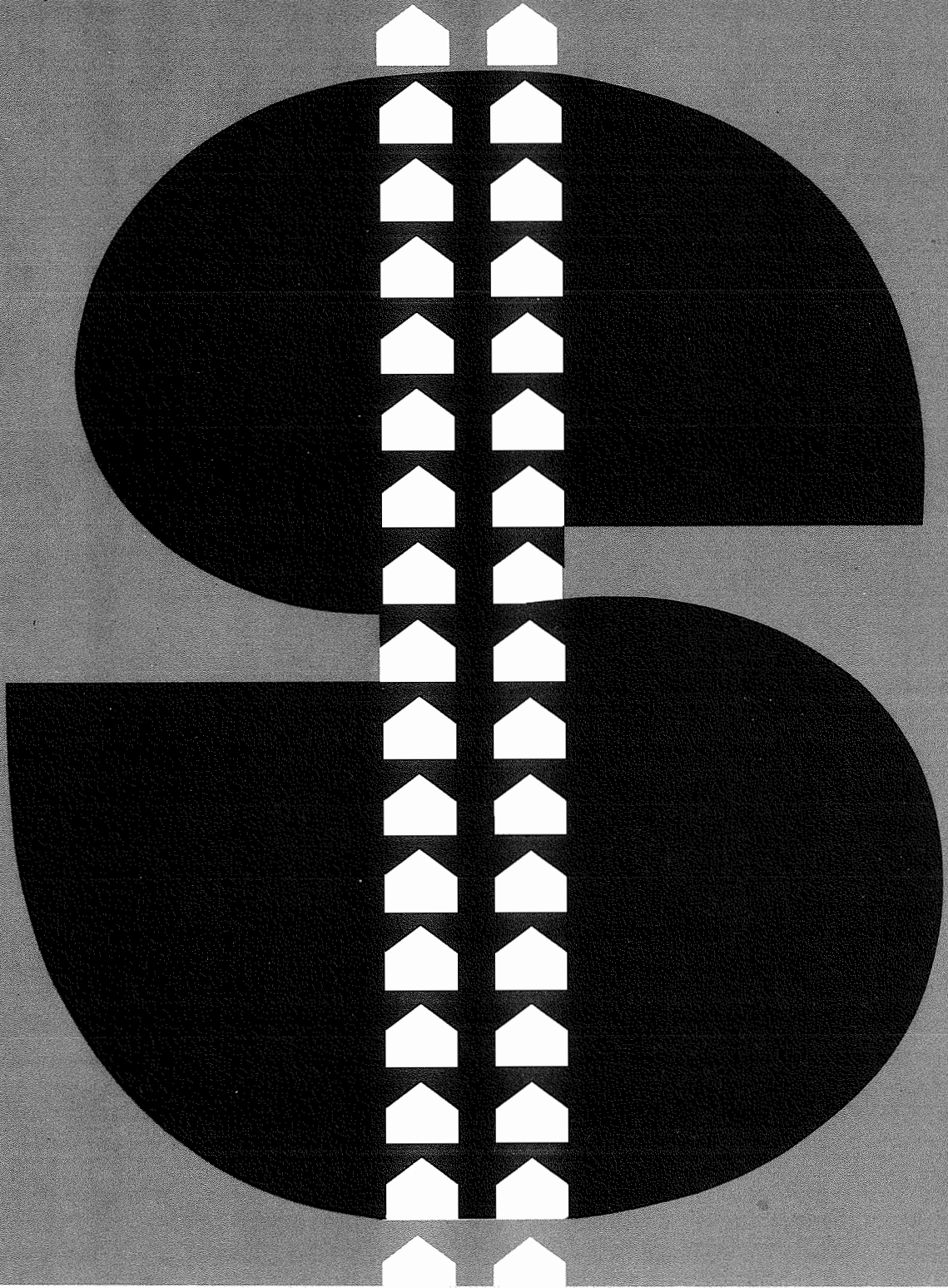
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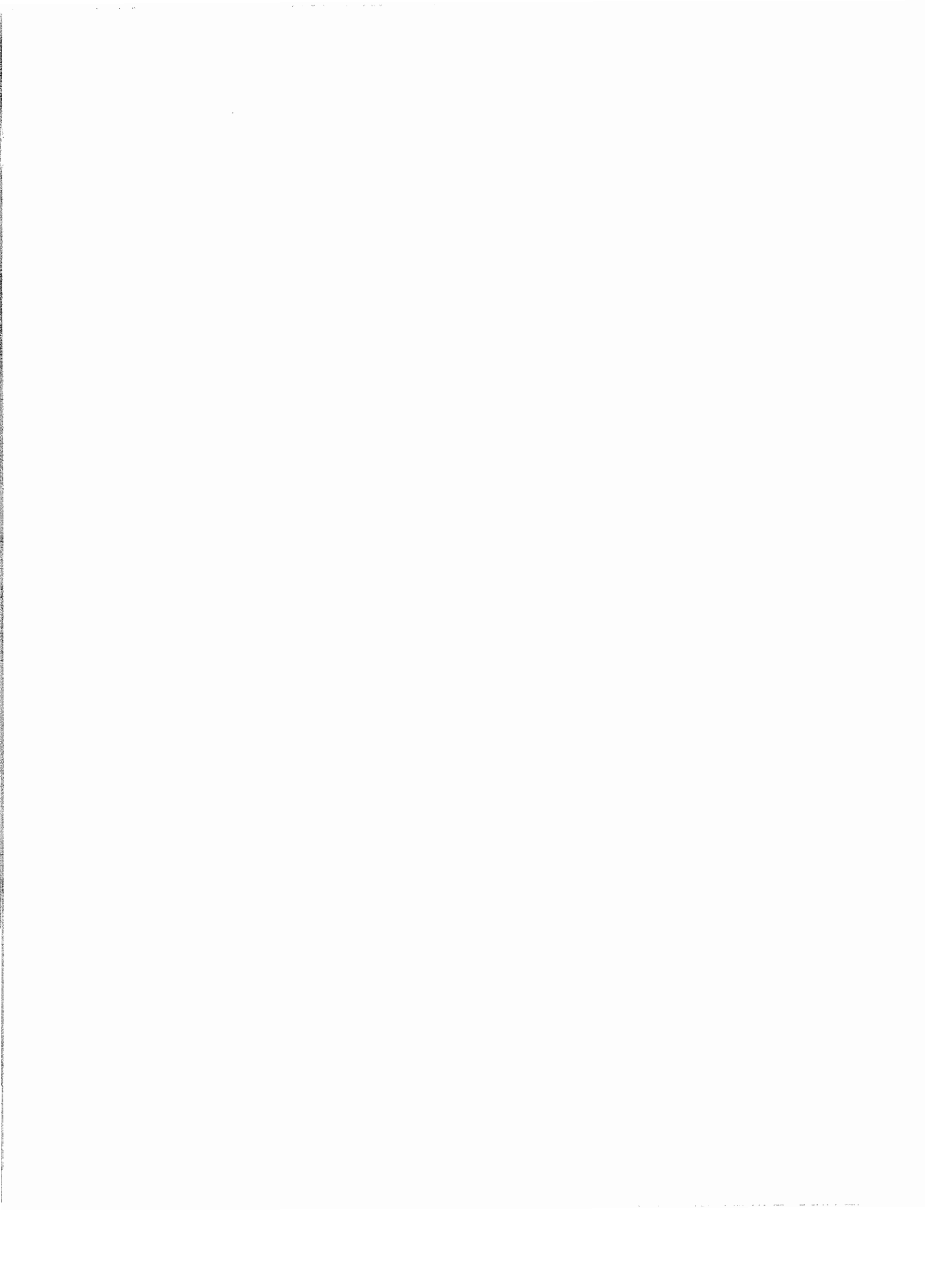
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Cost-Effective Analysis of Pre-Selected Housing Systems
Volume 5

Department of Housing and Urban Development
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COST EFFECTIVE HOUSING SYSTEMS FOR DISASTER RELIEF

VOLUME 5

COST-EFFECTIVE ANALYSIS
OF PRE-SELECTED HOUSING SYSTEMS

Prepared for
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Division of Energy, Building Technology and Standards
U. S. Department of Housing and Urban Development

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ABSTRACT

This Task Report presents the approach and results of the cost-effectiveness analysis of 13 temporary housing systems pre-selected in Task I-B-2 (Volume 4).

The preceding analysis in Task I identified potentially applicable technology by surveying the entire range of currently available housing systems and screening out those products that did not meet a set of first-level criteria. Systems passing the test of this broad and mainly qualitative analysis were pre-selected for quantitative analysis in this Task.

The "cost per family assisted" for a given housing system was determined to be the best measure for comparing cost-effectiveness. It is defined as the cumulative average cost incurred by the government over the average useful life of a given housing unit divided by the cumulative number of families who used that unit.

Two sets of assumptions formed the basis for computing "cost per family assisted":

1. A standardized model scenario for using temporary housing systems for HUD disaster relief missions; within this scenario, two types of factors affecting cost-effectiveness were identified: cost parameters and inventory parameters.
2. Estimates for each cost and inventory parameter applied to each of the 13 pre-selected systems.

The model scenario for using the housing systems was then expressed as a mathematical formula with the cost and inventory parameters as variables.

The analysis yielded the following results: The Special Design Mobile Home (a proposed, smaller and more rugged adaptation of the Single-Wide Standard Mobile Home) ranked as the most cost-effective housing system. Its overall cost per family assisted is approximately \$7,600 and lies 10% below the Single-Wide Standard Mobile Home currently employed by HUD (if used the most cost-effective way).

A system consisting of Two Sectional Boxes built to container standards ranked third, an Expandable Box fourth, and a Sectional Box and Knock-Down fifth.

These results must be regarded as hypothetical, as they are based on estimates for products which are, with the exception of the Single-Wide Standard Mobile Home, not currently manufactured and used as specified in the study. Prototypes of these specially adapted housing systems would have to be built and field-tested during the subsequent stage of HUD's temporary housing evaluation project to determine actual costs. To prepare HUD's decisions on this subsequent stage, Task III provides for the four highest ranking systems a detailed use scenario and outline performance specifications.

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I INTRODUCTION AND SUMMARY

This volume is part of an extensive study of the cost-effectiveness of using housing systems as temporary shelter during federal disaster relief missions. It documents the work performed under Task II of the study, with the purpose of analyzing in detail the most cost-effective, currently available technology.

A. EVALUATION CRITERIA AND APPROACH

HUD required that the cost-effectiveness of housing systems for disaster relief be evaluated on the basis of specified criteria. As discussed in Volume 4 of the study (Report for Task I-B-2), these HUD criteria apply to different levels of analysis.*

The first criterion, Livability, is clearly directed to the qualitative characteristics of each housing system and was applied to the initial evaluation of the entire spectrum of current lightweight housing systems technology in Task I. Housing systems that could not be adapted to conform to Minimum Livability Standards for Temporary Housing established for the study were excluded from further analysis.

Likewise the last criterion, Temporary versus Permanent Use, is directed to qualitative characteristics. It served as another initial screening device to sort out relocatable systems suitable as temporary housing from systems designed

* For a complete list of the HUD evaluation criteria see Volume 4, pp. 82-82.

for permanent use only. While it would have been meaningless to analyze the cost-effectiveness of applying such permanent housing systems to temporary uses, the study showed that certain permanent housing systems could become an important resource for disaster relief if the federal government adopts a proposed new Fast Delivery Permanent Home program. This program would provide disaster victims whose house is destroyed beyond repair with the option of receiving, in lieu of temporary housing, logistical and financial assistance for the purchase of a new permanent home.*

By applying the qualitative HUD criteria as first-level screening devices in Task I, 13 housing systems were pre-selected as potentially cost-effective if applied to disaster relief missions. Figure 1 lists these products in relation to all temporary housing systems identified and evaluated.

Thus, while the principal objective of Task I was to identify existing, potentially cost-effective technology, Task II had the purpose of measuring or estimating the cost-effectiveness of pre-selected systems and to rank them accordingly for further consideration by HUD.

The method selected for Task II was a life-cycle cost approach, integrating all quantifiable aspects of using a temporary housing system for disaster relief, including all those HUD criteria that directly influence cost. These criteria were: transportability, storage, site erection, maintenance and the economics of acquisition, use and reuse.

Overall life-cycle costs for different temporary housing systems for disaster relief can best be estimated and compared in the following manner:

First, a model scenario must be established, including all the major elements for a typical use cycle.

Second, all factors influencing cost-effectiveness must be identified for each element in the scenario, including cost factors, attrition or loss factors and salvage values.

* For the Fast Delivery Permanent Home program, see Volume 4, Report for Task I-B-2, pp. 193-316.

FIGURE 1
PRE-SELECTED TEMPORARY HOUSING SYSTEMS
BY INDUSTRY SEGMENT AND BASIC CONFIGURATION

INDUSTRY SEGMENT	BASIC CONFIGURATION							CORE & SPECIAL PACKAGED ENCL.	
	OR WHEELS	ONE BOX GENERAL	EXPANDABLE BOX ON WHEELS	GENERAL	TWO OR MORE SECTIONAL BOXES ON WHEELS	SECTIONAL BOX (ES) AND KNOCK-DOWN (S)	CORE AND PANELIZED		
A. MOBILE HOME INDUSTRY	1 Single-Wide Standard M.H. ² Suggested Standard M.H. ²	2 General	3 Expandable Mobile Home ² Guerdon M.H. ²	4 General	5 Double-Width Standard M.H. ²	6 General	7 Sectional Box (ES) and Knock-down (S)	8 Core and Panelized	9 Core & Special Packaged Encl.
B. MANUFACTURED HOUSING INDUSTRY; C. MANUFACTURERS OF SPECIAL RELOCATABLE SYSTEMS	<p>Evaluated for "Fast delivery permanent home" program. Manufacturers of marketed relocatable housing systems included under C, D below.</p>								
W	<p>1 **Special Design Mobile Home² Travel Trailer²</p> <p>2 **USA Home² Goodyear ES/C²</p> <p>3 **USA Home² Goodyear ES/C²</p> <p>4 Atlas Portable²</p> <p>5 **Fruehauf or similar¹</p> <p>6 Atco Ind. Ltd.² (Atlantic Intl.²) Elder Int'l.² (Porta-Kamp²)</p> <p>7 **Goodyear NEASS² Goodyear Personnel Shelter EXP</p> <p>8 AFCS¹ MUST Transportable Air-Supported Ref. Shelter¹</p> <p>9 Endure Prod.¹ Panelfab Intl.¹</p> <p>10 Circle Doms¹ Geodesic¹ O'Dome¹ Univ. Reg. Syst. A.O. Windfield¹</p> <p>11 Air-O-Struct.¹ Birdair Struct.¹</p> <p>12 **Armco¹ **Concor¹ Strahatgel¹</p>								
a. Military	<p>(1) Air Force</p> <p>(2) Army</p> <p>(3) Navy</p>								
b. Private Market Housing Systems	<p>(1) Camp Systems</p> <p>(2) Honeycomb Panel Systems</p> <p>(3) Dome systems</p> <p>(4) Miscellaneous Systems</p>								
c. Other Commercial Relocatable Shelter Systems	<p>(1) Air Structures</p> <p>(2) Metal Structures</p> <p>(3) Container Vans</p>								

C - Containerized System

- 1 - Existing technology without integral mechanical core.
- 2 - Existing technology with potential integral mechanical core.
- * - Included in cost-effectiveness analysis as marketed (meeting HUM/EPS Level I retention criteria).
- ** - Included in cost-effectiveness analysis with a floor plan specially adapted to meet the Minimum Livability Standards for Temporary Housing established for this study.

() The systems produced by the manufacturer in this category ("Basic Configuration") are not specifically evaluated in the report.

Third, the cumulative net cost after each use cycle must be divided by the cumulative number of families assisted by that system during that use cycle.

The resulting measure was termed "cost per family assisted." The lowest overall "cost per family assisted" during the lifetime of a temporary housing system is achieved after completion of the last use cycle and was considered the best measure of overall cost-effectiveness.

The model scenario for evaluating the cost-effectiveness of temporary housing systems in this study was developed from an analysis of HUD's current method of administering housing relief.* It includes the following major steps:

MAJOR STEPS OF USING TEMPORARY HOUSING FOR DISASTER RELIEF

First Use Cycle

Second to Last Use Cycle

Acquisition^(a)

Inter-Mission^(d)

Erection^(b)

Erection^(b)

Maintenance^(c)

Maintenance^(c)

- (a) Including all activities required to purchase the unit and to deliver it from the F.O.B. purchase point to the place of its first storage.
- (b) Including all activities to deliver the unit from a storage to a disaster area and to set it up for use by disaster victims.
- (c) All maintenance activities during use of the unit by disaster victims.
- (d) All activities between uses, including deactivation, repair and storage.

* See Volume 2 of this study: "Federal Experience with Disaster Housing Assistance."

A second element of the model scenario is the inventory of residual and salvage values after each use cycle. Both major steps and inventories can be directly expressed in terms of factors influencing cost-effectiveness.

B. FACTORS INFLUENCING COST-EFFECTIVENESS

Two types of variables correspond to major steps and inventories of the model scenario and influence the "cost per family assisted": cost parameters and inventory parameters. The latter consists of attrition parameters and residual and salvage values.

In addition, the cost of developing group sites for temporary housing increases the cost per family of any temporary housing system by a constant value.

1. COST PARAMETERS

The following categories served to organize all costs of a temporary housing mission* according to the major steps of the model scenario.

a. Acquisition Costs

- (1) F.O.B. Price (initial cost)
- (2) Transportation to Storage**
- (3) Initial Storage**

* Excluding HUD's administrative costs.

** For purposes of this study, it was assumed HUD would make future purchases of housing units prior to an immediate need and stockpile them in existing regional storage centers so that they would be ready for deployment when a disaster strikes.

If HUD decides to continue its past practice of purchasing temporary housing units for immediate deployment, these two cost parameters would not apply. However, in this case, based on sudden demand, F.O.B. prices can be expected to be higher than estimated in this study.

b. Erection Costs*

- (1) Transportation: Storage to Staging
- (2) Hold at Staging
- (3) Set-up Contract
 - (a) Transportation: Storage to Staging
 - (b) Rough Grading
 - (c) Foundation and Unit Erection
 - (d) Skirting
- (4) Utility Hook-up
 - (a) Sewer, Water, Electric
 - (b) Gas
- (5) Damage Repair
- (6) Labor Import

c. Maintenance Costs

- (1) Maintenance and Repair
- (2) Spare Parts

d. Inter-Mission Costs

- (1) Deactivation
- (2) Prepare for Shipment and Storage
- (3) Transportation to Storage
- (4) Storage
- (5) Repair for Reuse

These major cost parameters account for all expenses incurred by the federal government in providing temporary housing, excluding administrative costs.

* Excluding the cost of preparing group sites. Current legislation calls for this cost to be paid by the state or local government rather than the federal government. Therefore, for the purposes of this study it is considered as an average constant applying to any housing system used and to be added to the federally borne, variable "cost per family assisted."

2. INVENTORY PARAMETERS

a. Attrition Parameters

Because of the lack of data, this variable could not be related to experience as readily as the cost parameters. Two main parameters determining attrition were identified and served as a basis for attrition estimates:

(1) Maximum Number of Uses

This parameter varies from system to system and was defined as follows: If HUD acquires a statistically and operationally meaningful number of units of a given system (say, 1,000) and if these units are used as temporary housing in successive disasters, there will be a gradual loss or attrition until the last unit of that procurement is phased out. The maximum number of uses for a housing system is defined, in this sense, as the number of use cycles after which the last unit of a procurement can no longer be employed for disaster relief.

(2) Attrition Rate

For lack of more differentiated empirical data a straight-line attrition rate was assumed for all systems under study, similar to the straight-line depreciation rate often assumed for tax purposes. According to this assumption, a procurement of 1,000 units of a given system with an estimated maximum number of 10 use cycles would be reduced by 100 units after each use. In other words, after the first use 100 units would be non-reusable while 900 units could be refurbished for a second deployment, after which only 800 units would remain for reuse, and so on until there were no more reusable units remaining after the tenth use.

b. Salvage and Residual Values

The assumptions regarding attrition parameters imply that after any use cycle, except the last one, there are reusable units available for a subsequent mission as well as non-reusable units to be disposed of.

After the last use cycle, only non-reusable units are left. Of course, whether a unit is reusable or not will be reflected in its value. Likewise, the number of use cycles during which a given unit has served as temporary housing will affect its residual value. Consequently, salvage values of non-reusable and residual values of reusable units after completion of the first use cycle of a system were identified as two variables. Furthermore, assumptions were made as to the rate at which these values would decline after subsequent use cycles.

To arrive at the net cumulative cost of a given housing system through a given use cycle, the salvage and residual values of the cumulative non-reusable and reusable units must be deducted from the cumulative cost. The "cost per family assisted" is this net cumulative cost divided by the cumulative number of families served.

3. SUMMARY OF COST-EFFECTIVENESS FACTORS AND SOURCE OF ESTIMATES

In summary, the following main variables affect the cost-effectiveness of temporary housing systems for disaster relief:

Cost Parameters

A = Acquisition Costs
 B = Erection Costs
 C = Maintenance Costs
 D = Inter-Mission Costs

Attrition Parameters

N = Maximum Number of Uses

Salvage and Residual Values

S = Salvage Value of Non-Reusable Units After the First Use (It was assumed this value would decrease by a $\frac{1}{2}$ multiplier after each subsequent use.)

T = Residual Value of Reusable Units After the First Use
(It was assumed that this value would decrease by a
1/fT multiplier after each subsequent use.)

fT = Devaluation Factor of Reusable Units (It was assumed
that this factor is smaller than 2; i.e., T decreases
less rapidly than S); estimated for each system

In addition to the variables, the following constant ap-
plies to all systems and must be included in the total
"cost per family assisted" if the cost-effectiveness of
temporary housing assistance is to be compared with the
proposed Fast Delivery Permanent Home assistance:

E = Average Cost Per Family Assisted for Group Site
Preparation

Based on information from HUD, manufacturers and nation-
wide cost data files, the firm of McKee-Berger-Mansueto,
Inc., under a subcontract, analyzed all factors involved
in applying each pre-selected housing system to each
step of the model scenario and estimated numerical values
for each variable and for the constant.

C. MODEL FOR LIFE-CYCLE COST ANALYSIS AND CONCLUSIONS

The model scenario defines the total cost per family assisted
as a relationship between the variables and the constant. To
facilitate computer application the scenario was expressed in
the following mathematical form:

$$W_1 = \frac{\overbrace{1000(A+B+C)}^{Z_1} - \frac{S}{2^{y-1}} \left(\frac{1000}{N}\right) - \frac{T}{f_T^{y-1}} \left(1000 - y \frac{1000}{N}\right)}{1000y - \frac{1000}{N} \left(\frac{y}{2}\right) (y-1)} + E$$

$$W_2 \dots W_N = \frac{z_2 \dots z_N \left[z_{y-1} + \left[1000 - (y-1) \left(\frac{1000}{N} \right) \right] (B+C+D) - \frac{S}{2^{y-1}} \left(\frac{1000}{N} \right) - \frac{T}{f_T^{y-1}} \left(1000 - y \frac{1000}{N} \right) \right]}{1000y - \frac{1000}{N} \left(\frac{y}{2} \right) (y-1)} + E$$

where W_1 = cost per family assisted after the first use,

W_N = cost per family assisted after the last use, and

y = the number of a given use cycle.

The formula permitted testing the impact of individual variables on the "cost per family assisted." Acquisition Costs (A) and Maximum Number of Uses (N) were found to be the two most significant variables. For example, one system, Two Sectional Boxes (Containerized), was found highly cost-effective despite its high estimated acquisition cost because of a high estimated number of uses.

The most cost-effective housing system, according to the approach chosen and the estimates supplied by the subcontractor, is the Special Design Mobile Home. With a \$7,590 overall cost per family assisted after the last use it is expected to be a significantly more economic system than the second most effective system, the Single-Wide Standard Mobile Home currently used by HUD (\$8,265 per family assisted after the last use). Controlling for the constant E (share of group site development cost), which was the same value for all systems, the cost per family assisted after the last use for the Special Design Mobile Home is expected to be 10% below the corresponding value for the Single-Wide Standard Mobile Home. On the other end of the spectrum were metal structures and geodesic domes, the systems requiring the highest degree of site assemblage (\$14,000-21,000 per family assisted).

As shown in Figure 1, the systems evaluated in the previous Task (Volume 4) were classified in a matrix of two main organizing principles: industry segment and a fundamental design characteristic termed "Basic Configuration."

The intent of this classification was to facilitate a systematic transition from the initial focus on industries and their existing products to generic systems which can be specially adapted for use as cost-effective temporary disaster relief housing.

The five housing systems that ranked highest in the Task II analysis represent, in this order, the following four types of Basic Configuration:

<u>Basic Configuration</u>	<u>Housing System Analyzed</u>
1. One Box on Wheels	Special Design Mobile Home
2. Two Sectional Boxes (Containerized)	Fruehauf or similar
3. Expandable Box	Altair Industries
4. Sectional Box and Knock-Down	Atlantic International

Upon completion of Task II the HUD Government Technical Representative selected these four system types for more detailed study in Task III.

II LIFE-CYCLE COST ANALYSIS

A. MODEL SCENARIO FOR USING TEMPORARY HOUSING SYSTEMS FOR DISASTER RELIEF

The model scenario for using temporary housing systems in successive disaster relief missions was developed from an analysis of HUD's past and current disaster relief operations. It served as a uniform framework for life-cycle cost analysis and was applied to all pre-selected housing systems. The model scenario is expanded to a more detailed description in Task III.

The model scenario was conceived in two main parts per each use cycle: major steps and inventories.

1. MAJOR STEPS

The first major step during the first use cycle is Acquisition (including all activities to purchase the unit and to deliver it from the F.O.B. purchase point to the place of the first storage*).

The first major step during each subsequent use cycle includes all activities between uses such as deactivation, repair, transportation, 12 months' storage and delivery to the place of the next use. It is referred to as Inter-Mission.

* It was assumed that HUD would purchase and stockpile units.

Two additional major steps in the model scenario are repeated in each use cycle: Erection (including all activities to deliver a unit from a manufacturer or storage area to a disaster site and to set it up for use by disaster victims) and Maintenance (during the use of the unit by disaster victims).

2. INVENTORIES

The second main part of the model scenario per use cycle is an inventory of what is available for the subsequent mission. Such an inventory can best be discussed and estimated for statistically large enough samples of a housing system. For the purpose of the study a procurement of 1,000 units was assumed as a basis for estimating inventories.

Figure 2 lists the sequence of major steps and inventories per use cycle.

B. FACTORS AFFECTING COST-EFFECTIVENESS

The purpose of the model scenario was to express the elements of typical disaster relief missions in a format which would facilitate accounting for estimated costs and values and, at the same time, form the basis for a life-cycle cost-effectiveness model.

All major steps of the model scenario are directly related to cost parameters. Likewise, the inventories of the scenario are related to inventory parameters.

1. COST PARAMETERS

Table 1 lists the estimates for the cost parameters for the 13 pre-selected systems, prepared by McKee-Berger-Mansueto, Inc. (MBM) under a subcontract.

The only system that has been used by HUD as temporary housing for disaster relief is the Single-Wide Standard Mobile Home. Therefore, an effort was made to establish the actual costs of HUD's past mobile home operations as a base line for further estimates.

FIGURE 2

MAJOR ELEMENTS OF THE MODEL SCENARIO FOR USING 1,000
 UNITS OF A TEMPORARY HOUSING SYSTEM FOR HUD DISASTER RELIEF MISSIONS

	<u>First Use Cycle</u>	<u>Second to Second-to- Last Use Cycle</u>	<u>Last (Nth) Use Cycle</u>
I Major Steps	A. Acquisition	D. Inter-Mission	D. Inter-Mission
	B. Erection	B. Erection	B. Erection
	C. Maintenance	C. Maintenance	C. Maintenance
II Inventories	S Disposition of Non-Reusable Units	S Disposition of Non-Reusable Units	S Disposition of Non-Reusable Units
	T Assessment of Residual Value of Reusable Units	T Assessment of Residual Value of Reusable Units	

TABLE 1
ESTIMATED HUD COST PARAMETERS FOR PRE-SELECTED TEMPORARY HOUSING SYSTEMS

	0	1	2	3	4	5	6	7	8	9	10	11	12
Cost Parameters													
	Single-Wide Standard Mobile Home	Special Design Mobile Home	Expandable Guerdon Mobile Home	USA Home	Altair Industries	Fruheauf or Similar	Atlantic International	Goodyear MPASS	ATCO Industries Ltd.	Panelfab International	Geodesic	Armco	Concor
A. Acquisition Costs													
1. FOB Price	\$ 6,000	\$8,500		\$15,945	\$ 9,845	\$17,170	\$13,300	\$18,205	\$14,705	\$12,405	\$11,945	\$22,545	\$15,405
2. Transportation to Storage	380	380		690	480	560	664	562	562	562	484	612	484
3. Initial Storage	60	60		750	450	60	300	350	350	350	500	500	300
SUB-TOTAL A	\$ 6,440	\$8,940		\$17,385	\$10,775	\$17,790	\$14,264	\$19,117	\$15,617	\$13,317	\$12,929	\$23,657	\$16,189
B. Erection Costs													
1. Transportation: Storage to Staging	\$ 356	\$ 356		\$ 649	\$ 450	\$ 806	\$ 623	\$ 529	\$ 529	\$ 529	\$ 454	\$ 574	\$ 454
2. Held at Staging	12	12		40	30	30	40	40	30	40	40	40	40
3. Set-up Contract													
a. Transportation: Staging to Site	24	24		41	30	54	41	33	33	33	30	38	30
b. Rough Grading	300	300		300	300	300	300	300	300	300	300	300	300
c. Foundation & Unit Erection	1,060	1,060		1,645	1,335	1,235	1,360	1,595	1,885	1,935	2,770	3,140	2,400
d. Skirting	327	327		327	327	327	327	327	327	327			
4. Utility Hook-up													
a. Sewer, Water, Electric	1,000	1,000		1,000	1,000	1,000	1,000	1,000	1,200	1,000	1,200	1,200	1,200
b. Gas	300	300		300	300	300	300	300	300	300	300	300	300
5. Damage Repair	30	30		100	50	30	50	50	50	50	30	200	75
6. Labor Import				300	100		160	160	160	160	300	1,240	400
SUB-TOTAL B	\$ 3,409	\$3,409		\$ 4,375	\$ 3,922	\$ 4,082	\$ 4,201	\$ 4,007	\$ 4,814	\$ 4,347	\$ 5,424	\$ 7,032	\$ 5,199
C. Maintenance Costs													
1. Maintenance & Repair	\$ 388	\$ 258*		\$ 500	\$ 463	\$ 388	\$ 368	\$ 375	\$ 463	\$ 325	\$ 400	\$ 425	\$ 588
2. Spare Parts	70	46*		100	75	105	100	150	150	100	250	250	100
SUB-TOTAL C	\$ 458	\$ 304*		\$ 600	\$ 538	\$ 493	\$ 468	\$ 525	\$ 613	\$ 425	\$ 650	\$ 675	\$ 688
D. Inter-Mission Costs													
1. Deactivation	\$ 95	\$ 95		\$ 150	\$ 150	\$ 100	\$ 125	\$ 200	\$ 125	\$ 200	\$ 250	\$ 300	\$ 300
2. Prepare for Shipment & Storage	229	229		600	350	205	390	550	800	800	1,500	2,000	1,300
3. Transportation to Storage	380	380		690	480	560	664	562	562	562	484	612	484
4. Storage	60	60		850	500	95	350	450	450	450	650	650	450
5. Repair for Reuse	800	400*		1,100	850	610	1,000	990	900	900	880	1,900	1,100
SUB-TOTAL D	\$ 1,564	\$1,164		\$ 3,390	\$ 2,330	\$ 1,570	\$ 2,529	\$ 2,752	\$ 2,987	\$ 2,912	\$ 3,764	\$ 5,462	\$ 3,634

Source: Asterisked items: contractor; all other estimates: McKee-Berger-Manueto, Inc.

The main source of these historical costs were HUD's records from relief operations in Wilkes-Barre, Pennsylvania, from June to September 1972, in the aftermath of tropical storm Agnes. As the HUD data were not available in the complete, consistent and aggregate form required for the life-cycle cost analysis, they had to be reviewed, reorganized and tabulated.

Cost parameters for the 12 housing systems pre-selected in addition to the Single-Wide Standard Mobile Home were estimated by the subcontractor from extensive contacts with the manufacturers of these systems, supplemented by MBM's construction estimating experience. Since these 12 housing systems represent modifications and special adaptations of existing technology which have not yet been fully engineered, built and tested, the cost figures are based on estimates only.

The Appendix to this volume provides MBM's assumptions and sources for the cost estimates.

2. INVENTORY PARAMETERS

a. Attrition Parameters

The loss of units or attrition after a use cycle of temporary housing assistance is a major factor influencing cost-effectiveness. At the same time, this variable is particularly difficult to estimate. HUD's own records on past mobile home operations were not sufficiently conclusive regarding the number of disaster relief use cycles a Standard Mobile Home can be expected to survive without unreasonably high repair costs.

Two main parameters served to estimate attrition for this study:

(1) Maximum Number of Uses

The rate of depletion of a fleet of housing units, termed the "attrition rate," is a function of the maximum number of uses that can reasonably be expected of a procurement of temporary housing

units. The maximum number of uses was estimated by MBM by analyzing the inherent factors of construction, erection, maintenance, storage, livability and transportation associated with each housing system in relation to the Single-Wide Standard Mobile Home currently used by HUD/EPS. These factors are descriptively summarized in Figure 2.

(2) Attrition Rate

The attrition rate equals the share of an initial fleet of 1,000 housing units that cannot be reused in subsequent missions after each mission.* It is based on the premise that after the last use assigned to the fleet none of the units would be left in usable condition; that is, by then they would all have been salvaged. For example, a fleet (of any system) that could reasonably be expected to last for ten uses would experience an attrition of 100 units per use. Thus, at the end of five uses 500 reusable units would remain, while after ten missions no reusable units would remain. In the absence of data supporting a variable attrition rate, a constant rate of attrition was assigned for each housing system. The attrition rate (the number of units lost after each use) for any system is calculated by dividing the size of the fleet by the maximum number of uses expected for that system. Thus, when the fleet consists of 1,000 units and the maximum number of uses is N, the attrition rate is

$$\frac{1000}{N} \quad [1]$$

The estimates for N are shown in Table 2.

* The 1,000-unit fleet is a reasonable minimum acquisition for a single housing system from the viewpoint of the economics of production, procurement, management, maintenance and storage, transportation and deployment in relief missions. The life-cycle analysis is based on a 1,000-unit fleet for all housing systems.

FIGURE 1

SUMMARY OF SYSTEMS CHARACTERISTICS INFLUENCING

COST AND INVENTORY PARAMETERS OF TEMPORARY HOUSING SYSTEMS

	Standard Mobile Home	Special Design Mobil Home	Expandable Box: USA Home	Expandable Box: Alclair	Container System	Sectional Box: Atlantic	Knock Down: Atlantic	Core & Panel: Goodyear	Core & Panel: Alcoa	Core & Panel: PanelFab	Dome System: Goddard	Metal System: Armaco	Metal System: Concor
Advantages - LIVABILITY													
Potentially flexible plan								●	●	●	●	●	●
Disadvantages- LIVABILITY													
Negative psychological impact					●						●	●	●
Limited privacy between rooms											●	●	●
Advantages - TRANSPORTABILITY													
All subsystems shipped inside	●	●	●	●	●	●							
Potential integral chassis & wheels					●	●							
Efficient hauling (greater than 1 du./truck)			●	●		●	●	●	●	●	●	●	●
Integral chassis and running gear	●	●											
Designed for continual relocation		●											
Maneuverability			●		●								
Disadvantages - TRANSPORTABILITY													
Open side needs protection					●								
Open side needs protection and bracing					●	●							
Conventional stick-built connections			●	●		●	●						
Inefficient hauling (less than 1 du./truck)					●								
Requires more than one shipping package								●	●	●	●	●	●
Advantages - STORABILITY													
Compact storage package			●	●		●	●	●	●	●	●	●	●
Can be stacked			●	●		●	●	●	●	●	●	●	●
Efficient units/acre		●			●	●	●	●	●	●	●	●	●
Designed for storage			●		●			●	●	●	●	●	●
Disadvantages - STORABILITY													
Requires interior storage								●	●	●	●	●	●
Open side needs protection					●	●							
Potential deterioration of wood	●	●	●	●		●	●				●		
Inaccessibility of interior				●									
Advantages - SITE ERECTION													
No unit erection necessary	●	●			●	●							
Integral utility subsystems	●	●	●	●	●	●							
No heavy equipment required	●	●			●			●	●	●	●	●	●
Disadvantages - SITE ERECTION													
Moderate unit erection			●			●		●					
Extensive unit erection							●		●	●	●	●	●
Lengthy erection process									●	●	●	●	●
Specialized erection equipment required			●				●						
Semi-skilled labor required			●					●	●	●	●	●	●
Special connecting joint required					●	●	●				●		
Potential water/air infiltration @ joints			●					●	●	●	●	●	●
Potential leveling problems	●	●			●	●	●	●	●	●	●	●	●
Potential parts damage during erection			●				●	●	●	●	●	●	●
Large/heavy part size							●				●	●	●
Many parts to assemble								●	●	●	●	●	●
Difficult adaptation of utility subsystems					●			●	●	●	●	●	●
Advantages - MAINTENANCE													
Metal or metal-clad exterior surfaces	●	●			●	●	●	●	●	●	●	●	●
Replacement parts stocked	●	●			●			●	●	●	●	●	●
Availability of skilled personnel	●	●			●								
Minimal perimeter = low heat loss													
Disadvantages - MAINTENANCE													
Moveable parts			●	●			●						
Exposed wood exterior			●	●							●		

TABLE 2
VALUES FOR LIFE-CYCLE COST ANALYSIS FOR PRE-SELECTED TEMPORARY HOUSING SYSTEMS

	0	1	2	3	4	5	6	7	8	9	10	11	12
A	Single-wide Standard Mobile Home	\$ 6,440	\$ 8,940	Expandable Guerdon Mobile Home	\$ 17,390	\$ 10,775	Fruehauf or Similar	Atlantic International	Goodyear MPASS	ATCO Industries Ltd.	Panelfab International	Geodesic	Armco Concor
B	Acquisition Costs	\$ 3,410	\$ 3,410		\$ 4,380	\$ 3,920	\$ 4,080	\$ 4,200	\$ 4,010	\$ 4,810	\$ 4,350	\$ 5,420	\$ 7,030
C	Erection Costs	\$ 460	\$ 300*		\$ 600	\$ 540	\$ 490	\$ 470	\$ 520	\$ 610	\$ 430	\$ 650	\$ 680
D	Maintenance Costs	\$ 1,560	\$ 1,160*		\$ 3,390	\$ 2,330	\$ 1,570	\$ 2,530	\$ 2,750	\$ 2,990	\$ 2,910	\$ 3,760	\$ 5,460
E	Inter-Mission Costs	\$ 1,400	\$ 1,400		\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400
N	Site Cost	\$ 1,400	\$ 1,400		\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400	\$ 1,400
S	Max. No. of Uses	5(7)	10		7	7	14	8	9	7	8	5	4
T	Initial Salvage Value: Non-Reusable Units	\$ 1,500	\$ 2,130		\$ 1,700	\$ 1,090	\$ 1,825	\$ 1,330	\$ 1,930	\$ 1,580	\$ 1,350	\$ 1,300	\$ 4,000
f _T	Initial Residual Value: Reusable Units	\$ 1,980	\$ 2,800		\$ 3,000	\$ 2,180	\$ 3,650	\$ 2,660	\$ 3,850	\$ 3,150	\$ 2,690	\$ 2,500	\$ 4,800
	Devaluation Factor Reusable Units	1.33	1.33		1.67	1.43	1.25	1.43	1.43	1.43	1.33	1.67	1.54

NOTE: All money figures are rounded to the nearest \$10.

SOURCE: Asterisked items: contractor; all other estimates: McKee-Berger-Manauato, Inc.

b. Salvage and Residual Values

Salvage values were identified for "non-reusable" housing units that cannot be repaired for reuse after a mission and can only be sold for scrap. Residual values were identified for "reusable" housing units that are available for a subsequent housing mission. It was determined that the depreciation in the value of a housing unit is proportional to the number of times a unit is used. Initial salvage and residual values upon which the values in subsequent housing missions were based were established by MBM for each housing system. Both salvage and residual values were based on a share of the acquisition cost of the unit. The salvage value of a non-reusable housing unit at the end of a specific housing mission can be expressed as

$$\frac{S}{2^{y-1}} \quad [2]$$

where S = initial salvage value of the non-reusable unit and y = present use (mission) number.

The residual value of a reusable housing unit at the end of any housing mission can be expressed as

$$\frac{T}{f_T^{y-1}} \quad [3]$$

where T = initial residual value of the reusable unit and f_T = the factor by which T is reduced after a given number of uses. (The f_T factor, which was assumed constant within a system, varies depending on the system type.)

The salvage and residual values for any one mission are always percentages of the values for the preceding use. In the case of non-reusable units, the value is one-half the value for the preceding use. For reusable units it depends on the type of housing system. The estimates for salvage and residual values are shown on Table 2.

C. MODEL FOR LIFE-CYCLE COST ANALYSIS

A model for the life-cycle cost analysis was established to apply the recurring HUD and state constant costs, attrition rate and salvage and residual values to each housing system. Using these costs and values, it was possible to construct an equation which could be used to obtain the cost per family assisted on a per-use basis for each system. The equation is based on a hypothetical procurement of 1,000 units.

The cost per family assisted for any use can be described as: the total net cost for the current use, plus the net costs of all preceding uses less the residual value of reusable units remaining after the current use divided by the number of families assisted for the current use plus the cumulative number of families assisted from all previous uses.

Thus, the gross expenditure by HUD for a hypothetical fleet of 1,000 units of any system, for the first use, is

$$1000(A+B+C) \quad [4]$$

where: A = Acquisition Costs (from Table 1),
 B = Erection Costs (from Table 1) and
 C = Maintenance Costs (from Table 1);

and for the second and any subsequent use is

$$[1000 - (y-1) \left(\frac{1000}{N}\right)](B+C+D) \quad [5]$$

where: D = Inter-Mission Costs (from Table 1), and
 N = Maximum Number of Uses expected of a system.

II

However, from these gross expenditures HUD is able to recover the salvage value of the non-reusable units lost as a result of the current use. This value, which can be expressed as

$$\frac{S}{2^{Y-1}} \left(\frac{1000}{N} \right) \quad [6]$$

must be subtracted from the gross HUD expenditures. Thus, the net HUD expenditure for the first use is

$$1000(A+B+C) - \frac{S}{2^{Y-1}} \left(\frac{1000}{N} \right) \quad [7]$$

and for the second and any subsequent use is

$$\left[1000 - (y-1) \left(\frac{1000}{N} \right) \right] (B+C+D) - \frac{S}{2^{Y-1}} \left(\frac{1000}{N} \right) \quad [8]$$

At the end of any use, HUD has also to consider the residual value of the remaining reusable units, which will further reduce the HUD expenditure. Therefore, this value, which can be expressed as

$$\frac{T}{f_T^{Y-1}} \left(1000 - y \frac{1000}{N} \right) \quad [9]$$

must also be subtracted. Thus, the total expenditure by HUD minus all recoverables is, for the first use,

$$1000(A+B+C) - \frac{S}{2^{Y-1}} \left(\frac{1000}{N} \right) - \frac{T}{f_T^{Y-1}} \left(1000 - y \frac{1000}{N} \right) \quad [10]$$

and for the second and any subsequent use is

$$\left[1000 - (y-1) \left(\frac{1000}{N} \right) \right] (B+C+D) - \frac{S}{2^{Y-1}} \left(\frac{1000}{N} \right) - \frac{T}{f_T^{Y-1}} \left(1000 - y \frac{1000}{N} \right) \quad [11]$$

II

Having determined the total HUD expenditure minus all recoverables, it is possible to divide this sum by the cumulative number of families assisted through any given number of uses. The cumulative number of families assisted can be expressed as

$$1000y - \frac{1000}{N} \left(\frac{Y}{2}\right) (y-1) \quad [12]$$

This equation states that the cumulative number of families assisted is 1,000 multiplied by the given use number minus the total number of units lost through attrition. Thus, the total HUD cost per family assisted for the first use is

$$\frac{1000 (A+B+C) - \frac{S}{2^{y-1}} \left(\frac{1000}{N}\right) - \frac{T}{f_T^{y-1}} (1000 - y \frac{1000}{N})}{1000y - \frac{1000}{N} \left(\frac{Y}{2}\right) (y-1)} \quad [13]$$

As stated above, the total HUD cost per family assisted for any use is the cumulative costs of all preceding uses plus the net cost of the current use less the residual value of reusable units remaining after the current use divided by the cumulative number of families assisted. Thus, to calculate the HUD cost per family assisted for the second and subsequent uses all previous HUD costs must be carried over and added to the cost of the current use. This can be expressed as

$$\frac{z_{y-1} + [1000 - (y-1) \left(\frac{1000}{N}\right)] (B+C+D) - \frac{S}{2^{y-1}} \left(\frac{1000}{N}\right) - \frac{T}{f_T^{y-1}} (1000 - y \frac{1000}{N})}{1000y - \frac{1000}{N} \left(\frac{Y}{2}\right) (y-1)} \quad [14]$$

where Z = the HUD costs from all previous missions.

(It should be noted that the value of Z never includes the residual value of the reusable units shown as equation [9]. Thus Z_1 , which is the cost of the first use and is carried over to calculate W_2 , is the same as expression [7] while $Z_2 \dots Z_N$ is the same as expression [8] plus the value of Z_{y-1} .)

To arrive at the total cost per family assisted for each use, the site cost (a state expenditure on a per-family-assisted basis) must be added to expressions [13] and [14] (the costs to HUD for assisting each family). Equations [15] and [16] below show this cost added to expressions [13] and [14] as well as the position and extent of the Z values. Thus, the total cost per family assisted, for the first use, is

$$W_1 = \frac{\overbrace{1000(A+B+C)}^{Z_1} - \frac{S}{2^{y-1}} \left(\frac{1000}{N} \right) - \frac{T}{f_T^{y-1}} \left(1000 - y \frac{1000}{N} \right)}{1000y - \frac{1000}{N} \left(\frac{y}{2} \right) (y-1)} + E \quad [15]$$

where W_1 = the cost per family assisted after the first use cycle
and E = site costs,

and for the second and any subsequent use is

$$W_2 \dots W_N = \frac{\overbrace{Z_2 \dots Z_N}^{Z_{y-1} + [1000 - (y-1) \left(\frac{1000}{N} \right)] (B+C+D)} - \frac{S}{2^{y-1}} \left(\frac{1000}{N} \right) - \frac{T}{f_T^{y-1}} \left(1000 - y \frac{1000}{N} \right)}{1000y - \frac{1000}{N} \left(\frac{y}{2} \right) (y-1)} + E \quad [16]$$

where W_2 = the cost per family assisted after the second use cycle
and W_N = the cost per family assisted after the last use cycle.

Table 2 gives the values of the notations used in the formulas. Table 3 recapitulates the location and derivation of each notation.

D. LIFE-CYCLE ANALYSIS AND RANKING

The results of the life-cycle cost analysis shown in Table 4 are the sums derived by applying the values (Table 2) to equations [15] and [16]. The cost per family assisted is shown for each use, through the maximum number of uses established for each system.

Costs for the Single-Wide Standard Mobile Home were calculated for five and seven uses in order to demonstrate the sensitivity of the cost per family assisted to N, a variable particularly difficult to estimate. The results shown in Table 4 show that the overall cost per family assisted would drop only by 4%, from \$8,265 to \$7,945, if N is seven instead of five uses.

Figures 4 through 16 illustrate the total cost per family assisted for each use for each of the 12 specially adapted housing systems plus the Single-Wide Standard Mobile Home. Each system exhibits the lowest overall cost per family assisted after its maximum number of missions (N). However, in most cases the cost curves tend to "flatten out" the more the units are used.

Table 5 shows the ranking of the systems on the basis of the cost per family assisted after the last use established for each system. The Special Design Mobile Home is the most cost-effective housing system, with a cost per family assisted over ten uses of \$7,590. At the estimated maximum number of uses (five) anticipated from the Single-Wide Standard Mobile Home, the cost will be \$8,265 per family assisted. Controlling for the constant E, this value is 10% above the Special Design Mobile Home. The third most cost-effective system would be one made up of two sectional boxes, built to container standards and, therefore, of superior ruggedness. With 14 maximum uses anticipated from this system, it would cost \$9,710 per per family assisted.

If HUD wishes to employ any system as a disposable shelter, the costs per family assisted in line 1 of Table 4 apply. Based on the cost and value data estimated and compiled, such single use would not be a cost-effective approach for any of the systems evaluated.

TABLE 3

LOCATION, DESCRIPTION AND DERIVATION
OF NOTATIONS USED IN FORMULA

<u>Notation</u>	<u>Description</u>	<u>Location</u>	<u>Derivation</u>
A	Acquisition Costs	Table 2	Table 1 subtotal A
B	Erection Costs	Table 2	Table 1 subtotal B
C	Maintenance Costs	Table 2	Table 1 subtotal C
D	Inter-Mission Costs	Table 2	Table 1 subtotal D
E	Site Costs	Table 2	A constant
N	Maximum Number of Uses Expected for Any Given System	Table 2	Task II part 1
S	Initial Salvage Value of Non- Reusable Units	Table 2	Task II part A-2-a
T	Initial Salvage Value of Reusable Units	Table 2	Task II part A-2-b
f_T	Reduction Factor for T	Table 2	MBM calculations
W	Cost Per Family Assisted	Calculated from formula	
Y	Any Use Number Designation		
Z	Previous Use Cost to HUD	Calculated from formula	

TABLE 4
LIFE CYCLE COST ANALYSIS FOR PRE-SELECTED TEMPORARY HOUSING SYSTEMS
(Total Cost Per Family Assisted at Each Use)

No. of Uses	0		1		2		3		4		5		6		7		8		9		10		11		12	
	Single-Standard Mobile Home	Wide Home	Special Design Mobile Home	Expandable Guerdon Mobile Home	USA Home	Altair Industries	Fruehauf or Similar	Atlantic International	Goodyear MPASS	ATCO Industries Ltd.	Panelfab International	Geodesic	Armco	Concor												
1.	\$ 9,825	\$9,800	\$11,315		\$20,955	\$14,565	\$20,540	\$17,835	\$21,425	\$19,515	\$16,980	\$18,140	\$28,170	\$20,295												
2.	8,785	8,700	9,235		16,395	11,990	14,650	13,965	16,055	15,565	13,680	15,585	23,200	16,560												
3.	8,450	8,320	8,550		14,800	11,105	12,700	12,640	14,205	14,215	12,565	14,705	21,650	15,310												
4.	8,310	8,135	8,195		13,990	10,665	11,710	11,970	13,260	13,545	12,015	14,290	21,100	14,705												
5.	8,265	8,030	7,975		13,525	10,415	11,105	11,575	12,685	13,160	11,690	14,120	14,390													
6.		7,970	7,825		13,270	10,275	10,700	11,335	12,320	12,950	11,495															
7.		7,945	7,720		13,150	10,215	10,410	11,195	12,085	12,855	11,380															
8.			7,650				10,195	11,135	11,945		11,330															
9.			7,610				10,035		11,880																	
10.			7,590				9,915																			
11.							9,825																			
12.							9,765																			
13.							9,725																			
14.							9,710																			

Note: All figures are rounded to the nearest \$5.

TABLE 5
RANKING OF PRE-SELECTED TEMPORARY HOUSING SYSTEMS

<u>Housing System</u>	<u>Basic Configuration</u>	<u>Max. # of Uses</u>	<u>Cost Per Family Assisted</u>	<u>Rank</u>
Special Design Mobile Home	One Box on Wheels	10	\$ 7,590	1
Single-Wide Standard Mobile Home	One Box on Wheels	5	8,265	2
Fruehauf or similar	Two Sectional Boxes (Containerized)	14	9,710	3
Altair Industries	Expandable Box	7	10,215	4
Atlantic International	Sectional Box and Knock-Down	8	11,135	5
Panelfab International	Core and Panelized	8	11,330	5
Goodyear MPASS	Core and Panelized	9	11,880	7
ATCO Industries	Sectional Box and Knock-Down	7	12,855	8
USA Home	Expandable Box	7	13,150	9
Geodesic	Core and Special Pack- aged Enclosure	5	14,120	10
Concor	Core and Special Pack- aged Enclosure	6	14,265	11
Armco	Core and Special Pack- aged Enclosure	4	21,100	12
Expandable Guerdon Mobile Home	Expandable Box	data not made available to contractor		

FIGURE 4

COST PER FAMILY ASSISTED

System: SINGLE-WIDE STANDARD MOBILE HOME

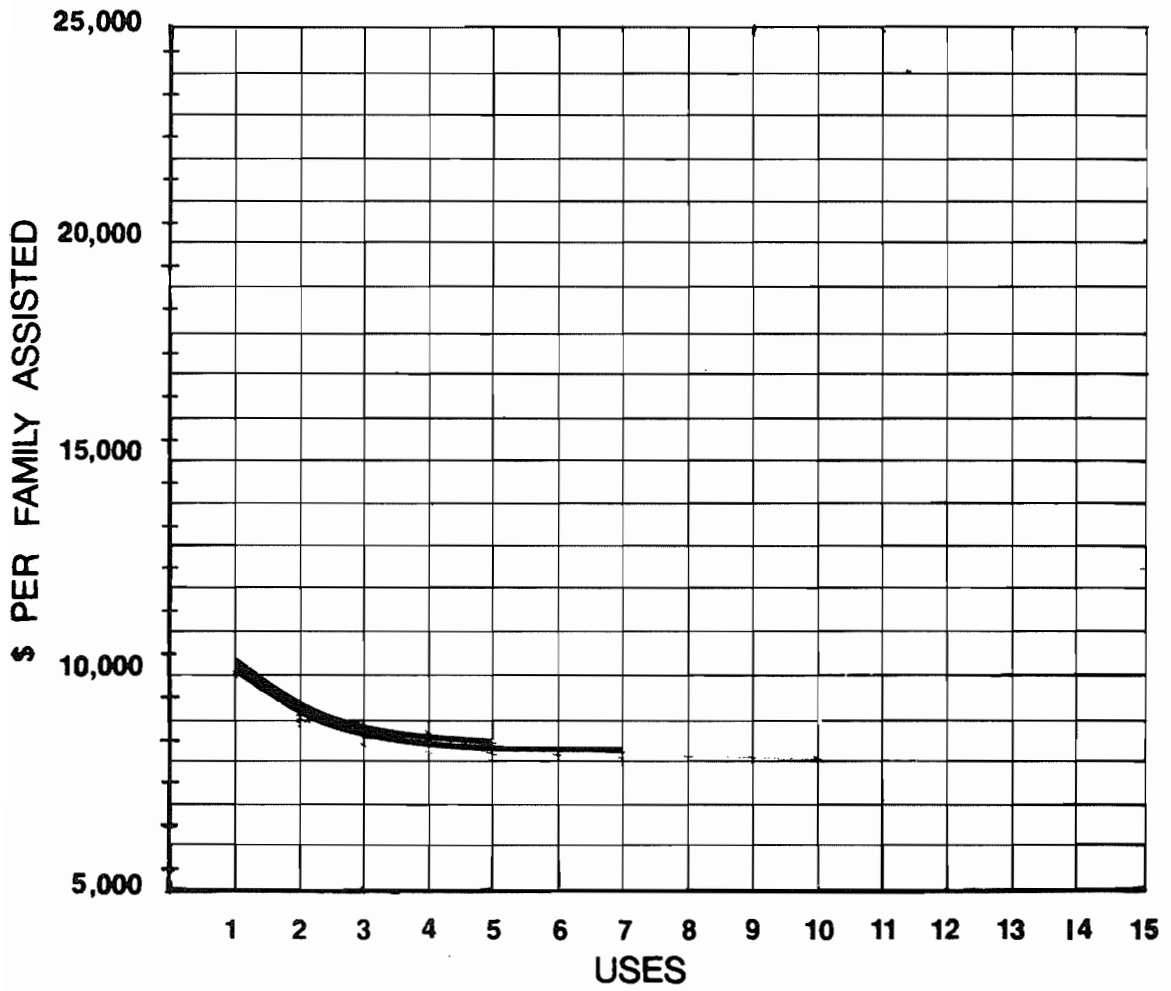


FIGURE 5

COST PER FAMILY ASSISTED

System: SPECIAL DESIGN MOBILE HOME

1

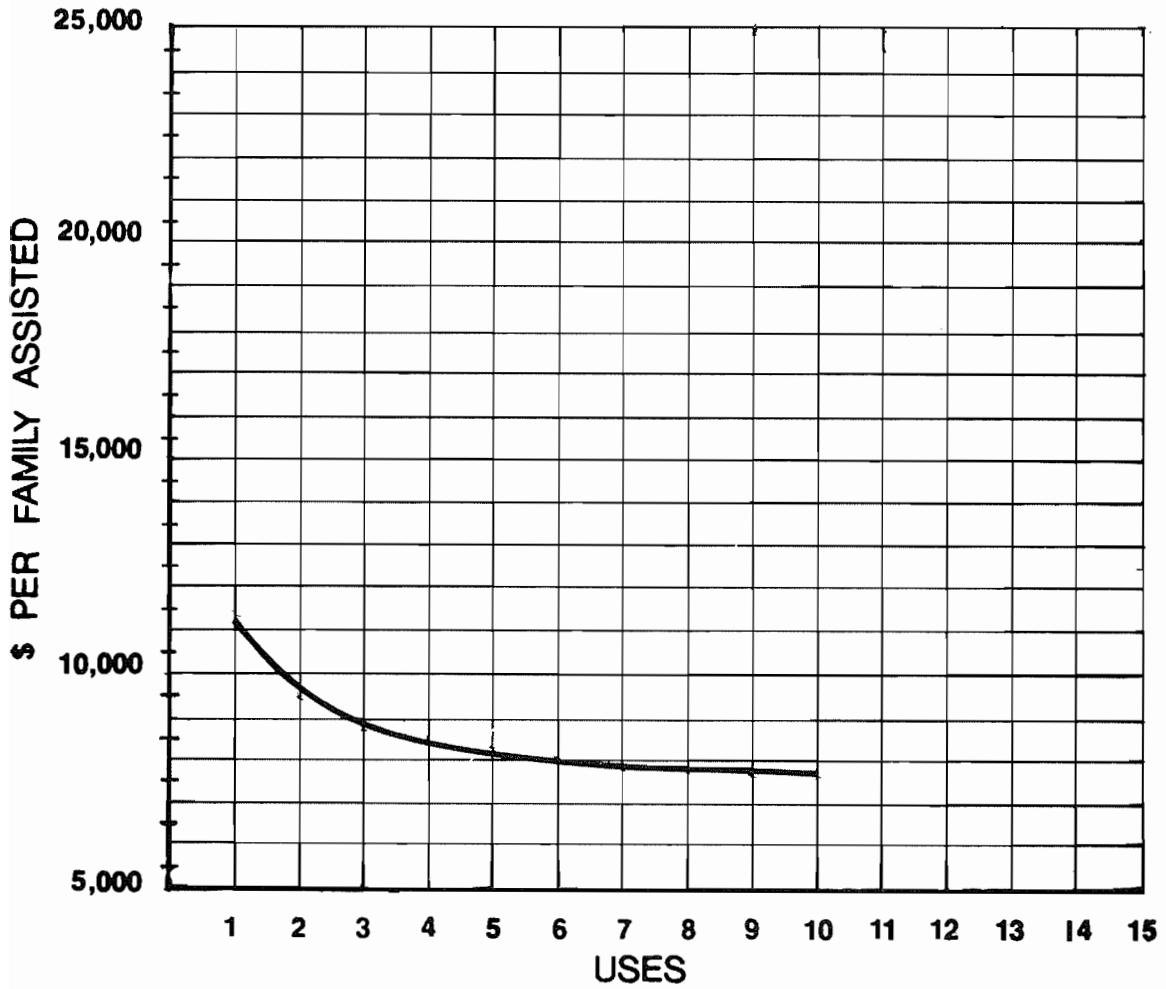


FIGURE 6

COST PER FAMILY ASSISTED

System: EXPANDABLE GUERDON MOBILE HOME

2

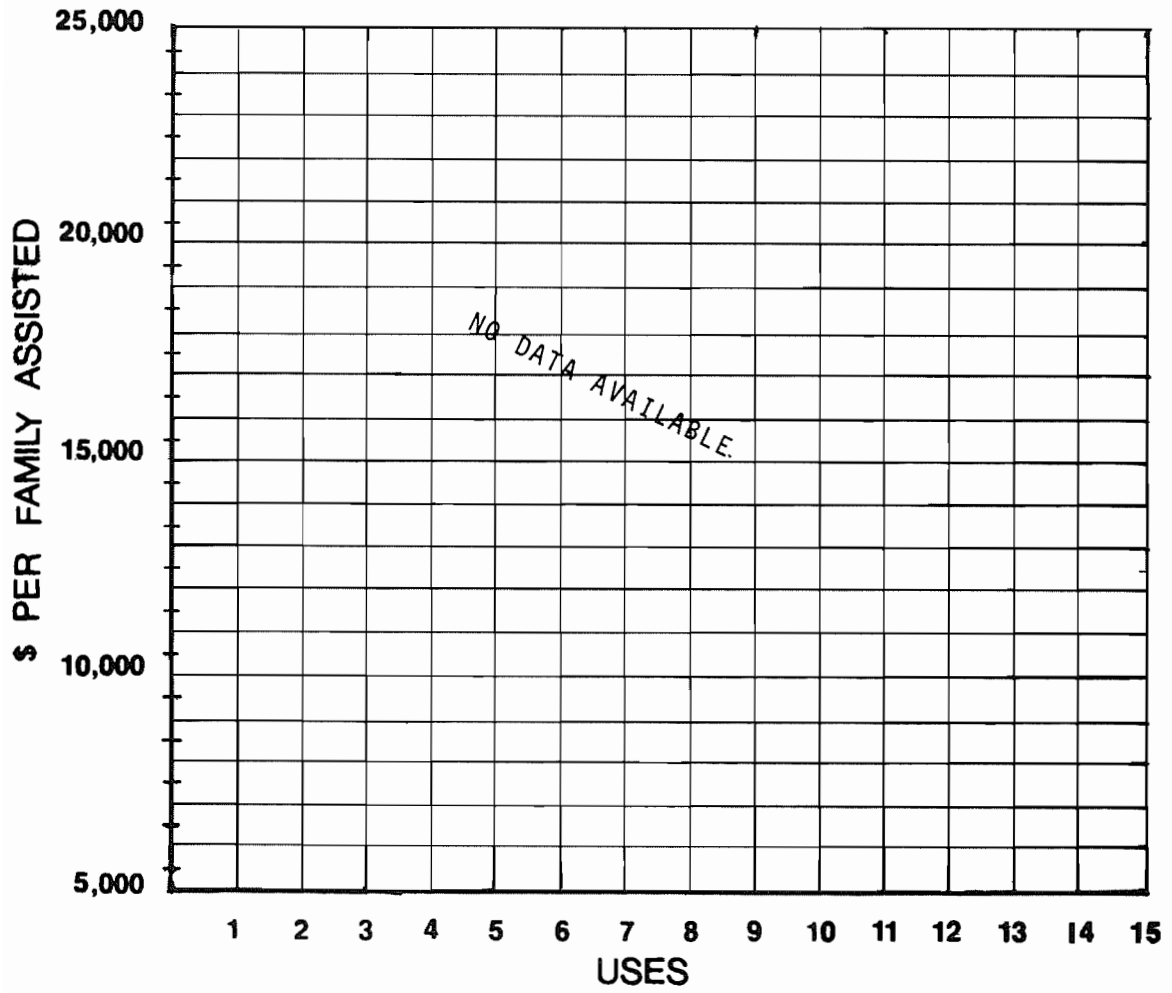


FIGURE 7

COST PER FAMILY ASSISTED

System: USA HOME

3

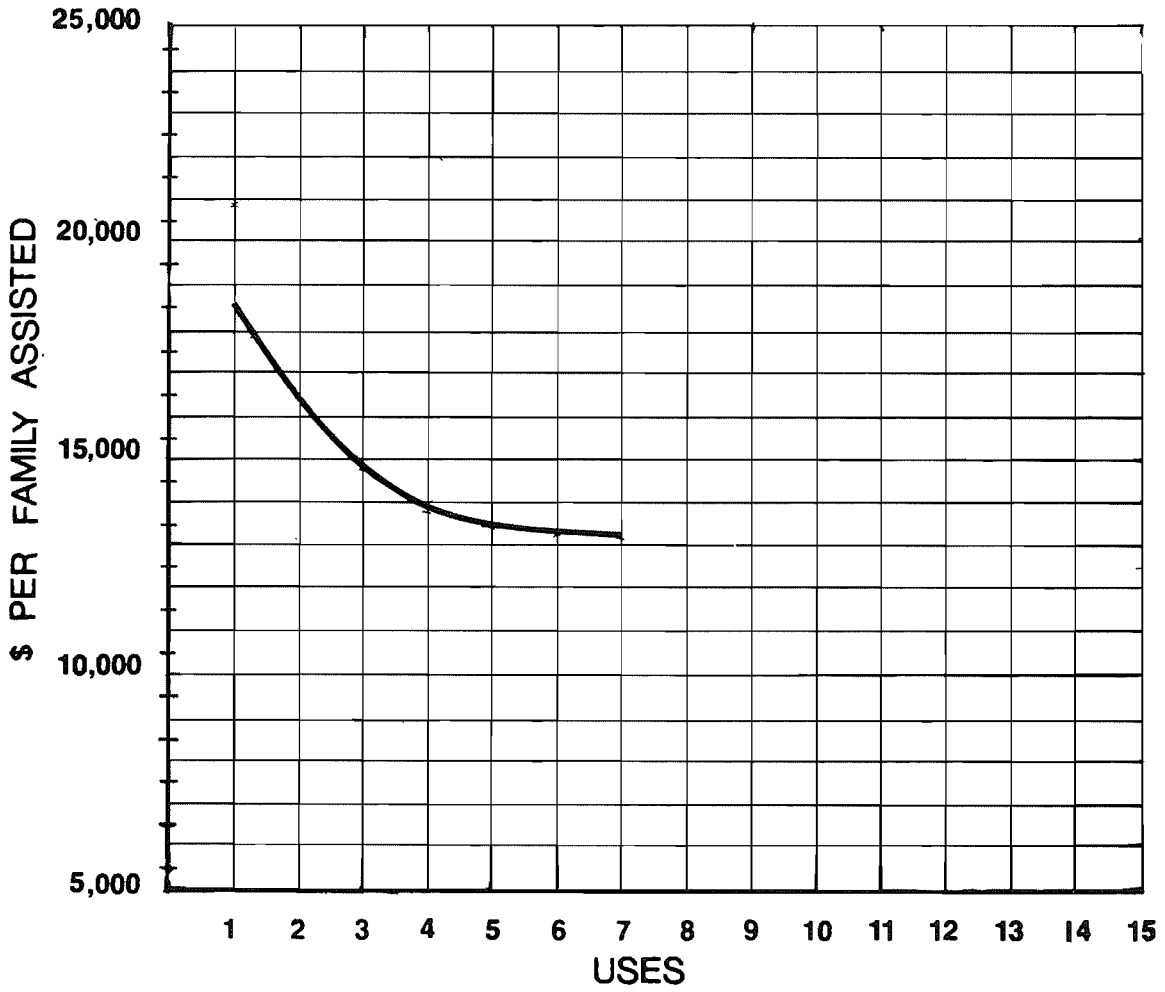


FIGURE 8

COST PER FAMILY ASSISTED

System: ALTAIR INDUSTRIES

4

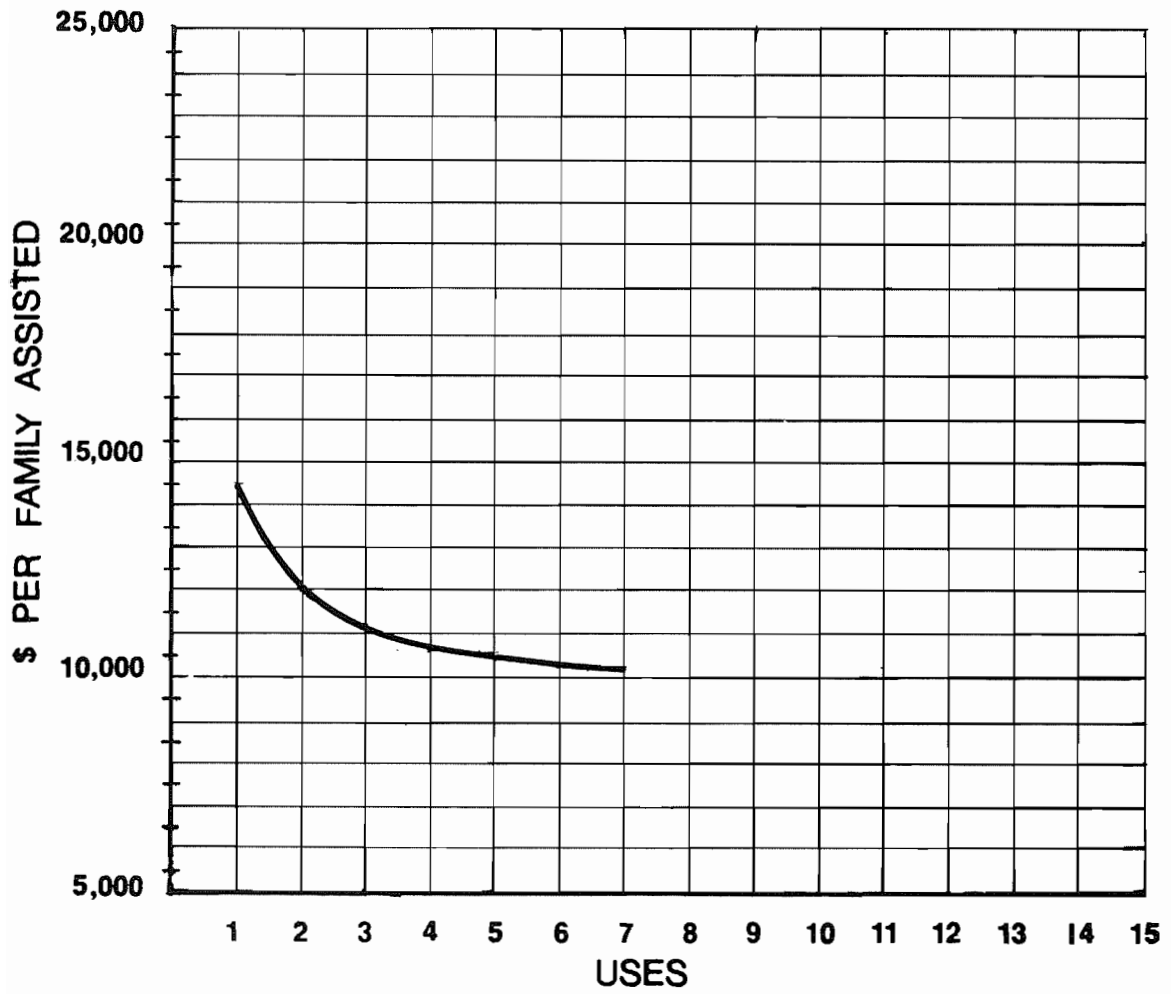


FIGURE 9

COST PER FAMILY ASSISTED

System: FRUEHAUF OR SIMILAR

5

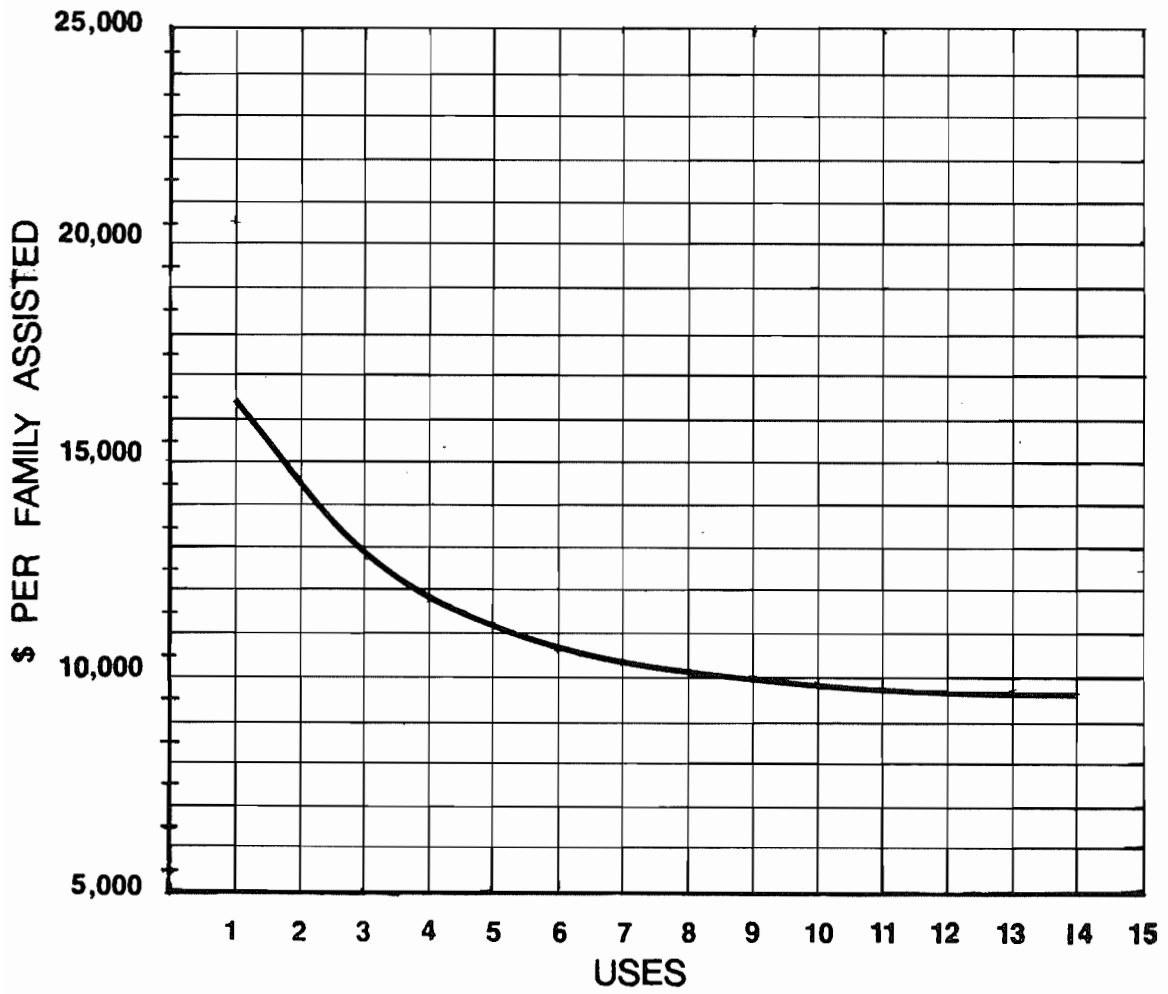


FIGURE 10

COST PER FAMILY ASSISTED

System: ATLANTIC INTERNATIONAL

6

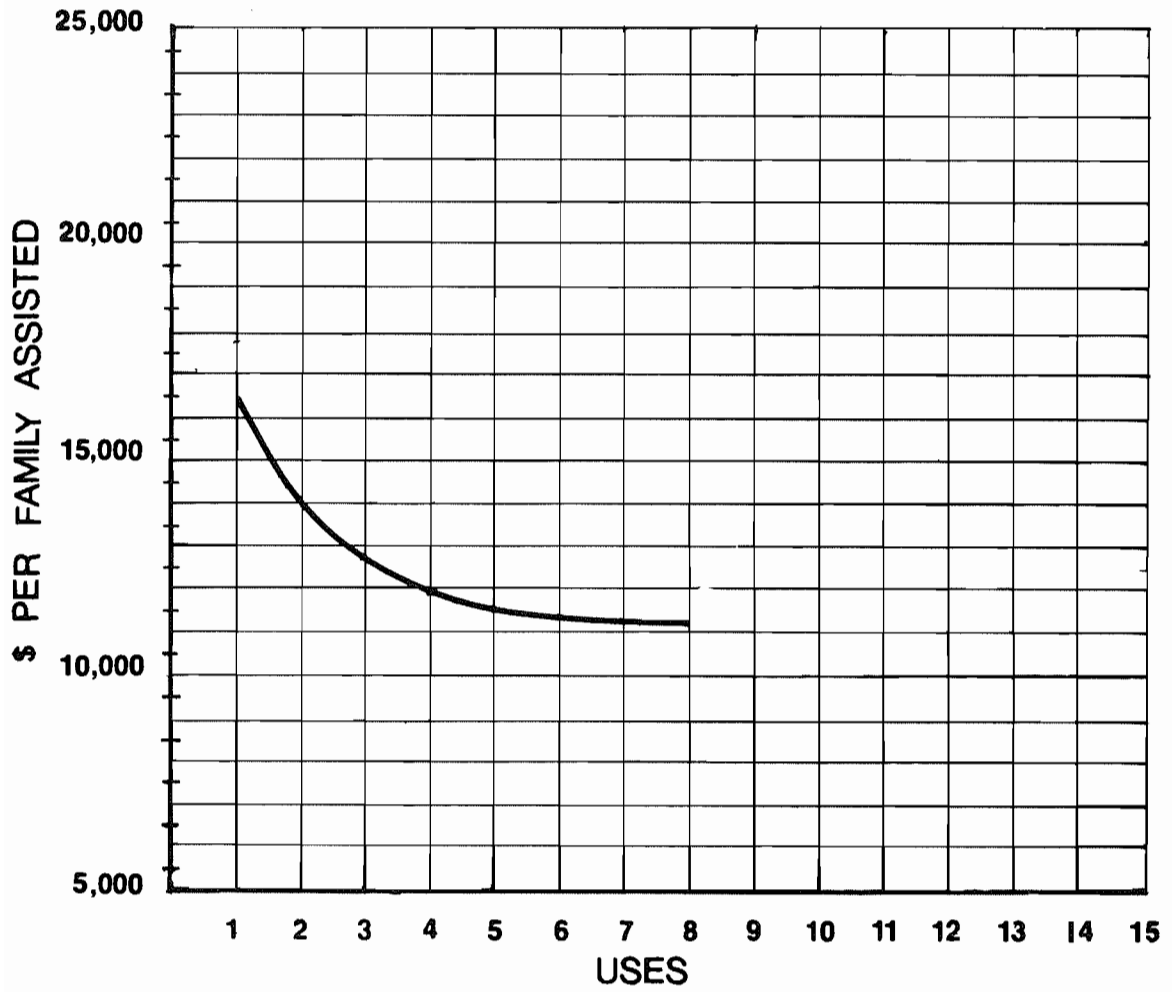


FIGURE 11

COST PER FAMILY ASSISTED

System: GOODYEAR MPASS

7

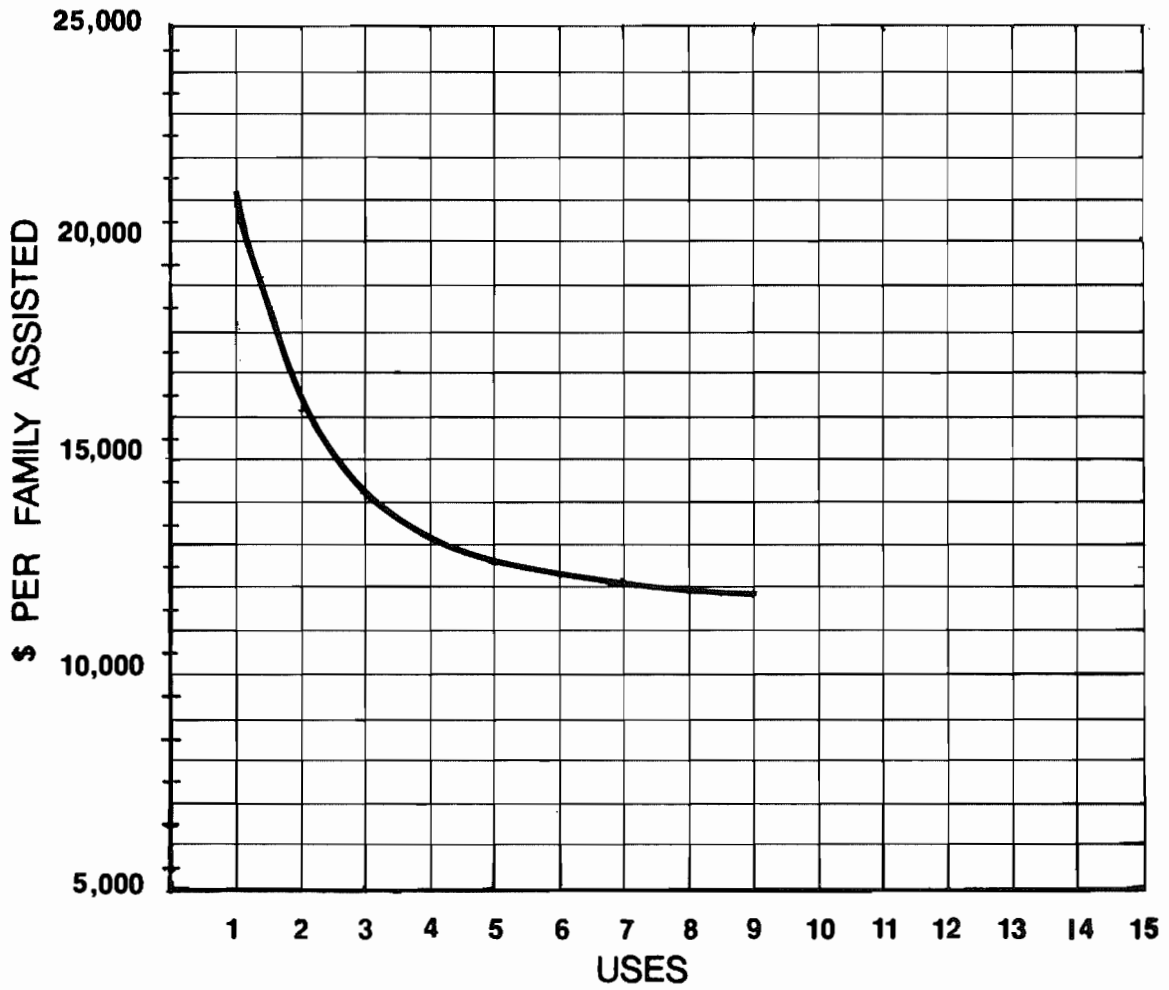


FIGURE 12

COST PER FAMILY ASSISTED

System: ATCO INDUSTRIES LTD.

8

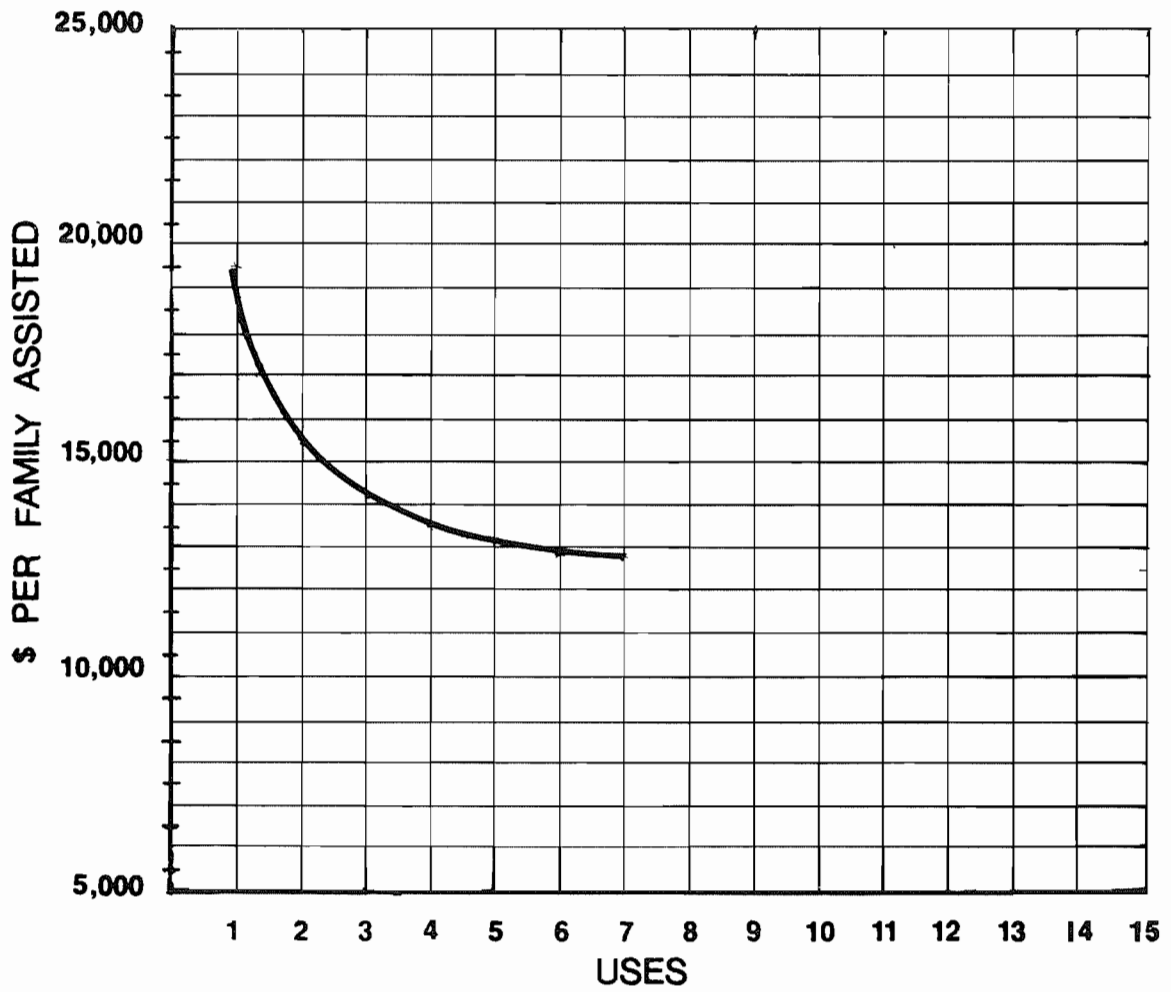


FIGURE 13

COST PER FAMILY ASSISTED

System: PANELFAB INTERNATIONAL

9

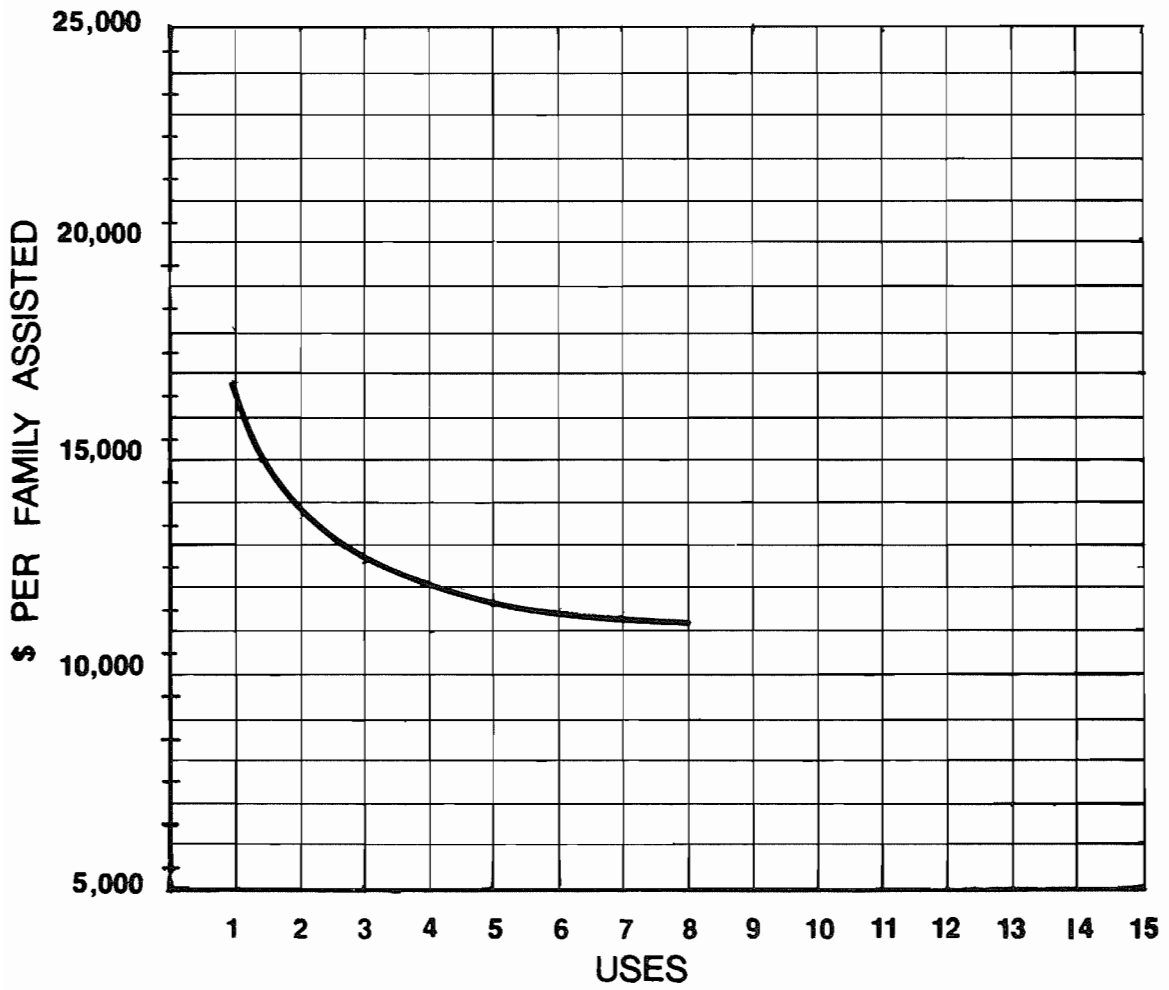


FIGURE 14

COST PER FAMILY ASSISTED

System: GEODESIC

10

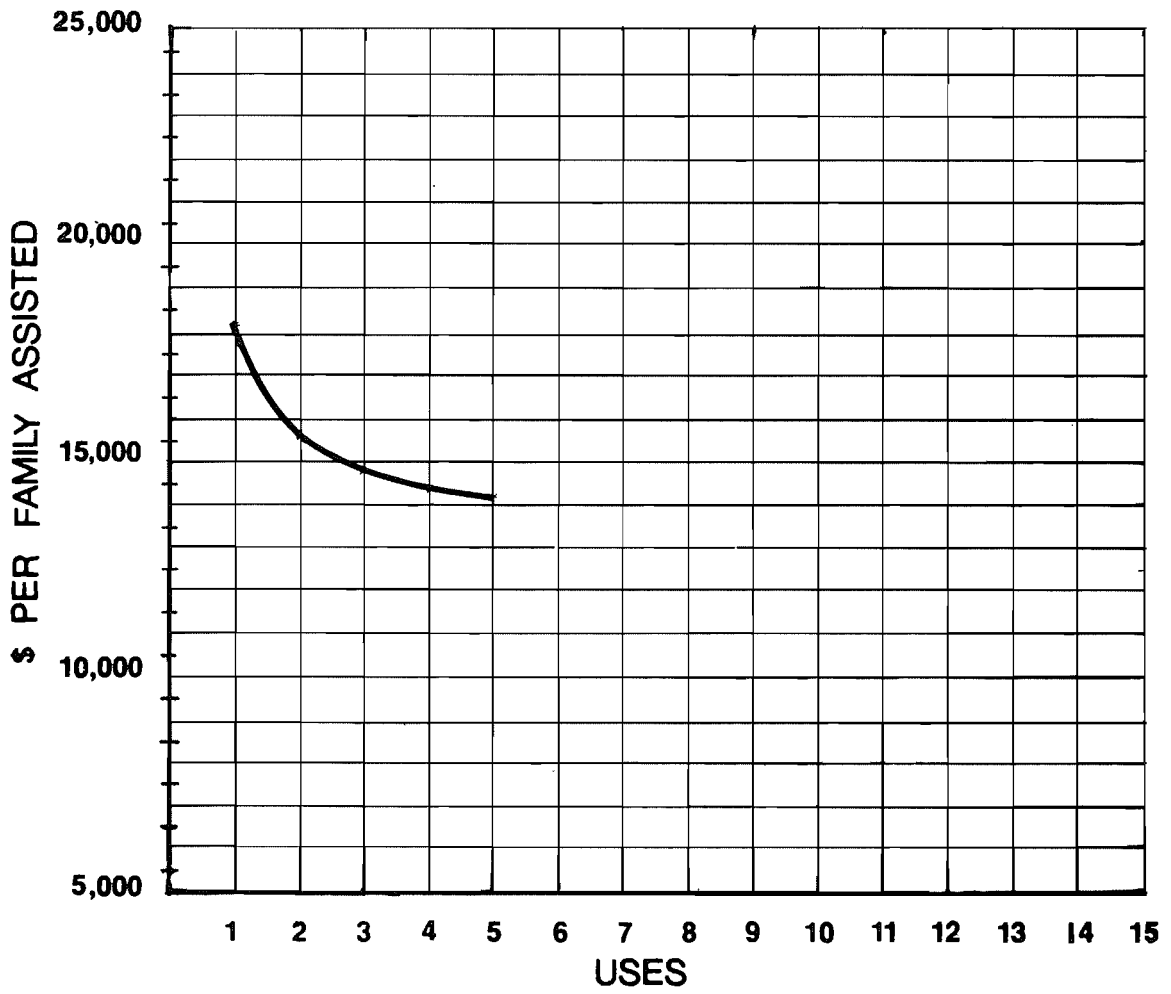


FIGURE 15

COST PER FAMILY ASSISTED

System: ARMCO

11

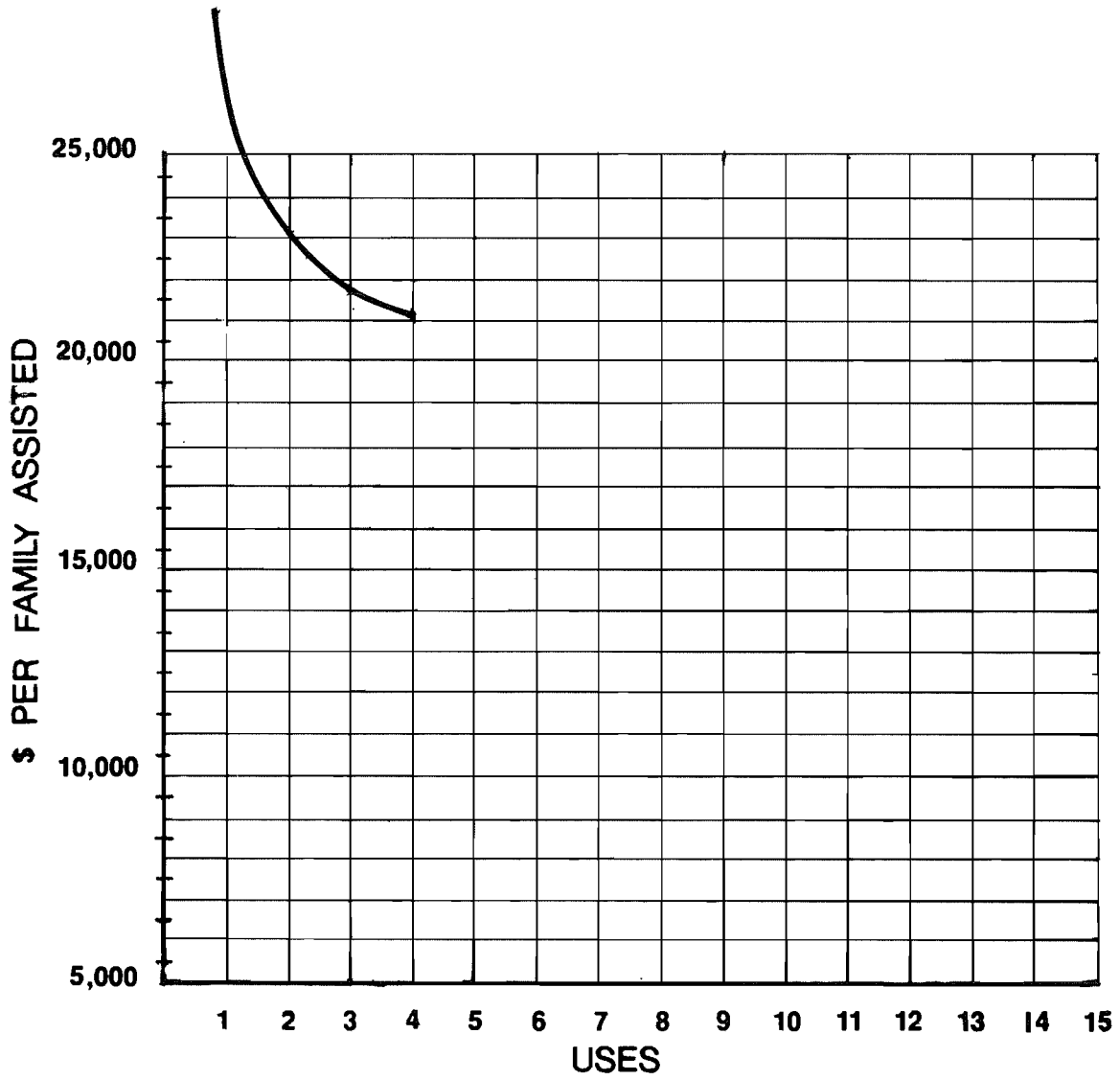


FIGURE 16

COST PER FAMILY ASSISTED

System: CONCOR

12

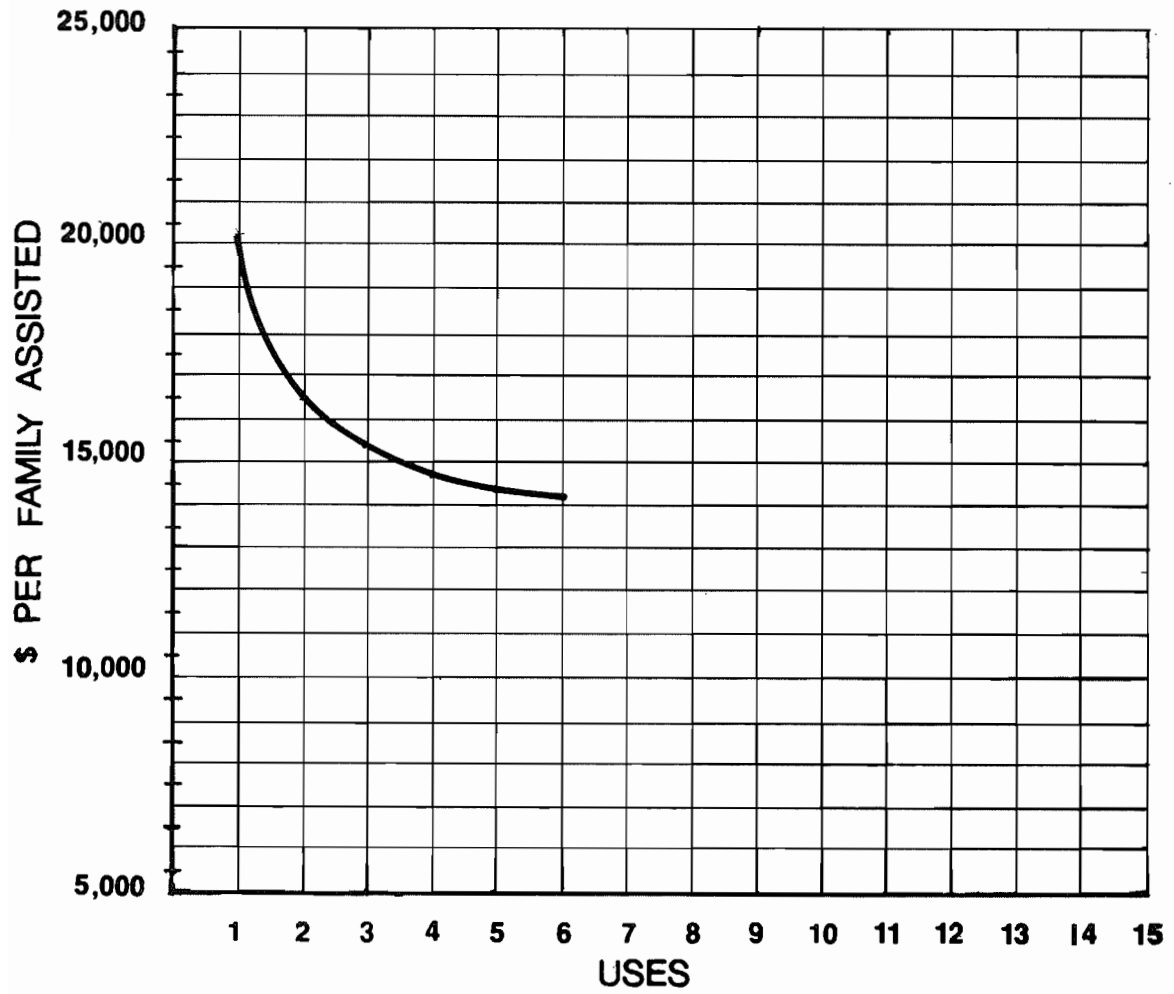


FIGURE 17

SELECTED TEMPORARY HOUSING SYSTEMS BY BASIC CONFIGURATION

INDUSTRY SEGMENT	BASIC CONFIGURATION				SECTIONAL BOX (ES) AND KNOCK-DOWN(S)	CORE AND PANELIZED	CORE & SPECIAL PACKAGED ENCL.		
	1 ON WHEELS GENERAL	2 EXPANDABLE BOX ON WHEELS	3 TWO OR MORE SECTIONAL BOXES ON WHEELS	4 GENERAL				5 GENERAL	6 GENERAL
A. MOBILE HOME INDUSTRY	<p>1</p> <p>Single-Wide Standard M.H.²</p> <p>Ruggedized Standard M.H.²</p> <p>Special Design Mobile Home²</p> <p>Travel Trailer²</p>	<p>2</p> <p>Expando Mobile Home²</p> <p>Expandable Quardon M.H.²</p>	<p>3</p> <p>Double-Wide Standard M.H.²</p>	<p>4</p>	<p>5</p>	<p>6</p>	<p>7</p>	<p>8</p>	<p>9</p>
B. MANUFACTURED HOUSING INDUSTRY:	Evaluated for "fast delivery permanent home" Program. Manufacturers of marketed relocatable housing systems included under C.b below.								
C. MANUFACTURERS OF SPECIAL RELOCATABLE SYSTEMS									
a. Military									
(1) Air Force									
(2) Army									
(3) Navy									
b. Private Market Housing Systems									
(1) Camp Systems									
(2) Honeycomb Panel Systems									
(3) Dome Systems									
(4) Miscellaneous Systems									
c. Other Commercial Relocatable Shelter Systems									
(1) Air Structures									
(2) Metal Structures									
(3) Container Vans									

C - Containerized System

- 1 - Existing technology without integral mechanical core.
- 2 - Existing technology with potential integral mechanical core.
- 3 - Included in cost-effectiveness analysis as marketed (meeting HUD/FPS Level I retention criteria)¹.
- 4 - Included in cost-effectiveness analysis with a floor plan specially adapted to meet the Minimum Livability Standards for Temporary Housing established for this study.

() The systems produced by the manufacturer in this category ("Basic Configuration") are not specifically evaluated in the report.

III CONCLUSIONS

Upon completion of the life-cycle cost analysis performed under this Task the HUD Government Technical Representative selected the five highest ranking housing systems for further study. Figure 16 shows these systems within the matrix for classification and evaluation used throughout Volumes 4 and 5 of this study (reports for Task I-B-2 and Task II). They represent the following four types of "basic configuration":

1. One Box on Wheels
2. Expandable Box*
3. Two Sectional Boxes (Containerized)
4. Sectional Box and Knock-Down

This selection completed the transition from the initial focus of this study on industries and their products to a focus on generic types of systems meaningful for subsequent stages in HUD's effort to identify and procure more cost-effective housing systems for disaster relief.

Volume 6 of this study (Report for Task III) completes the analysis of applicable systems technology under the present contract stage with outline performance specifications for the four types of basic configuration selected, and with a detailed use scenario for the four selected systems types.

* Since no data for evaluating the Expandable Guerdon Mobile Home were made available for the study, the question whether this system is more cost-effective "on wheels" or "general" was left open.

III

The performance specifications are to guide the development of prototypes designed to better meet disaster relief requirements by modifying existing technology in certain respects. Systematic field tests of such prototypes will then enable HUD to collect data on actual performance measured in terms of the life-cycle cost and inventory parameters outlined in this Task Report. A more rigorous, complete and consistent procedure for monitoring the cost of HUD's current mobile home operation in terms of the life-cycle parameters would establish a more reliable basis for comparing the costs of alternative housing systems with the Single-Wide Standard Mobile Home.

APPENDIX

SOURCES AND ASSUMPTIONS FOR HUD COST PARAMETERS

(Table 1)

A. ACQUISITION COSTS

1. FOB PRICE

The FOB purchase price was based on information obtained from the manufacturers of the 12 pre-selected housing systems. MBM's estimates supplemented these costs where major components (i.e., plumbing and heating systems) were not included by the manufacturer in the basic system. Systems presently not manufactured were estimated separately, using MBM historical data and information supplied by the Joint Venture.

2. TRANSPORTATION TO STORAGE

Transportation to storage is the cost to transport the unit 400 miles from the manufacturer to a HUD/EPS storage area.*

3. INITIAL STORAGE

Initial storage is the cost for storing the unit for one year at a HUD/EPS storage area. Included in this cost is protective maintenance, security, equipment, setting units in place, personnel, quality control and required storage of subsystems.**

B. ERECTION COSTS

1. TRANSPORTATION: STORAGE TO STAGING

Transportation from storage to staging is the cost to transport the unit 375 miles from a HUD/EPS storage area to the disaster staging area.***

* All transportation costs are based upon applicable tariffs, truck load rates and other information supplied by the Mobile Home Carriers Conference, Inc., and private carriers.

** A shorter period of storage -- for example, six months -- has very little effect on the cost per family assisted for each system.

*** The 375-mile figure for transportation from storage to staging was supplied by EPS.

2. HOLD AT STAGING

These costs are incurred in monitoring the unit at the staging area prior to dispatching it to a housing site.

3. SET-UP CONTRACT

a. Transportation: Staging to Site

Transportation from staging to site is the cost of transporting the unit 25 miles from the staging area to the housing site.

b. Rough Grading

Rough grading is the cost to level a site sufficient for foundation placement.

c. Foundation and Unit Erection

Foundation and unit erection is the cost (including materials, equipment, manpower, inspection and quality control, where required) of erecting, blocking and leveling the unit. Foundation costs were based on the requirements of each system. Erection data were based on general information supplied by manufacturers. Labor costs and necessary equipment costs were estimated by MBM.*

d. Skirting

Skirting is the cost of materials and labor for placing a metal shield around the perimeter of those systems which require it.

4. UTILITY HOOK-UP**

a. Sewer, Water, Electric

Sewer, water and electric hook-ups are the costs of connecting these utilities to the individual unit.

* The average cost per man-hour used in these calculations was \$10, the rate paid in Wilkes-Barre during the Agnes relief effort.

** Costs were based on historical data obtained from Wilkes-Barre and Brandenburg, Kentucky. The monies paid by HUD for the utility hook-ups in Brandenburg were seemingly quite excessive. However, these costs were carried in this study to maintain consistency within the report.

b. Gas

The gas hook-up is the cost of installing and connecting gas service to the unit.

5. DAMAGE REPAIR

Damage repair is the cost to HUD of repairing damage incurred in travel. These costs are based on descriptive HUD data.

6. LABOR IMPORT

Labor import is the cost of providing supervisory personnel with specialized skills for erecting the unit (as recommended by the manufacturer of the system) that may not be available locally.

C. MAINTENANCE COSTS

1. MAINTENANCE AND REPAIR

Maintenance and repair on individual unit sites includes one man with truck, small tools and average maintenance items to service 40 units for one year. For group sites, maintenance includes one man with truck, small tools and average maintenance items to service 70 units for one year. Maintenance costs are based on descriptive data furnished by HUD representatives at the Brandenburg disaster site and HUD historical data.

2. SPARE PARTS

Spare parts is an estimate of the materials needed to cover repair and replacement of parts in the field.

D. INTER-MISSION COSTS

1. DEACTIVATION

Deactivation is the cost of disconnecting the unit preparatory to shipment. Costs are based on HUD historical data and

do not include removal of underground utilities, which are commonly left in place and back-filled.

2. PREPARATION FOR SHIPMENT AND STORAGE

Costs incurred in preparation for shipment and storage include disassembly, cleaning, fumigating, protecting and securing interior items like furniture, inspecting and removing foundations. Costs are based on disassembly information supplied by the manufacturers and HUD historical data.

3. TRANSPORTATION TO STORAGE

Transportation to storage is the cost to transport the unit 400 miles from the disaster site to a HUD/EPS storage area.

4. STORAGE

This inter-mission outlay repeats the same costs involved in Initial Storage, and also includes storage of those items not supplied with the original unit, such as heating and plumbing systems. It also includes site preparation at the storage area, power, standby personnel and inspection as required.

5. REPAIR FOR REUSE

Repair for reuse is the cost of fully restoring and reconditioning the unit for use in subsequent relief missions. This cost was established by MBM and is derived from the following factors: 35% of the basic unit price (excluding non-replaceable items such as added utility systems) was determined to be the maximum cost beyond which repair is no longer feasible, plus the cost of a complete furniture replacement after every fourth mission. This sum is then prorated over the maximum number of uses expected for any given housing system. One-half the established basic unit price was used for housing systems (i.e., Special Design Mobile Home and Fruehauf or similar) designed for extensive travel.

An equation for repair for reuse was devised where N is the maximum number of uses for any given housing system and \$2,000 is the cost for complete furniture replacement. Thus,

$$\text{Repair for Reuse} = \frac{[.35] [\text{basic unit cost}] + [\text{furniture replacement cost}] \left[\frac{\text{maximum number of uses}}{\text{furniture replacement every fourth mission}} \right]}{\text{maximum number of uses}}$$

which can be restated as

$$\text{Repair for Reuse} = \frac{[.35] [\text{basic unit cost}] + \$2,000 \left[\frac{N}{4} \right]}{N}$$

and, for systems originally designed for extensive travel, can be stated as

$$\text{Repair for Reuse} = \frac{[.175] [\text{basic unit cost}] + \$2,000 \left[\frac{N}{4} \right]}{N}$$

