TRANSIT PASSENGER SHELTERS:
BASIC DESIGN PRINCIPLES

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The report analyzes the problem of passenger shelter design with the object of maximizing user welfare while contending with the constraints of environmental fit and cost. Each element of welfare (comfort, safety, convenience) is considered separately in the light of the constraints imposed by fit and cost.

This analysis is used to develop a list of design criteria for shelters and a prototype shelter design is developed based on these criteria.

The report also contains information on other problems confronting the shelter designer and a report on the shelters in use in the United States in 1970.
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This prototype passenger shelter was designed based on the principles developed in this report.
Transit Passenger Shelters: Basic Design Principles

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Section I - The Problem

The problem of traffic congestion in most American cities has reached serious proportions. There is a growing realization that alternatives to automobile travel must be developed. In recent years cities have been improving transit networks for the purpose of providing greater overall mobility and to lessen the harmful impact of automobiles on the urban environment.

One of the drawbacks of transit usage, particularly bus transit, is the necessity to wait at a transit stop on the street exposed to the weather, traffic and crime.

Waiting in a public, open space should be a pleasing and desirable experience. Whether it is or not depends on the entire set of factors that constitute the local environment and only to a small extent on the design of the waiting area itself.

It is recognized that the best designed hardware cannot change what is basically a poorly designed environment; however, the primary purpose of this report is to focus on the basic principles for the design of passenger shelters to minimize the hazards faced by the transit passenger and make the total transit trip a more pleasant experience.

It can be seen in Figures I-1 through 1-6 that the situation for the pedestrian/transit passenger is chaotic, unsafe and unpleasant. Moreover anyone waiting for a bus is often exposed to rain or snow and is a vulnerable target for violent crime.
To make matters worse, discussion of transit shelters assumes that the space for the shelter must be taken from the little remaining sidewalk area as if the possibility of intruding into the automobile domain were unthinkable.

Because of the limited spaces available, it is necessary to consider the needs of those outside the shelter as well as those inside. A design must deal with the issues of health, welfare and safety and not just the physical attributes of the shelter. It must be remembered that intra-urban circulation involves both pedestrian and vehicular circulation, and it is at one of the interfaces of the two flows, the transit stop, that shelter is needed.

For the purposes of this report, we will define shelter as that which affords protection against a hazard, i.e., a peril to health, welfare and safety. The major hazards to transit passengers waiting in the street are; inclement weather, fatigue, lack of space and isolation.

In seeking a design that can best protect passengers against these hazards, we are confronted by a three part question:

1. How can those exposed to hazards of the urban street best be sheltered while waiting for a transit vehicle?
2. How can the shelter best fit into the limited pedestrian space among the great variety of activities and facilities?
3. How can it be done economically?

The third part of question is most crucial considering the limited funds available for transit improvements and the tendency of some to desire
pedestrian corner congestion

Figure 1-1
the unexamined pedestrian street environment...what is going on?.... and where is the space for it?...

Figure 1-2
VISUAL CHAOS:

where is the bus stop sign?...
is the bus coming?...

Figure 1-3
which bus is coming?

is it going to stop?

Figure 1-4a
will it stop at the curb?

Figure 1-4b
cut back the sidewalk! send pedestrians to an island!

torture the bus driver! tie up the city!

make room for the private vehicle!

Figure 1-5
where am i supposed to be?
expensive structures designed not with the welfare of the passenger in mind, but to satisfy aesthetic tastes.

The main concern of the study is the welfare of the waiting passenger as affected by the constraints of environmental fit and costs.

In dealing with these elements the following must be considered:

- Urban management - cost - benefit analysis, priorities, quality of transit service.
- Urban design/product design - street and shelter spatial organization
- Urban micro-climate - wind, temperature, etc., at a particular street location
- Urban behavior - community values, individual values

With these in mind, the criteria for passenger shelters were developed. The analysis of shelter related problems is followed by the development of a prototype design which is a practical demonstration of the design principles and a flexible model which can be used in many areas of the country.
Section II - Data Collection

It is not surprising that so few shelters have been constructed considering the frustrations of obtaining funds and dealing with objections from public and private sources. The prevailing attitude toward shelters is reflected in the difficulty involved in collecting data concerning them. In general the records of shelter locations, cost and design could not be obtained from cities. Difficulty was also encountered in obtaining technical data from manufacturing organizations.

A. Cities Surveyed:
In 1969-70 forty-seven cities were surveyed concerning the number and type of shelters available (see Appendix A). Thirty-two confirmed that they had shelters in use. These varied widely in design, type of construction, degree of enclosure and condition. There were a total of 2622 shelters in the thirty-two cities. Three-fourths were less than five years old and 720 were funded with the assistance of the Urban Mass Transportation Administration's Capital Grant program.

B. Shelters In Use:
There seem to be as many different shelter designs as there are designers and fabricators. This situation tends to keep the price of shelters high and precludes the economies available from the production of standard units.

Shelters fall into two broad categories, open and partially enclosed. The open types do not have wall elements and generally afford less than adequate protection. Open shelters may be further classified by the
type of support structure: post-and-beam, single or double cantilever, umbrella and canopy.

Few shelters have protection (enclosure) on all sides and none is fully enclosed (there are no doors on entrances and exits). Partially enclosed shelters are supported by a post-and-beam structure or paneled wall supports.

Some fabricators assemble shelters with varying degrees of enclosure with the use of metal or wood framed panels where the framework is load bearing or stock window walls or large sheet enclosure with a post-and-beam structure.

The types of materials used are as varied as the shelter designs. Fabricators often use shelter designs based on components designed for another use such as window walls, or curtain walls.

Panels are made of glass, acrylic, polycarbonate metal, transite, plywood, hardboard, porcelain enameled metal or sandwich types with metal, transite hardboard or other skin over styrofoam, gypsum, paper, wood or other core. There is an increasing tendency to use transparent wall panels and the use of most of the above materials will probably decrease.

Roofs are made of metal, transite, plastic sheet or a composite using a variety of materials.

Finishes used on the materials also vary. Wood, plywood and masonite are generally painted. Steel may be painted, have a baked enamel or porcelain enamel finish or have a stainless steel jacket. Transite is either painted or natural and glass and plastic have natural finishes.
Existing shelters may also provide other amenities such as artificial lighting, heating or ventilation. None provide cooling.

Figure II-1 through II-6 are examples of domestic shelters in use and Figure II-7 through II-11 show foreign shelters.

C. Shelter designers, fabricators and suppliers:
Thirty-eight shelter designers, fabricators and suppliers were surveyed. Only eight of twenty-five U.S. firms could furnish data sheets, price lists or consumer literature. None of these shelters was listed in the 1971 Sweets Catalogue Files¹. Since the time of the survey, however, there has been a greater interest in shelters and the situation may have changed.

D. Costs:
Reported costs of shelters varied from $300 to $3,000 per unit, but most information was incomplete. Often it was impossible to isolate the shelter cost from the total cost of a larger project.

Cost figures vary greatly because of variations in size and design which respond to different environmental fits and service values.

E. Shelter related problems:
During the course of collecting data concerning shelters, several cities were visited and the problems relative to the use of shelters were observed firsthand. Two major problem areas are placement (location) and vandalism.

¹Sweets Division, McGraw-Hill Information Systems Company, N.Y., N.Y.
Architectural and Light Construction Catalogue Files
shelters in the U.S.
München
steel frames
wood roof construction

foreign shelters

London
maintenance and repair by private advertising company which erects shelters in return for advertising rights
Figure II-8
Placement: Two major difficulties involved in locating shelter are limited sidewalk widths and objections from adjoining property owners.

Property Owners and Storekeepers: Property owners' reaction to the placement of transit stops and shelters varies. None likes to have anything in front of his property that will attract noisy, unruly activity or behavior, such as a transit stop and shelter serving a nearby school might do; nor do they like objects that permanently block the view of and/or from their property. Storekeepers welcome a transit stop close by, but preferably not in front of their premises, and object to whatever they see as a blockage affecting access to their shops or viewing of their displays and signs.

Conflicting Uses: There are no comprehensive, systematic studies of the functions and activities of the street system. Most arrangements are haphazard and do not resolve conflicting needs or wants. Transit system design is handicapped by crowded streets where transit vehicles must move and stop, and by inadequate sidewalks where vehicles load and unload.

Police departments have jurisdiction over movement in the streets and their major concern is to accommodate all vehicular movement. The pedestrian movement has to adjust to the situation as best it can. Sidewalks have been getting narrower to add width to the roadbed to satisfy increasing demands by vehicular movement and parking. Transit systems, therefore, have difficulty in securing sidewalk space for shelter. In the competition for right-of-way the pedestrian has been the loser.
Inadequate sidewalk widths are a public concern because of the inconvenience, discomfort, and hazards resulting from lack of space for and congestion created by various pedestrian street activities such as: access to adjacent activity spaces on both sides of the sidewalk, window-shopping, thru-movement, trees, street services (mailboxes, street lights, hydrants, signposts, benches, alarm-boxes, sidewalk elevators, subway and elevated structure stairways and escalators, waiting shelters, phone booths, vending kiosks for news, for flowers, etc.).

**Physical Dangers:** Poorly placed stops and shelters, such as at a difficult vehicular turn, exposes waiting passengers and shelters to a hazard from moving vehicles. Inadequate sidewalk width forces use of a shelter with shallow depth and less enclosure than is needed. (See Figure II-12)

Personal safety, especially at night, is easily threatened when a shelter is located in a dimly lit isolated area. Most problems are in the downtown and low-density residential areas.

**Shelters:** Figures II-13 and II-16 show various ways that transit passengers may be sheltered. Figure II-17 is a sequence of photographs and drawings showing a technique to indicate sidewalk user behavior.

**Street Clutter:** Identification of transit stops from the distance of half a city-block is a problem for both users and drivers. The prevailing chaos is due to sign congestion and unsystematic and dysfunctional sign design and placement.
a street shelter here? — or a sheltered sidewalk?
WAITING FOR A BUS

(a) and (b) show poor visibility of approaching vehicle by those waiting in shelter. Sidewalk movement is obstructed by boarding passengers.
(c) and (d) show sidewalk movement impeded by those waiting in or under shelter.
(e) reflects the prevailing situation.

(f) is a proposed improvement; recessed street level frontage could be required by zoning ordinance.

Figure II-15
(g) and (h) show no need for a special sidewalk structure in sidewalk archade on covered street.
Sidewalk User Behavior

Figure II-17
**Visability:** Being hidden from view, even partially, particularly within a shelter which is poorly lighted and/or isolated from public activity, allows or encourages attack or molestation.

Trees in the street are beneficial in providing shade, minimizing hard-surface reflecting heat, breaking the wind, even offering shelter from precipitation, but they can interfere with vision of and from the shelter if care is not taken in placement, trimming, etc.

**Wind Patterns:** Within the same urban entity, wind behavioral patterns in the street may vary from location to location, influenced by the surrounding street layout, by the form of natural and man-made elements, or the configurations of the street canyon walls at each location.

**Vandalism:** The following comments are based upon observation in several cities:

- In one city, a number of open all-steel shelters, included benches designed for wood but built of steel. The benches' overhanging, quarter inch steel seat slats were bent down, probably the result of a sledgehammer.

- Another city has an admirably large number of all-steel shelters, enclosed on three sides. They looked like toolsheds. They appeared "vandalized" on installation.

- Shelters are often abused by being used as toilets and sleeping places by vagrants.

- Abuse of convenience of the facility (seat, phone, etc.) often results in damage to the structure itself.
Section III - Analysis

The task of planning and designing shelter is to optimize user welfare, while contending with two sets of constraints: A spatial one of environmental fit and an economic one of transit systems costs.

For environmental fit three elements are important:

**Bulk**: Width, length, height, etc.;

**Location**: Placement to fulfill transit needs as well as those of other sidewalk activities;

**Aesthetics**: Overall size, form, appearance, as part of the total scene or streetscape.

The primary elements of transit system costs are:

**Capital**: Initial investment in shelter proper and in ancillary installations.

**Operating and Maintenance**: Power, cleaning, servicing of ancillary installations such as light, heat, seats, information, and repairs, etc.

Welfare has three elements:

**Comfort**: Space, body support, weather protection.

**Safety**: Visibility, escape, location.

**Convenience**: Quality of town and streetscape, communication and other street services like shopping, first aid, comfort station.
The components of the element of comfort can be further divided into space, (amount and quality), body support (underfoot, hip and back) and an atmospheric protection (precipitation, air movement, light and temperature).

With the above sets in mind the interrelationships among the elements are investigated with the help of a diagram. It can be seen that welfare, our primary concern, is constrained by fit and cost. The subsequent discussion refers to this diagram and each interface is discussed in turn. The results are a list of all the items to be considered in performing an analysis of a shelter. The next section will develop criteria based upon this list.

Each element of welfare (comfort, safety, convenience) will be considered separately in light of the constraints imposed by the six elements of fit and cost.
AI/B1 - Comfort/Measurements

a. Enclosed space, "windowed" or fully transparent and less than 8 feet in any direction is uncomfortable for extended occupancy by more than one person;

b. A minimum enclosed depth of 6 feet is needed to accommodate comfortably a seated person and others passing by;

c. Enclosed space less than 6 feet in any direction is inadequate for two-way passage;

d. Enclosed space of less than six feet depth induces claustrophobia, even if it the shelter is transparent and occupancy is of short duration;

e. Seating is most comfortable with at least a depth of 7 feet;

f. A transparent enclosure tends to expand the space perceived;

g. A shelter which opens to the curb requires greater distance from the curb. On narrow sidewalks, units with insufficient depth have been frequently used. The question of sidewalk widths should be resolved within the comprehensive urban planning process;

h. Canopy and umbrella type cantilevered open, or partially open shelters can be more protective than those supported by their perimeter. Their roofs can be better insulated and projected over the sidewalk space beyond the line where supports could be placed;

i. A 8" wide rail 26' - 34" high will provide a bodyrest, handrail and bumper;

j. Wheelchairs need a minimum of 32" wide clear openings for passage;
ENVIRONMENTAL FIT

I. COMFORT
II. SAFETY
III. CONVENIENCE

DEVELOPMENT OF DESIGN CRITERIA

1 Includes waiting transit user
2 Includes transit system management

Figure III-1
k. An electronic emergency signaling or monitoring system in the shelter is desirable, but as yet too costly, except for the conventional public telephone;

l. Space requirements for a public phone and/or other conveniences within the shelter are incompatible with the space requirements of those waiting for transit vehicles, unless the shelter is larger than the separate facilities put together;

m. Public telephones, and kiosks for flowers, snacks, cigarettes, first-aid, comfort station, etc., can be located adjoining or near by using separate, basic shelter units adaptable to such uses. They would attract users other than transit users and decrease the isolation of the waiting passengers;

AI/B2 - Comfort/Location

a. Contaminants (noise, dust, fumes, humidity, glare, and vibration) are experienced in open and partially enclosed shelters, generally at the same levels as outside it; any substantial improvement through design would require full enclosure and artificial corrective systems;

b. Fumes, dust, and mud increase within the shelter when openings face the curb and roadbed;

c. Shelters with openings facing the curb require a greater distance between the two and thus reduce sidewalk width for pedestrian movement;

d. Shelters, which allow free pedestrian movement are necessary on narrow sidewalks; see also A III/B2;
e. Street layout, and orientation, pattern, and form of street enclosures help determine wind pattern and velocity and thus affect the micro-climate of the shelter environment;
f. Climatic variation in the U.S. calls for variation in the types of shelter provided. The variables of climate in individual cities are rain, snow, temperature, wind, excessive heat or humidity;

The combined effect of two or more elements increases the problem of weather-protecting the waiting transit user. The more difficult problems arise when wind is combined with any of the other variables. One can be protected from rain and snow by seeking overhead shielding; however, wind can virtually negate the effect of this shielding by "driving" rain or snow. In addition, skin temperature is reduced by increased wind velocity.

The range of the normal average temperatures in January for cities in the continental United States falls between 8° and 66° F. A normal individual can move about comfortably with relatively little protection until the temperature drops to approximately 50° F. Below this point the traveler adds heavy clothing in order to remain within the comfort range. At approximately 30° F., wind can cause a considerable degree of discomfort.

These three ranges are illustrated on the following continuum of the mean average January temperature:
70° A roof is sufficient where wind is not excessive.

50° Enclosure is required to protect the user from wind so that the chill factor does not reduce the surface temperature of the user.

30° Heating is required in addition to enclosure; special consideration should be given to pavement surface temperature.

When the temperature range is between 0° and 30° F. and dampness persists, and protection from wind and precipitation is provided, the person waiting, still has one direct contact with a source of discomfort--his feet rest on the pavement. Where this condition exists, heating within the shelter is needed. The individual is probably dressed to protect himself from the cold, therefore, additional heat beyond that necessary to keep the pavement free of ice or snow and the feet warm might even make waiting uncomfortable.

Figure III-2 indicates the areas of the United States in which simple enclosures or enclosures with heating is recommended. Figures III-3 - III-5 indicate the effects of shelter on occupant comfort.

AI/B3 - Comfort/Bulk

* a. Integral structural support and enclosure systems (where vertical members both support the roof and serve as enclosure panel framing) are less adaptable to varying depths, degrees, arrangements and applications of enclosure and, thus, to a variety of spatial and climatic sidewalk situations;
b. Enclosures open at top and bottom have the advantage of providing good air circulation; preventing trash from piling up within and outside shelter;

c. A simple transparent enclosure increases heat within shelter--advantageous in cold season or climate, disadvantageous in warm season or climate; an opaque, reflective enclosure keeps shelter cooler;

d. A baffling insulating material under a simple sheet roof will decrease noise discomfort of hard rain, hail, etc.;

e. A hip-high rail prevents anyone from walking into transparent enclosure, provides support when leaning or sitting, and serves as a handrail;

f. A heat source placed low within the shelter is preferable to one placed overhead, because heat rises. A person remaining stationary feels cold most at his feet. Radiant floor heating keeps the floor dry, prevents formation of ice on the floor and keeps people's feet warm;

g. The need for seating within a shelter depends on waiting time. Except for the handicapped, most people do not sit down during the short waiting time and crowded conditions of rush hours. Shelter space is better utilized to provide more room for standees at crowded bus stops;

h. An unresolved problem remains: How to accommodate the person in a wheelchair on the bus? Work is being done to develop solutions in other projects;

i. Appropriately scaled and placed colored pictorial materials, including aesthetically pleasing advertisements (i.e., an inside and outside strip at roof level) could minimize perceived waiting time, and produce revenue as well;
ENCLOSURE REQUIRED

ENCLOSURE AND HEATING REQUIRED
effects of shelter on occupant's comfort

Figure III-3a
effects of shelter on occupant’s comfort

Figure III-3b
effects of structure on occupant's comfort

Figure III-4a
effects of structure on occupant's comfort

Figure III-4b
effects of shelter on occupant's comfort
A1/C1 - Comfort/Capital

a. How much space is needed to shelter one person?

A feeling of comfort depends on the following physical and psychological factors:

- The waiting period;
- The perceived total environment (type of enclosure, surroundings);
- The severity of the hazard;
- The personal space;
- The alternatives or choices available;

Shelters with transparent enclosure that provide five to eight square feet per person provide protection in inclement weather without physical and/or psychological discomfort, when waiting is 7 to 10 minutes.

b. For simple cost comparison without consideration of benefit--the following information is needed:

- Purchase price or complete unit;
- Packing and handling costs;
- Shipping costs;
- Size and type of unit (open or enclosed, artificially lighted and/or heated, etc.) with plans and specifications;
- Useful life expectancy of unit;
- Site preparation of unit;
- Installation costs;
- Yearly maintenance costs;
- Cost of repair due to vandalism;
A comparative analysis was made of shelters in various cities ranging in cost from $500 to $3,000 per unit. Differences in quality and environmental fit and service offered were compensated for by weighting. The results of the analysis are shown in Figure III-6.

The index (curved band) shown on the chart cannot supply precise information, but there is a strong indication that past the $35.00/square foot cost for enclosed shelter, benefit decreased at an increasing rate. In a comparative sense, those who spend up to the $35.00/sq. foot cited above—generally received more value.

* Assuming an adequately sized basic unit shelter at all transit stops, ($23 per square foot) the total initial shelter cost divided by the total estimated trips during a fifteen year life period provides a useful, meaningful cost figure, per trip. The capital cost per trip is approximately two-thirds of one cent.

\[
\frac{5,000 \text{ stops} \times 72 \text{ sq. ft.} \times \$23.00 \text{ per sq. ft}}{300,000 \text{ trips} \times 5.3 \text{ days} \times 52 \text{ wks.} \times 15 \text{ yrs.}} = 0.66\,\$^1
\]

Another useful and meaningful figure is the percentage the cost of the sidewalk shelter (no stations) component represents compared with the total cost of the transit system. The initial cost figure to provide shelters for a proposed metropolitan bus system component appears to be approximately ten percent (10%) of the bus system cost, with an estimated 1971 cost of $35.00 per square foot for a total of 105,000 square feet of maximally enclosed urban sidewalk-type shelter space,

\(^1\)Estimate by "VPI & SU" for a city comparable to Cleveland.

\(^2\)Estimate by "VPI & SU" for a city comparable to Seattle.
quality/unit cost trend including urban design attributes

Figure III-6
with seating and lighting. To provide shelter at every stop within this intra-urban system would require an estimated fifty percent (50\%) increase in shelter space, thus raising the shelter cost to approximately fifteen percent (15\%) of the bus system cost. A lower shelter square footage cost would correspondingly lower the percentage figures. Shelter and its costs should be dealt with in total system context;

* c. Working with a basic modular unit consisting of a roof and appropriate vertical structural support, shelters can be produced to a variety of degrees of completion and forms, to suit climates, seasons, requirements of comfort, and capital budgeting and financing;

d. Working as indicated under "c" makes it easy, moreover, to have user or citizen involvement in financing of seating and enclosure, thus completing the basic unit provided by the transit system, or municipality;

A1/C2 - Comfort/ Maintenance

* a. Seat support, if integral with shelter support structure, may unnecessarily transfer damage to the main structure if vandalized;

* b. Radiant floor heating installation is less likely to be subject to vandalism than exposed fixtures;

c. Two kinds of design seem to especially provoke hostility and a destructive urge in some people, regardless of socio-economic status:
  ° Self-centered and resource wastefulness on the part of the designer or owner;
  ° Patently cheap design, particularly resented by the under-privileged in their environment, because it suggests contempt;
AI/C3 - Comfort/Replacement

No interfacing found

AII/B1 - Safety/Measurements

* a. More than 6 feet clear width is required in a corridor space, with openings at opposite ends, to permit escape from molesters;

AII/B2 - Safety/Location

a. Shelter opening to curb may force person escaping from molesters into vehicular roadbed;

b. Shelter has to be a minimum 18 inches from curb for the following reasons:
   - To avoid being touched or hit by transit vehicle (which leans slightly to curb);
   - To provide minimal safety zone for pedestrians having to reach the sidewalk from the vehicular roadbed;

c. Shelter openings facing curb would require a minimum 42 inch distance from the curb to assure accessibility and safety;

d. The safest location for a transit stop and shelter is in a populated area, under the visual surveillance of people who could furnish aid, or alert others who could do so;

e. The danger of a vehicle jumping the curb at a shelter area is not substantially greater than elsewhere. Protection against vehicles should be no more in shelter areas that in other crowded sidewalk areas;
AII/B3 - Safety/Bulk

a. Structural support systems are whole systems and must be treated as such; parts of different designs are not interchangeable, and to make any changes in them requires analysis of the whole system;

* b. To be secure against elements shelter has to be designed to withstand vertical and lateral forces. Anchorage at ground and roof levels of a basic modular unit with minimal or no enclosure should be designed for maximum local wind velocity and uplift;

* c. A transparent enclosure allows vision into, through and from the shelter, an effective aid for personal safety;

d. Opaque ceilings facilitate indirect lighting;

e. Tall transparent planes at pedestrian movement levels can be invisible and dangerous; a marker is needed to alert pedestrians that they are approaching a solid obstacle;

f. Maximum comfortable openness offers comparable safety by letting any call for help be heard better and by facilitating escape. Shelter safety requires two openings, at opposite ends, for easy exit;

* g. Ice-free floor is highly desirable and can be obtained with radiant floor heating;

* h. Street light for shelter lighting at night is inadequate, even with translucent or transparent roof; higher level of lighting is needed for reading and to highlight shelter for greater safety;

* i. Exposed points, sharp edges, and sharp corners are dangerous and cause injuries;
AII/C1 - Safety/Capital
   a. Underground power installation is safer but more costly;
   b. Telecommunications installation for transit stops—which would
      greatly improve safety—may be expected in the future, as a
      necessary public expenditure;

AII/C2 - Safety/Maintenance
   * a. Joining and securing of components should be either hidden or
      done using fasteners that can be manipulated only with special
      tools.

AII/C3 - Safety/Replacement
   No interfacing found

AIII/B1 - Convenience/Measurements
   No interfacing found

AIII/B2 - Convenience/Location
   a. A wide strip in the sidewalk area, next to the 18" safety zone
      at the curb, can accommodate any and all fixed furnishings, such
      as shelters, elevators, underpass and overpass stairways, escalators,
      kiosks, trees, etc;
   b. A study of sidewalk users' behavior and interaction would be of
      great interest for the study of shelter location, and an effective
      technique for it is time-lapse motion picture photography;
      Figure II-17 illustrates this.
AIII/B3 - Convenience/Bulk

a. Information on routing can be accommodated by even a single, basic waiting shelter unit. Information on the total transit system, or on the neighborhood street system should appear on waiting units if transparency, or comfort are not diminished. Otherwise, minor ancillary elements containing the information can be installed nearby;

b. Enclosure limits overlap sidewalk space use, and such overlap use is helpful on a narrow sidewalk;

c. Opaque enclosure at ground level hides from view persons sitting on the floor, reclining or bent over;

* d. Open area under enclosure permits hosing from outside and the free flow of water on the sidewalk; it keeps enclosure panels free of dirt, of corrosive chemicals used to clean, to melt ice and snow, and free of damage done with cleaning equipment;

e. Arrangement of opaque structural elements of shelter should facilitate visibility from shelter to permit identification of a transit vehicle;

* f. Lighting level sufficient for reading should be provided;

* g. Overhead installation of power lines to the shelter is unsightly;

h. Compatibility with the streetscape required:
   * Shelter to be part of, or act as a catalyst for design of integrated street furnishings;
   * Transparency for lightness (to minimize bulk);
   * Transparency for not hiding, obscuring parts of the street environment from view, especially storefronts;
For universality: straightforward, unselfconscious, functional simplicity of line and form, neutrality of color except as accent in limited and well-selected area, to add to streetscape;

i. Good fit in the streetscape helps to promote civic pride, and facilitates identification with place and community;

AIII/C1 - Convenience/Capital

a. Basic unit structure with multi-use potential can aggregate market and reduce costs;

b. Designs with integral structural support, rather than component parts are less flexible and cannot take advantage of economies caused by a more flexible design;

c. Enclosure to ground level means higher installation costs, because of sloping and uneven condition of sidewalks;

d. Opaque enclosure elements can be less expensive than transparent ones;

e. Molded, monolithic plastic shelter elements, or units, offer lower purchase and installation costs, but higher transport and maintenance (replacement) costs;

f. Minimal, well-designed, overhead advertising can produce some revenue, while adding a spot of change, color and interest;

g. Flat structural sub-assembly elements permit easy, economical handling, shipment to, and assembly on site;

h. To minimize field work, the anchorage of the vertical support can be designed, fabricated and installed to readily receive
the standard preassembled structure for mounting and attachment above pavement level. Removal of the structure for reinstallation elsewhere should be just as easy;

i. Canopy type designs require subsurface footings, some other types do not; the simplest, least expensive anchorage types are ones that can be supported by the pavement. Foundation and anchorage require structural analysis in all cases;

AIII/C2 - Convenience/Maintenance

a. Transparent or translucent roofs show accumulating dirt, trash, and surface damage on top and thus require more frequent cleaning and repair;

b. Exposed surfaces need the hardest possible finish for economy of maintenance, and resistance to willful destruction;

c. Good environmental fit helps to promote civic pride, facilitates identification with place and community, and ultimately keeps down frustration, vandalism and maintenance costs;

d. The fuller the enclosure the higher not only the first cost, but also the maintenance and repair costs because vertical enclosing surfaces need regular cleaning and retouching. Most damage is suffered through sidepanel breakage; maintenance costs are thus much lower where, climate permitting, there is less side-shielding or enclosure. Where the design permits the ready removal of side screening it may be economical to do so at the beginning of the good weather season. This also allows movement of air during hot periods;
e. Annual maintenance and repair costs are reported to be $250 to $300 per enclosed shelter. Since these figures do not include salaries of managerial staff, trucks, cleaning equipment, etc., a more realistic estimate might be closer to $400, especially for glass-enclosed shelters;
f. Shelters should be designed and built to retain their effectiveness and attractiveness over a minimum lifespan of 15 years requiring twice-a-year wet-cleaning and bi-weekly sweeping. Otherwise, except for accidents and vandalism they should be maintenance free;
g. Roofs can be drained by the use of pipe members of the structural frame as leaders;
h. Sidewalk pavements are seldom level. Unless the fall is too steep--more than 1:15--attempts at providing a level floor will require costly special work and possibly more sidewalk space;
i. Power for heat and light should be brought to the shelter underground; controls should be remote;

AIII/C3 - Convenience/Replacement

a. Transparent or translucent roofs are more easily damaged by falling objects, etc., and require more frequent replacement;
Section IV - Criteria for Shelter Design

A large number of analytical considerations were presented in the preceding sections. The problem is to determine which of these often conflicting statements are the most important in developing criteria for a shelter which maximizes comfort, convenience and safety while staying within economical limits.

In making the value judgements required for criteria development, personal safety is the overriding consideration followed by comfort, then convenience. The asterisked items in Section III are considered to be the most important in developing design criteria. Based upon these analytical elements, the following design criteria have been developed:

Recommended Design Criteria

That shelters be provided in large numbers, with public funds, in the public urban open space and should have the following characteristics:

- Flexibility in size and arrangement of enclosure walls
- Maximum possible transparency of enclosure on all sides
- Modular unit approximately 50 square feet; a 6 foot minimum depth; 7 feet between enclosed sides
- Heat reflecting opaque roof
- Bottom of enclosure a minimum of 9 inches above the floor
- A minimum of two access openings, at opposite ends of the enclosed space; minimum clear opening width 32 inches.
- Provision for reading level artificial lighting within shelter
- Radiant floor heating for snow and ice removal, and for ambient warmth
- Unit support structure as free as possible of ancillary furnishings, and equipment; seats supported on floor
- Engineering of structure designed for all local weather conditions.
- Shelter space free of convenience facilities (telephone, news, etc.)
- Avoidance of exposed sharp corners and edges
- Use of durable finishes
- Concealment of non-permanent assembly jointing
- Straightforward, functional appearance
- A cost range of $20 to $30 per unit square foot, F.O.B. site, and a minimum useful life of 15 years.
Section V - Prototype Shelter

Prototype "A" as shown on the following construction and perspective drawings, is a design for a basic, modular unit, satisfying the recommended criteria for transit stop shelter design, plus the following additional requirements:

. Additional use potential, for other functions, to reduce unit purchase price through market aggregation:
. Additional use potential for other street functions to help improve the organization of street furnishings.

See Figures V-1 - V-8.

A sidewalk zone of some seven feet width will properly accommodate all kinds of street functions, activities and their facilities. One consideration, three feet of clear space is maintained between posts on all sides of the octagon (a wheelchair requires 32" clear width).

The basic, modular unit provides protection against sun and rain, and to a lesser degree against wind; as a more enclosed unit, with the use of additional vertical metal frames and additional transparent filler panels, it meets greater wind protection needs; singly it meets minimal space needs, coupled in series or clusters, with or without the use of roof panel fillers, it meets greater space needs.

The basic, modular unit accommodates two system line diagrams or charts, without seriously reducing transparency and good vision; it roofs over eight and a half feet width of sidewalk, but encroaches on movement three and a half feet only. It can do this as a cantilevered roof.
structure and it does it economically with the use of wide base (frame) support and balanced (double) cantilever. With greater enclosure (more frame supports) cantilever action is being reduced and anchorage at ground level is less critical. The more enclosed unit, according to degree of enclosure encroaches five feet-ten to eight feet-one inches. A minimal foot and a half clear sidewalk safety zone between roadbed (curbline) and shelter support at ground level is needed for pedestrians, and a minimal fourteen inch clear safety zone is being provided at roof level for approaching and loading transit vehicles.

Enclosure may be octagonal or rectangular with a variety of patterns, through the simple use of additional standard elements (vertical metal frames, filler panels (octagon) or framed corner panels (rectangle). The latter could be molded plastic elements. (Figures V-9, V-12 and V-13)

An alternate of the basic unit, modified by omission of one overhang (cantilevered roof section), reducing its width to little over six feet, could be used for very narrow sidewalks. (see ceiling plan)

This basic, modular unit, with such simple modifications as the use of greater enclosure, different enclosure panels, regular or dutch doors, interior furnishings and fixtures, varied fascias, lends itself to a large number of variations in overall appearance through detail, color, texture and such street uses as:
**Prototype - A -**

<table>
<thead>
<tr>
<th>Scale: 1/8&quot; = 1'-0&quot;</th>
</tr>
</thead>
</table>

**Elevation**

- **Prototype** - Intra-Urban Mass Transit Street Shelter
- **Date**: Dec., 1971
- **Project Dir.**: Frank E. Ehrenthal
- **Project No**: VA-MTD-3
- **Virginia Polytechnic Institute and State University**

Figure V-2
Figure V-4
Figure V-8
Information
Telephones
Postal Service
Express Banking
Transit Ticket & Token Sales
Sports, Cultural Events Promotion, Tickets
Comfort Stations
First Aid Stations
Street Artists (Portraits, etc.)
Crafts Assistance
News, Magazines, Cigars
Paperbacks, Cards
Flowers
Snacks and Drinks
Ice Creams, Fruits
Roasted Chestnuts, Baked Apples
Novelty Toys, Games (Sales)
Shoe Shine
Key Duplicating
Table Top Games (Chess, etc.) Playing
Exhibits
Poster Kiosks (Storage, Sidewalk Elevator Inside)

In a straight line or free flow series, or in clusters the unit lends itself to the creation of such spaces as park pavilions, exhibits, terrace cafes, various uses at expositions, fairs, etc. See Figure V-10 and V-11.
Section VI

Appendices
Shelters - Variations to Suit Climate

--- indicates walk enclosure line
- - - indicates roof line

Figure V-9
pavilion type shelter combinations
shelter combinations and variations with filler roof units
Other Uses for Kiosk Design

**NEWS, MAGAZINES**

**FLOWERS**

**SNACKS**

**BANK DEPOSITS - STAMPS**

Figure V-12
Other Uses for Kiosk Design

TELEPHONES AND TOILET
WITH ATTENDANT
(TOILET KEY MAY BE WITH PHONE ATTENDANT, AT NEWS KIOSK OR SNACK KIOSK)

POSTER KIOSK
WITH SIDEWALK ELEVATOR TO SUBWAY

Figure V-13
Appendix A

Cities Surveyed
## List of Cities Surveyed

<table>
<thead>
<tr>
<th>City</th>
<th>Agency &amp; Address</th>
<th>Previously Reported Shelters</th>
<th>Presently Shelters In Use</th>
<th>Active Shelter Program</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Akron</td>
<td>Metropolitan Transit Authority 416 Kenmore Blvd. Akron, Ohio</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>2. Atlanta</td>
<td>Atlanta Transit System P.O. Box 1592 125 Pine Street, N.W. Atlanta, Ga. 30301</td>
<td>no</td>
<td>1</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>3. Baltimore</td>
<td>Baltimore Transit System Baltimore, Maryland</td>
<td>no</td>
<td>?</td>
<td>yes</td>
<td>60 shelters funded by UMTA Capital Grant program</td>
</tr>
<tr>
<td>6. Brisbane</td>
<td>Brisbane Dept. of Transportation Brisbane, Alabama</td>
<td>yes (284)</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>7. Chicago</td>
<td>Chicago Transit Auth. Merchandise Mart Plaza P. O. Box 3055 Chicago, Ill. 60654</td>
<td>no</td>
<td>1</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>9. Cincinnati</td>
<td>Cincinnati Transit Co. Cincinnati, Ohio</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>experimental pro</td>
</tr>
<tr>
<td>City</td>
<td>Agency &amp; Address</td>
<td>Previously Reported Shelters</td>
<td>Presently In Use</td>
<td>Active Shelter Program</td>
<td>Remarks</td>
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<tr>
<td>10. Cleveland</td>
<td>Cleveland Transit System</td>
<td>yes (1093)</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1404 E. 9th Street</td>
<td></td>
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<tr>
<td></td>
<td>Cleveland, Ohio 44114</td>
<td></td>
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<tr>
<td>11. Dallas</td>
<td>Dallas Transit System</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td></td>
<td>101 N. Peak</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Dallas, Texas</td>
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<tr>
<td>12. Danville</td>
<td>Danville Transit System</td>
<td>no</td>
<td>no</td>
<td>no</td>
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<tr>
<td></td>
<td>Danville, Virginia</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>13. Dayton</td>
<td>City Transit of Dayton</td>
<td>yes</td>
<td>200</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dayton, Ohio</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14. Decauter</td>
<td>Decauter City Lines, Inc.</td>
<td>yes</td>
<td>?</td>
<td>?</td>
<td>no further information</td>
</tr>
<tr>
<td></td>
<td>Decauter, Illinois</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>(1)</td>
<td></td>
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<tr>
<td>15. Duluth</td>
<td>Superior Transit Co.</td>
<td>yes</td>
<td>?</td>
<td>yes</td>
<td>5 shelters funded by UMTA Capital Grant program</td>
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<tr>
<td></td>
<td>Duluth, Minn.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Detroit</td>
<td>Detroit Dept. of Street Railways</td>
<td>yes</td>
<td>270</td>
<td>yes</td>
<td>47I shelters funded by UMTA Capital Grant program</td>
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<tr>
<td></td>
<td>14130 - 3rd Avenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>Highland Park, Mich. 48203</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Fitchburg</td>
<td>Fitchburg &amp; Leominster Street Railway Co.</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td></td>
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<tr>
<td></td>
<td>R1427 Water Street</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Fitchburg, Mass. 01420</td>
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<td></td>
<td></td>
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<td>18. Fresno</td>
<td>Fresno Transit System</td>
<td>no</td>
<td>?</td>
<td>yes</td>
<td>12 shelters funded by UMTA Capital Grant program</td>
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<tr>
<td></td>
<td>Fresno, California</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>19. Honolulu</td>
<td>Honolulu Dept. of Traffic</td>
<td>yes</td>
<td>?</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City &amp; Cty. of Honolulu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Honolulu, Hawaii 96813</td>
<td></td>
<td></td>
<td></td>
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<td>City</td>
<td>Agency &amp; Address</td>
<td>Previously Reported Shelters</td>
<td>Presently Have Shelters</td>
<td>Active Shelter Program</td>
<td>Remarks</td>
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<td>------------------</td>
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<td>---------------------------------------------</td>
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<tr>
<td>20. Kansas City</td>
<td>Kansas City Area Trans. Authority 1627 Main Street Kansas City, Mo.</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>reported shelters previously</td>
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<tr>
<td>23. Montreal</td>
<td>Urban Community Transit Commission 159 Craig St., W. Montreal 126, Quebec</td>
<td>yes</td>
<td>177</td>
<td>yes</td>
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<tr>
<td>24. Nashville</td>
<td>Nashville Transit Co. Nashville, Tenn.</td>
<td>yes</td>
<td>(5)</td>
<td></td>
<td>no further information</td>
</tr>
<tr>
<td>25. Nassau County</td>
<td>Dept. of Transportation Nassau County Office Bldg. 240 Old Country Road Mineola, New York 11501</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>Nassau County recently contracted with Community Bus Shelters, Inc. for minimum of 500 shelters over 5 yr. period.</td>
</tr>
<tr>
<td>26. New Orleans</td>
<td>Public Service, Inc. P. O. Box 60340 New Orleans, La. 70160</td>
<td>yes</td>
<td>15</td>
<td>yes</td>
<td>limited</td>
</tr>
<tr>
<td>27. New York</td>
<td>New York City Trans. Administration 51 Chambers Street New York, New York</td>
<td>no</td>
<td>50</td>
<td>yes</td>
<td></td>
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<tr>
<td>28. Norfolk</td>
<td>Va. Transit Co. 509 E. 10th Street Norfolk, Virginia</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td></td>
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<tr>
<td>29. Pittsburgh</td>
<td>Port Authority Pittsburgh, Pa.</td>
<td>no</td>
<td>1</td>
<td>no</td>
<td>shelter donated</td>
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</table>

36
<table>
<thead>
<tr>
<th>City</th>
<th>Agency &amp; Address</th>
<th>Previously Supported</th>
<th>Presently Supported</th>
<th>Have Shelters In Use</th>
<th>Active Shelter Program</th>
<th>Remarks</th>
</tr>
</thead>
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<tr>
<td>31. Pueblo</td>
<td>Pueblo Transit System Pueblo, Colorado</td>
<td>no</td>
<td>?</td>
<td>yes</td>
<td></td>
<td>90 shelters funded by UMTA Capital Grant program</td>
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<tr>
<td>32. Richmond</td>
<td>Va. Transit Co. 101 S. Davis Avenue P. O. Box 1635 Richmond, Va.</td>
<td>no</td>
<td>1</td>
<td>no</td>
<td></td>
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<tr>
<td>33. Sacramento</td>
<td>Transit Authority P.O. Box 2110 Sacramento, Calif. 95810</td>
<td>no</td>
<td>1</td>
<td>no</td>
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<td></td>
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<tr>
<td>34. St. Louis</td>
<td>Bi-State Transit System 3869 Park Avenue St. Louis, Mo. 63110</td>
<td>no</td>
<td>42</td>
<td>no</td>
<td></td>
<td>UMTA Grant application unsuccessful; 125 shelters</td>
</tr>
<tr>
<td>35. St. Paul</td>
<td>Twin Cities Area Metrop. Trans. Comm. 106 Capital Sq. Bldg. St. Paul, Minn. 55101</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td></td>
<td>31 shelters funded by UMTA Capital Grant program (currently testing several)</td>
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<tr>
<td>36. St. Petersburg</td>
<td>St. Petersburg Transit System St. Petersburg, Florida</td>
<td>no</td>
<td>?</td>
<td>yes</td>
<td></td>
<td>4 shelters funded by UMTA Capital Grant program</td>
</tr>
<tr>
<td>37. San Antonio</td>
<td>Transit System Tower-Life Bldg. San Antonio, Texas 78205</td>
<td>no</td>
<td>1</td>
<td>no</td>
<td></td>
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<tr>
<td>38. San Francisco</td>
<td>Municipal Railway 949 Presidio Ave. S. F., Calif. 94115</td>
<td>no</td>
<td>23</td>
<td>no</td>
<td></td>
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<tr>
<td>39. San Juan</td>
<td>Autoridad Metropolitana de Autobuses Arpadado 1029 Hato Ray, Puerto Rico 00919</td>
<td>yes (50)</td>
<td>88</td>
<td>yes</td>
<td></td>
<td>15 shelters funded by UMTA Capital Grant program</td>
</tr>
<tr>
<td>40. Seattle</td>
<td>Transit System 1333 Airport Way S. Seattle, Wash. 98134</td>
<td>yes (58)</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>City</td>
<td>Agency &amp; Address</td>
<td>Previously Reported Shelters</td>
<td>Presently in Use</td>
<td>Active Shelter Program</td>
<td>Remarks</td>
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<tr>
<td>41. Stockton</td>
<td>Stockton Transit System Stockton, California</td>
<td>no</td>
<td>?</td>
<td>yes</td>
<td>20 shelters funded by UMTA Capital Grant program</td>
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<tr>
<td>42. Toledo</td>
<td>Community Traction Co. Toledo, Ohio</td>
<td>yes</td>
<td>?</td>
<td>?</td>
<td>no further information</td>
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<tr>
<td>43. Trenton</td>
<td>Trenton Transit System Trenton, New Jersey</td>
<td>no</td>
<td>?</td>
<td>yes</td>
<td>12 shelters funded by UMTA Capital Grant program</td>
<td></td>
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<tr>
<td>44. Vancouver</td>
<td>British Columbia Hydro &amp; Power Auth. Vancouver, B.C.</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td></td>
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</tr>
<tr>
<td>46. Winnipeg</td>
<td>Metropolitan Corp. of Greater Winnipeg Winnipeg, Manitoba</td>
<td>yes</td>
<td>?</td>
<td>?</td>
<td>no further information</td>
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</tr>
</tbody>
</table>

*See American Transit Association report entitled SPECIAL INQUIRY — PASSENGER SHELTERS AT BUS STOPS (Circulated February 13, 1968, to Selected Companies Who Had Previously Reported Having Shelters).*
Appendix B

Prototype Structural Analysis
Description of Structure

The basic structural components of the shelter are two aluminum frames, each consisting of two octagonal metal tubes with a 3-0" x 1-1/8" cross section, connected by three rectangular tube cross members, each 2-0" x 1-1/8" and a square 4-0" x 2-1/4" aluminum channel frame. The two vertical tubular frames are attached to the horizontal channel frame with fixed joints.

The combined action of the above creates a rigid roof which can sustain the moderate eccentric loading even when it occurs on the cantilevered portions of the roof. Additional rigidity is provided by the facia beams.

The two additional vertical frames which can be added, when more enclosure is desired, function structurally only in the sense that they transfer wind loads etc., on the filler panels to the primary skeleton and provide increased rigidity to the overall structure of the shelter.

The critical joints in the design occur at the four connection points with the ground. It is essential that these points be rigid.

Assumptions for Approximate Structural Analysis

Because of variations in climate and in sidewalk conditions an analysis will be made for each specific locality;

A simplified, minimal structural frame is assumed (without cross members, glazing);

Column to roof and column to ground joints are considered fully rigid;

Composite stiffening effects of cross members and of glazing not considered;
The continuity in the roof structure achieved by bolting the structural metal frame to the wood or alply diaphragm is acknowledged in the calculations (thus no torsional effects being considered).

**Roof Area and Assumed Loads**

Roof area = 8' -7" x 8' -7" = 73 square feet

Dead Load: 10lb/sq. ft. and 10lb/L. ft. (Facia); live load: 20lb/sq. ft.

Design Wind Pressure: 25lb/sq. ft. (Low structure)

See additional material (Figures B1 - B4) for detailed analysis.
SECTIONAL PROPERTIES

ROOF FRAMING SECTION

\[ I_x = 1.02 \]
\[ S_x = 0.69 \]
\[ r_x = 0.72 \]

COLUMN SECTION

ASSUME SECTION EQUIVALENT TO 3-0" O.D. TUBE, 1/4" IN THICKNESS (CONSERVATIVE);

\[ A = \pi D t = (3.14)(3.00)(0.25) = 2.36 \]
\[ I = 0.39 D^3 t = (0.39)(3.00)^3(0.25) = 2.63 \]
\[ S = \frac{2.63}{1.50} = 1.75 \]

Figure B-2
VERTICAL LOADING ON COLUMNS

TOTAL DOWNWARD ROOF LOAD:

\[(20+10)(73)+(10)(4)(8.5) = 2530 \text{ LBS.}\]

VERTICAL COLUMN COMPRESSION:

\[
\frac{2530}{(4)(2.36)} = 266 \text{ PSI}
\]

BECAUSE OF RIGIDITY IN ROOF DIAPHRAGM CONSTRUCTION, NO SIGNIFICANT COLUMN BENDING IS INDUCED BY VERTICAL LOADS.

SLENDERNESS RATIO FOR COLUMN: 100 (INSIGNIFICANT)

PORTAL ACTION UNDER WIND

a.) MINIMAL FRAME UNDER WIND ON FACIA:

TOTAL FORCE = \((0.80+.45)(25)(1.25)(8.5)(0.5)\) = 166 LBS. (INSIGNIFICANT)

Figure E-3
b.) MINIMAL FRAME WITH WIND ON "CLOSED" SHELTER

(EXTREME CONDITION WHEN ADDITIONAL COLUMNS
ARE NON-LOADBEARING)

TOTAL WIND FORCE = \( (7.83)(9)(25)(0.80+0.45) \)
\[ = 2,213 \text{ LBS.} \]

WIND ON ONE PORTAL = \( 2,213/2 = 1,107 \text{ LBS.} \)

\( P \) ACTING ON FACIA LEVEL = \( 1,107/2 = 554 \text{ LBS.} \)

\[ \text{MAX. BEND. MOM.} = \frac{P \cdot h}{2} = \frac{(554)(9)}{2} = 1,246 \text{ LB.FT.} \]

\[ \text{MAX. STRESS} = \frac{1,246}{1.75} = 8,500 \text{ PSI} \]

\[ \text{MAX. DEFLEC.} = \frac{Ph^3}{12EI} = \frac{(0.59)(554)(106)}{(12)(2.63)(10)} = 1.23'' \]

HENCE, STRESS LEVEL IS SAFE AND 1.23'' CAN BE

CONSIDERED A VERY SAFE UPPER BOUND FOR

HORIZONTAL DISPLACEMENT.

Figure R-4
Section VII

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