construction engineering research laboratory

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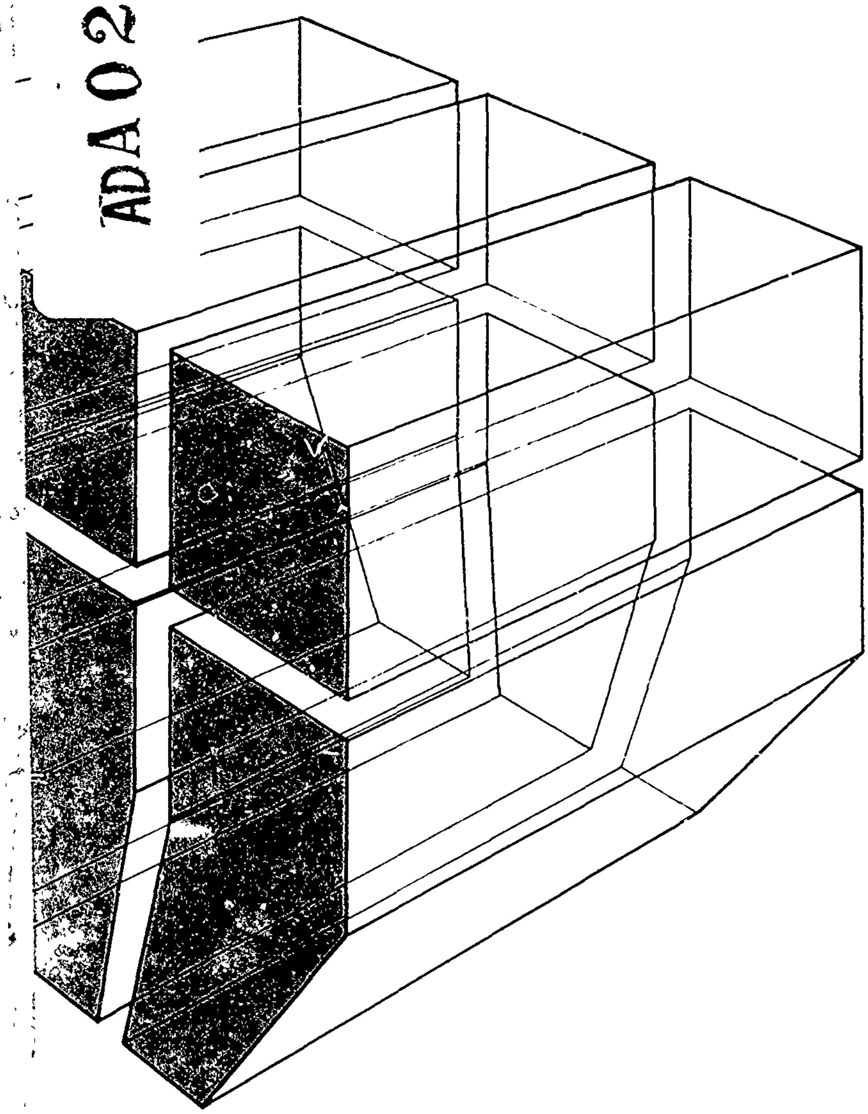
August 1976
Identification and Classification of Human Needs in the Military Facility

CONCEPTUALIZATION OF HABITABILITY EXPRESSIONS FOR THE HABITABILITY DATA BASE

by
T. A. Davis



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Habitability is defined and documents containing statements on habitability are identified within the context of the Corps of Engineers facility delivery process. This process is described as a cycle of events that includes master planning, construction programming, project development, design, and construction. Three generic and ten specific habitability expressions are conceptualized which relate properties of occupant activities (physical, physiological, and mental) to properties of facilities (dimensions of length, width, light and sound levels, temperature, etc.). Three expressions of cost-effectiveness

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are conceptualized as ratios of the dollar cost of a facility, facility property, or property categories divided by units of occupant needs for health, safety, performance and satisfactions. Structural, content, and technical assumptions are given, and data categories are defined by example. Further steps toward the development of prototype expressions are outlined.

FOREWORD

This research was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 1.01.012 4A762719AT03, "Architectural Research and Development in Support of Military Facilities," Task 01, "Architectural Criteria for Planning and Design of Military Facilities for Meeting Human Requirements," and Work Unit 001, "Identification and Classification of Human Needs in the Military Facility."

OCE technical monitors for this work unit were Richard Cramer and Robert Shibley.

The work was performed by the Architecture Branch (HPA), Facilities Habitability and Planning Division (HP), Construction Engineering Research Laboratory (CERL), Champaign, Illinois. Dr. Roger L. Brauer was Principal Investigator and Thomas A. Davis was Associate Investigator. Mr. Robert Porter is Chief of HPA, and Dr. Robert Dinnat is Chief of HP.

COL M. D. Remus is Commander and Director of CERL, and Dr. L. R. Shaffer is Deputy Director.

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CONCEPTUALIZATION OF HABITABILITY EXPRESSIONS FOR THE HABITABILITY DATA BASE

1 INTRODUCTION

Background

This report is part of an overall study to develop procedures to generate, evaluate, and communicate criteria which relate personnel requirements to architectural requirements. Specifically, the research will develop procedures which (1) identify physical, social, and psychological (personnel) requirements; (2) identify functional and technical (architectural) requirements; (3) accurately define relationships between personnel requirements and architectural requirements so that criteria can be developed from them; and (4) provide a means for collecting, analyzing, storing, and retrieving such relationship data in order to support criteria development and habitability research.

To date, work on the first three requirements has centered on development of an "objective definition of habitability," while the fourth requirement has been addressed by development of a prototype "Habitability Data Base" (HDB).

Approach

A theoretical position on facility evaluation[1] was analyzed for application to data categorization, storage, and retrieval in the HDB. Research literature to be stored in the HDB was coded, analyzed, and compared to the theoretical position. Data category inductions were made from the research literature and the theoretical position modified. The modified theoretical position is reported herein. This modified theory will be compared to habitability research data, habitability expressions developed from the conceptualizations herein, and the theory further modified as necessary to be consistent with the expressions.

During this approach to an objective definition of habitability three kinds of habitability statements were identified: requirements, expressions, and criteria. Each kind of statement was subjected to intensive analysis to ascertain its structure, content, and method of formulation. A study of habitability criteria has been reported by

[1] T. A. Davis, "Evaluating for Environmental Measures," *Proceedings of the 2nd Annual Environmental Design Research Association Conference, EDRA II,* Archea and Eastman, eds. (1970).

Davis[2]; habitability requirements are studied by Davis[3] in *Conceptualization of Habitability Requirements for the Habitability Data Base,* and habitability expressions are conceptualized in this report.

Purpose of Report

The purpose of this report is to set forth a conceptualization of the term "objective definition of habitability." The conceptualization is structured as a set of mathematical functions containing properties of facilities related to properties of occupants. The objective definition is expected to be useful in three applications. Two of these applications support the need to predict the utility and effectiveness of environments to be built for human occupancy through the generation and communication of criteria for facility evaluations and designs, and through design evaluations:

1. To form a basis for determining which habitability performance criteria need to be formulated as defined in AR 415-20.[4] These criteria find application in the master planning, construction programming, project development, design, and construction of Army facilities.

2. To justify the structure and content of the habitability performance criteria found primarily in the Department of the Army Technical Manual (DA/TM) 5-800 series, the Department of Defense (DOD) 4270.1,[5] and the DA Design Guide (DG) series. These criteria find application in the master planning, construction programming, project development, design, and construction of Army facilities.

The third application also supports the new construction applications, plus the need to allocate resources to existing facilities for rehabilitation and maintenance:

3. To conceptualize procedures with which to allocate dollars cost-effectively to the separate properties and constructs of existing and planned facilities. This procedure equates facility dollar costs to occupant needs.

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[2] T. A. Davis, "Formulating Habitability Criteria From Research Information," *Programming for Habitability*, W. F. E. Preiser, ed. (Department of Architecture, University of Illinois, 1974).

[3] T. A. Davis, *Conceptualization of Habitability Requirements for the Habitability Data Base*, Interim Report D-69 (Construction Engineering Research Laboratory [CERL], 1976).

[4] Department of the Army, *Project Development and Design Approval,* AR 415-20 (March 1974).

[5] Department of Defense, *Construction Criteria Manual,* DOD 4270.1 (March 1968).

2 THE CORPS FACILITY DELIVERY PROCESS

Major Activities

In its mission of delivering facilities for DA occupancy, the Corps of Engineers engages in five major activities:[6]

1. Master planning
2. Construction programming
3. Project development
4. Design
5. Construction.

The interrelationships of these activities are depicted in Figure 1 as a cycle of events beginning and ending with "occupancy."

Documents Containing Habitability Statements

Documentation of the policies and procedures which structure the facility delivery process, as well as the requirements and criteria which specify the facility to be built, contain sentences which state the known, the believed-to-be, the desirable, and/or the expected relationships between the occupants and the facilities to be built for their activities. All such statements are operationally defined here to be descriptive of "habitability." Although the word "habitability" may never occur in a given document, all documents which were found to contain a significant number of statements on the relationships between occupants and facilities have been labeled "documents containing habitability statements." Three such documents have been identified:[7] (1) the DOD 4270.1, (2) the DA Design Guides, and (3) the TM 5-800 series. Habitability information is occasionally found in other policy guidance, but these three documents are specifically designed to include such information.

Three other documents were identified which establish policy on the types of habitability statements to be included in "habitability documents": (1) AR 210-20, (2) AR 415-15, and (3) AR 415-20.

The relationship between these documents is shown in Figure 2, which also shows their relationship to the five major activities of the facility delivery process.

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[6] W. Preiser and R. Brauer, *Analysis of MCA Cycle Procedures for Impact on the Habitability of Facilities*, Technical Report (CERL [Draft]).
[7] Preiser and Brauer

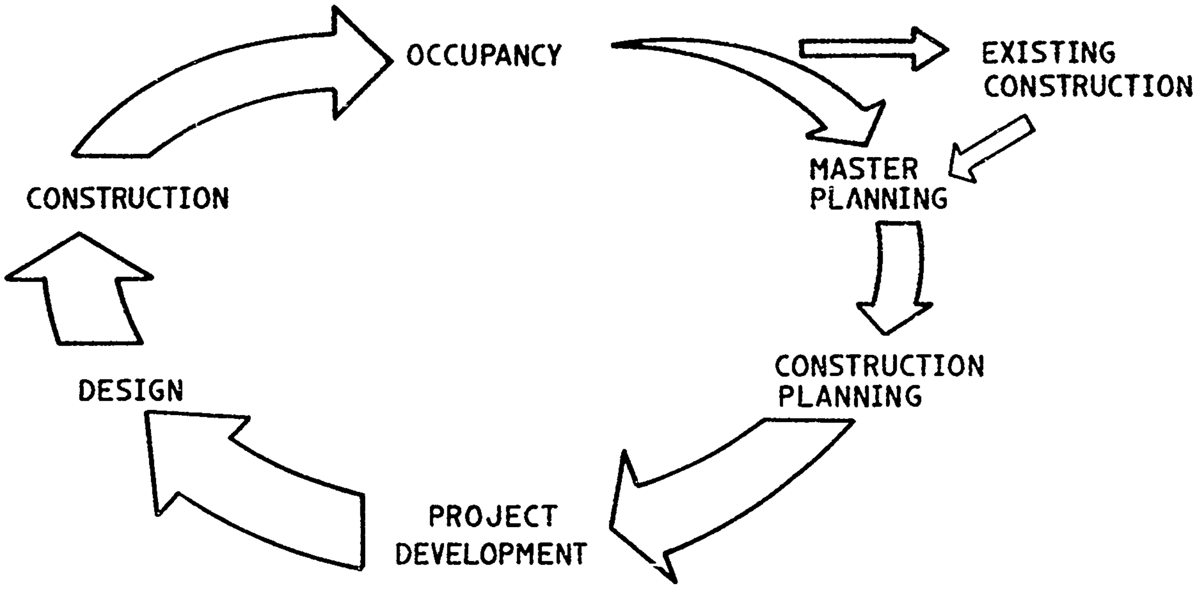


Figure 1. Cycle of activities in the Corps facility delivery process.

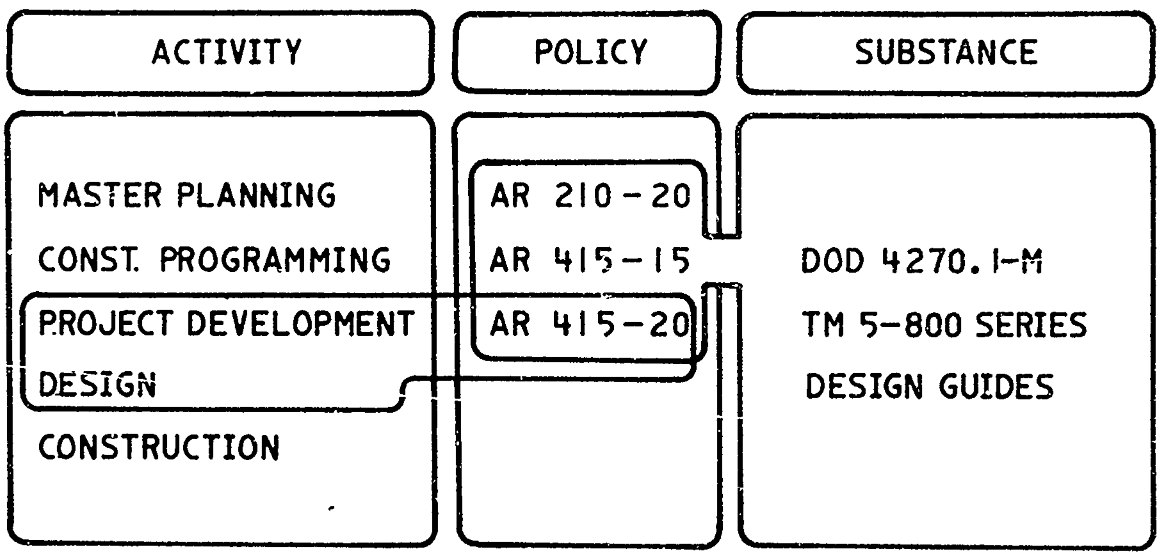


Figure 2. Relationship of documents containing habitability statements and major activities of facility delivery process.

Habitability Statements

Within the habitability documents above, five kinds of statements have been identified which are significant to habitability:

1. Occupant needs
2. Habitability requirements
3. Habitability expressions
4. Habitability criteria
5. Facility specifications.

These statements are used to develop the logic which translates occupant activities into instructions to architects; they describe the desirable or preferred properties of a facility. The word "occupant" is fully defined below to include individuals, groups of individuals, or organizations using facilities for their own purposes.

Occupant needs are statements describing occupant health, safety, performance, and satisfaction. Because they constitute the four categories for which habitability expressions are conceptualized, needs are fully defined in a separate section below.

Facility specifications are statements containing descriptive or prescriptive terms for items such as materials, equipment, and floor plans to be provided in a facility. An example is "a lecture classroom 30 x 50 ft" (HDB document 010). Specifications are normally included for engineering, architectural, or economic reasons rather than for habitability purposes.

Habitability requirements, expressions, and criteria were identified in preliminary work[8] for the HDB which supports the work reported here. The essential differences in the statements can be seen by examining the elements of each as shown in Figure 3.

Habitability requirements are statements of occupant objectives, goals, intentions, values, etc., for facilities in order that occupant needs can be fulfilled in them. An example is "Whenever human beings are present in closed spaces, the gaseous products of respiration, combustion from chemical processes, and excessive heat dissipated should be promptly and effectively removed by ventilation" (HDB document 028). A systematic approach to the generation of habitability requirements from occupant needs is described in a separate report.[9]

[8] T. A. Davis, "Systemizing Man-Environment Information: Toward a Model of Man-Environment Relations," *Man-Environment Systems*, Vol 4 (1974), pp 181-184.

[9] T. A. Davis, *Conceptualization of Habitability Requirements for the Habitability Data Base*, Interim Report D-69 (CERL, 1976).

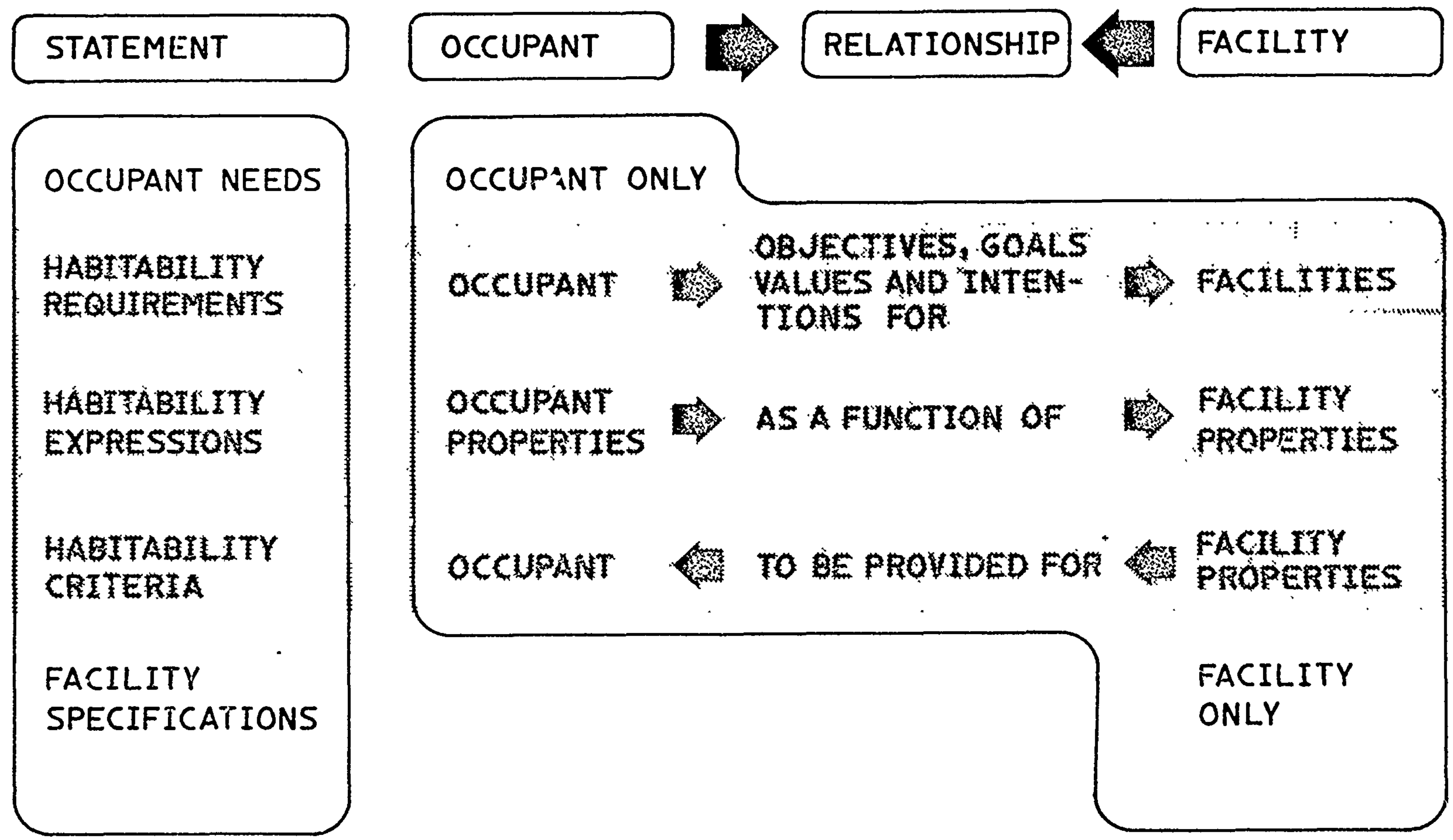


Figure 3. Elements of habitability-significant statements.

Habitability expressions, the subject of this report, are used to express assumptions, generalizations and research findings. The are statements of occupant activities as a function of facility properties. An example is: disease transmission is a function of floor area per man in sleeping spaces. Habitability expressions are generally and specifically defined in the following sections.

Habitability criteria are habitability statements that can be used either prescriptively for new facilities, or as standards against which an existing facility can be evaluated. An example is: "Inside heating design temperatures...should conform to the following: living and administrative areas - inactive employment 70°F..." (HDB document 028). A systematic approach to the formulation of habitability criteria from habitability requirements and expressions is described in an earlier publication.[10]

The relationships among these five kinds of statements are depicted in Figure 4 as a sequence of events from occupant to completed facility. Two events (or processes) in Figure 4 have not been discussed here: generalizations and designs. Generalizations are statements which take specific needs, requirements, or expressions and claim that they are probably valid for other or larger situations.[11] Designs are facility conceptualizations contained in plans and specifications, decor catalogues, or any other document which identifies a specific physical facility for an occupant need.

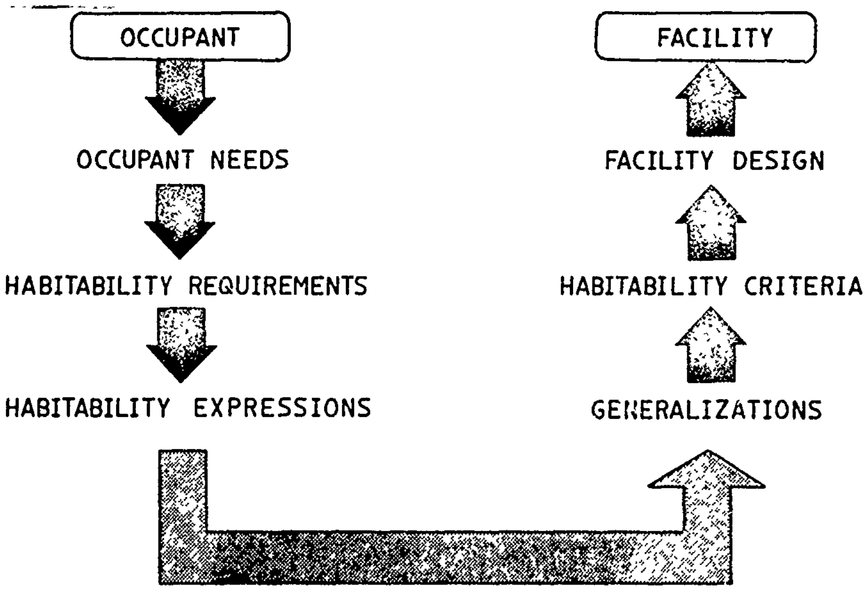


Figure 4. Interrelationships of habitability statements.

[10] T. A. Davis, "Formulating Habitability Criteria From Research Information," *Programming for Habitability,* W. F. E. Preiser, ed. (Department of Architecture, University of Illinois, 1974).

[11] Davis, "Formulating Habitability Criteria From Research Information."

3 DEFINITIONS

Research Goals

Within the context of the facility delivery process described above, this research project has the goal "to objectively define the relationships between Army personnel needs and the design of physical spaces and environmental features."[12] To clarify these terms, the following definitions have been adopted.

"To objectively define" means to synthesize and combine quantified relationship statements into mathematical expressions. The statements contain measurements quantifying properties of built facilities (e.g., length, width, and distance to a wall), related to measurements quantifying properties of occupants and their activities (e.g., their physical behavior, physiological states, and/or opinions, attitudes, and beliefs).

"The relationship between" refers to the fit of built facilities to Army activities (i.e., the Army as an organization) and to Army personnel activities (as individuals acting alone or in groups).

"Army personnel needs" is a shortened expression for the need to carry out Army tasks in built facilities within acceptable levels of human health, safety, and satisfaction.

"The design of physical spaces and environmental features" refers to the built facilities which are occupied (or to be occupied) by Army personnel. This phrase does *not* refer to the process of design itself, or to plans and/or specifications for facilities.

The problem posed by the above definitions can be simply stated as follows: what are the relationships between Army personnel needs and the built facilities they occupy (or are to occupy)? This question is portrayed in Figure 5.

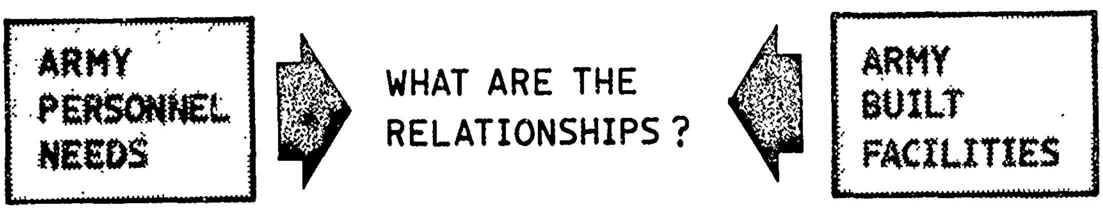


Figure 5. What are relationships of needs to facilities?

[12] "Identification and Classification of Human Needs in the Military Facility," *FY75 Final Research and Investigation Program* (CERL, July 1974).

In the definitions which follow, the phrase "Army personnel needs" is operationally defined in sections entitled "Occupants" and "Occupant Needs." The phrase "Army Built Facilities" is operationally defined in sections entitled "Habitability Properties" and "Contextual Properties." Finally, the phrase "What is the Relationship" is defined in sections entitled "Habitability," "Habitability Expressions," and "Habitability Expression Strengths."

Habitability

Habitability is the word used to describe the degree of fit of built facilities to occupants' needs. The more a facility fosters or "allows" the needs of the occupants, the better the fit; i.e., the more habitable the facility. Habitability, then, is a construct used technically here to represent the phrase "the relationship between" as defined above and portrayed in Figure 5. This construct is shown in Figure 6.

Figure 6. Habitability as relationships between personnel needs and built facilities.

This definition treats habitability as a system in which occupants interact with built facilities. The "degree of fit" is the state of the system at a particular time and place. The habitability expressions conceptualized below quantify those states.

Occupants

For habitability purposes, the word "occupants" is substituted for "Army personnel." Occupants are operationally defined to include three categories of users of built facilities:

1. Individual
2. Group
3. Organization.

An *individual* is one person acting alone. A *group* is two or more individuals acting as a formal or informal team, committee, or task force. Examples of the latter are committees on safety, value engineering, cost reduction, etc.--who might make recommendations on policy, but do not publish official policy statements (except for their own internal procedures).

Groups are treated either or both of two ways: as the sum of individuals of which they are composed, or as *organizations* if they can and do issue official policy statements. An organization is the Army and/or one of its administrative subdivisions. For this purpose, an organization is a paper concept. With the exception of the commander of an administrative unit, statements made by members (either individuals or groups) of an organization are usually considered to be theirs as individuals (or groups) unless the organization officially publishes them as policy. The three categories of users are shown in Figure 7, which is a further analysis of the elements of Figure 6.

Figure 7. Habitability and occupants.

Occupant Needs

Four categories of "needs" have been inferred from DOD and DA literature containing construction information:

1. Health
2. Safety
3. Performance
4. Satisfaction.

"Health" represents the concepts inferred from phrases such as "welfare," "life-support," "protection from thermal hazards," "maintenance of necessary physiological states." Health applies to individuals alone and in groups, but not to organizations.

"Safety" represents the concepts inferred from phrases such as "safe range of acoustical noise," "safe (and adequate) passageways," "safety factors, including minimization of....." As with health, safety applies to individuals alone and in groups, but not to organizations.

"Performance" represents the concepts inferred from phrases such as "functional requirements," "human performance," "human engineering," "to perform operation and maintenance tasks," "efficient arrangement of workplaces." Performance applies to all three categories of occupants.

"Satisfaction" represents the concepts inferred from such phrases as "minimize discomfort," "satisfactory," "adequate," "attractive," "acceptable," "nonrestrictive," "minimizing psychophysiological stress and fatigue." Satisfaction applies to individuals alone and in groups, but not to organizations.

Formal operational definitions of these needs are given in Chapter 4. Under normal (noncombat) conditions, the four categories of needs can be considered in ascending order in the study of habitability: the health and safety of personnel as necessary pre-conditions to all task performance, and all three as necessary *a priori* conditions to individual satisfaction. The four needs categories are shown by occupant category in Figure 8, which is a continued analysis of Figures 6 and 7.

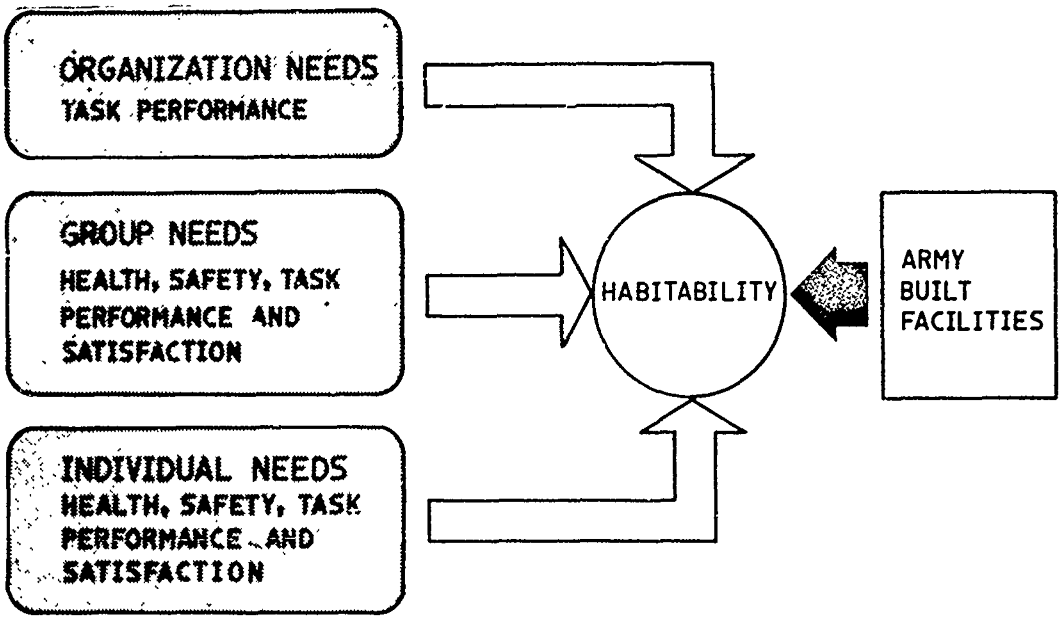


Figure 8. Habitability, occupants, and occupant needs.

Habitability Configuration

This section is an analysis of the configuration in which habitability occurs. Elements of the configuration are:

1. Occupant
   - Habitability properties
   - Contextual properties

2. Facility
   - Habitability properties
   - Contextual properties

3. Equipment

The configuration includes elements both without and within the direct habitability relationship. Elements within include habitability properties of both occupant and facilities, plus any equipment (furniture, machines, etc.) which is present in a setting. Elements without include contextual properties of both occupant and facilities. In other words, habitability occurs within a context of organizational climate, role expectancies and rewards, learning, productivity, and so on. And within a built facility, other man-equipment and man-man kinds of activities occur which are contextual to the study of habitability. The relationships among these categories are shown in Figure 9, which is an elaboration of Figure 8.

Figure 9 also indicates that the study of occupant-equipment relationships is in the field of human factors (or time and motion study, ergonomics, etc.) Similarly, the study of equipment-facility relationships is shown to be expressed by engineering data.

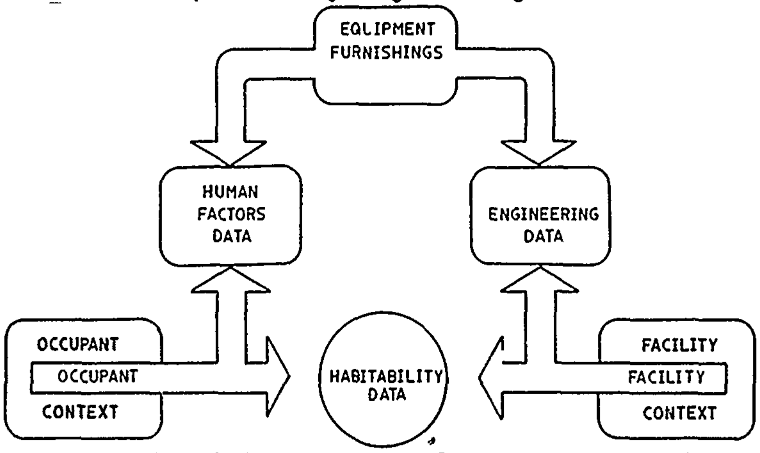


Figure 9. Habitability contextual category relationships.

It can be observed that under normal conditions the study of the occupant-equipment (or man-made) interface is not concerned with considerations of habitability as defined above. Studies of habitability usually show little concern for the anthropometry, for example, of the man-machine interface. On a larger scale, studies of such factors as organizational climate and learning are usually unconcerned with habitability. On the other hand, habitability studies seldom consider such factors as organizational climate and learning, probably because it is difficult to claim their improvement (under "normal" conditions) as a result of improved habitability *alone*.

One conclusion that can be drawn from the above observations is that wide ranges of habitability conditions are considered "normal" enough to be ignored by those who study humans and human activities in the facilities they occupy.

A second conclusion is that in order to generalize habitability data, the study of habitability must consider a wide range of contextual variables, which include all other influences such as socio-organizational, economic, psychophysiological, and natural setting elements.

A third conclusion is that the study of habitability must take into account a wide range of tasks of occupants of facilities, each of which may have special and unique habitability requirements.

The above observations and conclusions lead to an operational statement of a paradigm for the study of habitability as depicted in Figure 10. In this paradigm the equipment context has been combined with the facility context; in other words habitability occurs in the context of occupants in a facility containing equipment/furnishings. These terms are specified to the level of measurable properties in the sections which follow.

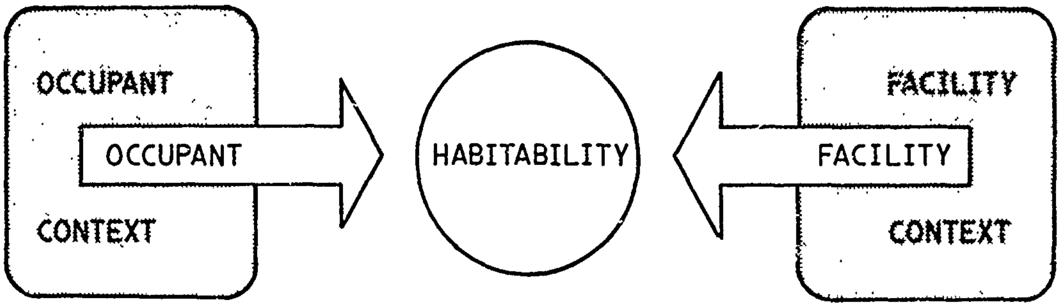


Figure 10. Habitability paradigm.

Habitability Properties

Measures of properties of occupants and facilities must answer specific habitability questions such as:

- How healthy are the air, water, sound levels, light levels, etc.?
- How safe are the work stations, corridors, doors, etc.?
- How functional are the work stations, equipment, etc.?
- How comfortable are the air, sound, lighting, etc.?
- How closely do the color scheme, equipment configurations, etc., conform to occupant preferences?

On a more general level, further questions can be posed:

- How aesthetically pleasing are the configuration, arrangement, color scheme, etc., of a room?
- What is the motivation of each individual occupant as a result of the built facility appointments and arrangements?
- What is the morale of the operating unit as a result of the built facility appointments and arrangements?

These questions about habitability are not in a form which can be answered directly. To be answerable, each question must first be put in a specific form that identifies the occupants, their needs, and the built facilities being occupied.

Both the questions and answers must contain data on *properties* which are descriptive of both occupants and facilities. Categories of properties which yield measures of properties responsive to habitability are as follows: for individuals and groups--physical, physiological and mental activities; for organizations and groups--structural and content activities; and for built facilities--the space; light; sound; air climate; and chemical, structural, motion and "other" radiation environments. Tables 1 and 2 contain listings of these categories plus examples of habitability properties which occur in each category. Figure 11 shows their relationships in a habitability diagram.

Table 1

Occupant Habitability Properties

Scale	Category	Habitability Properties
Individual	Physical Activities	Body posture, involvement, and movement; time beginning, end; frequency; etc.
	Physiological Activities	Blood pressure, respiration rate, sense acuities, etc.
	Mental Activities	Units of learning, manipulation, etc.; opinions, attitudes, and beliefs about properties of built facilities.
Organization	Structural Activities	Changes in job specs, lines of authority and responsibility, communication nets, operational policies and procedures, etc.
	Content Activities	Changes in population counts of structural nodes; changes in inputs and outputs, etc.
Group as Sum of Individuals	(Same as Individual)	Average, standard deviation, maximum, minimum, etc., of individual property measured.
Group as Organization	(Same as Organization)	(Same as Organization).

Table 2

Facility Habitability Properties

Scale	Category	Habitability Properties
Station	Space	Length, width, height, shape, location, etc., of assigned volumes.
	Light	Light sources, direction, background limits, glare of surfaces, etc.
	Sound	Sound sources, direction, background and intermittent decibels, reflection from surfaces, etc.
	Air Climate	Temperature, humidity, radiation flow and amount, air velocity, etc.
	Structure	Nominal descriptions of materials (steel, wood, etc.) and finish (paint, paper, etc.) of floor, ceiling, walls, openings, utilities and furnishings.
	Motion	Floor deflection, building sway, acceleration and deceleration of conveyances, etc.
	Air Chemicals	Concentrations of air particles and gases emitted by the facility and yielding odor, taste, etc.
	Other Radiation	Other than light and sound; frequency and amplitude of nuclear, infra-red, radio, TV, etc., radiation from the facility.
Room or Functional Area, Building, Vehicle or Complex	(Same as Station)	(Same as Station)

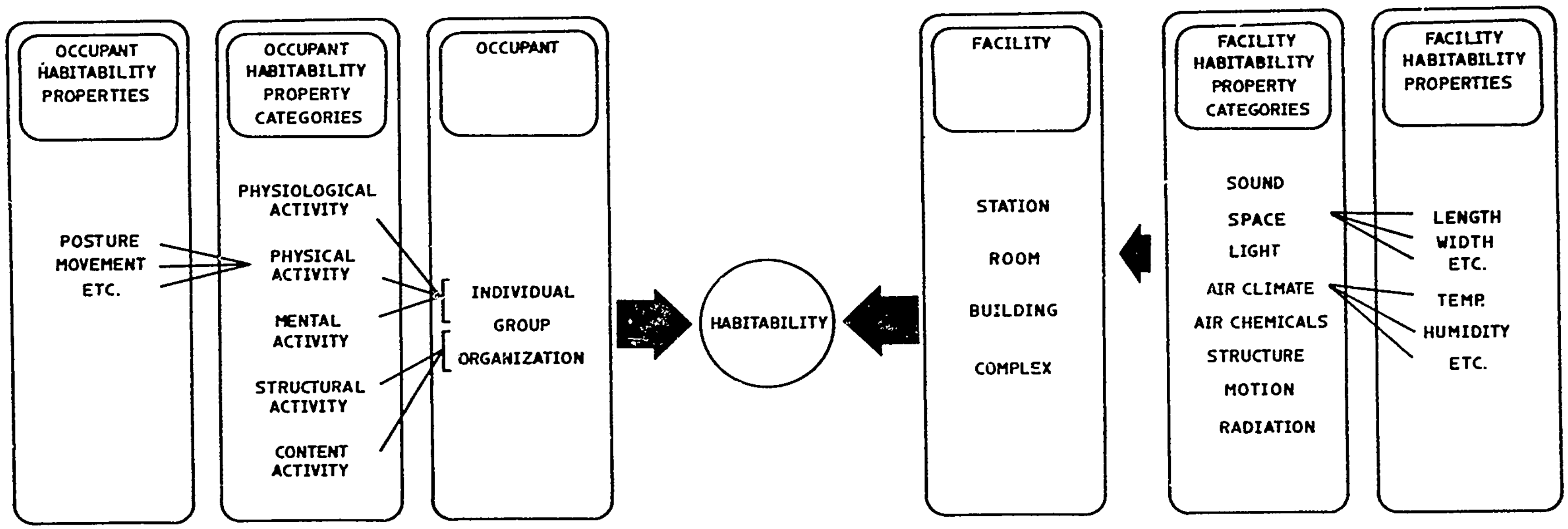


Figure 11. Habitability properties and property categories.

The above categories of habitability properties were first proposed for the evaluation of built facilities.[13] They have now been used and modified to closely represent available data during the coding of 10,000 lines of data for the HDB. Because of their proven utility for this purpose, they are also used to conceptualize habitability expressions below.

Contextual Properties

The habitability configuration shown in Figure 9 indicates three kinds of contextual information: occupant, facility, and facility equipment. The habitability paradigm in Figure 10 combines equipment with facility contextual information. These two kinds of information are, by definition, always contextual to habitability situations. Suggested categories for contextual information are as follows: for individuals and groups--their needs, biographical characteristics, and physical, physiological, and mental capacities; for organizations and groups--their needs, history, structure, and content; for facilities--the location, air and chemical climate, weather, equipment, and "other" radiation environments.

Tables 3 and 4 list all the contextual property categories and examples of each. Figure 12 shows their relationships in a habitability diagram which further details Figure 11. Figure 13 contains both habitability and contextual data as a summary of Figures 11 and 12.

Habitability Expressions

A habitability expression has been defined as a statement of an occupant habitability property (OH) as a function of a facility habitability property (FH). Assuming that both properties can be quantified and represented as counts or measures, the function can be cast as a mathematical function. For a given context:

A HABITABILITY PROPERTY OF AN OCCUPANT	IS A FUNCTION OF	A HABITABILITY PROPERTY OF A FACILITY

or

$$OH = f\ (FH_i) \qquad \text{[Eq 1]}$$

where i = one facility property.

[13] T. A. Davis, "Evaluating for Environmental Measures," *Proceedings of the 2nd Annual Environmental Design Research Association Conference, EDRA II,* Archea and Eastman, eds. (1970).

Table 3

Occupant Contextual Properties

Scale	Category	Contextual Properties
Individual	Physical Capacities	Height, weight, gross motion limitations and capabilities, etc.
	Physiological Capacities	Normal blood pressure, respiration rate, sense acuities, etc.
	Mental Capacities	I.Q., advancement scores, opinions, attitudes, and beliefs about contextual properties.
	Biography	Socio-economic data such as birth date, age, race, income, education, previous experience, etc.
	Needs	Health, safety, task performance, and satisfactions.
Organization	Structure	Job specifications, lines of authority and responsibilities, communication nets, operating policies and procedures, etc.
	Content	Population counts at structural nodes; inputs and outputs, etc.
	History	Age, income levels, growth counts, previous structures and contents, etc., socio-economic data.
	Needs	Task performance.
Group as Sum of Individuals	(Same as Individual)	Average, standard deviation, maximum, minimum, etc., of individual measures of properties.
Group as Organization	(Same as Organization)	(Same as Organization).

Table 4

Facility Contextual Properties

Scale	Location	Contextual Properties
Station	Location	Stations per room, building, etc.; other stations, rooms, and relationships; compass directions, geographic location and features, elevation, etc.
	Air Climate	Average, maximum, minimum, temperature, rainfall, wind velocity, humidity, sunshine, etc.
	Weather	Air climate at time of observation.
	Equipment	Nominal descriptions of machinery and furnishings, plus utilities required.
	Air Chemical	Atmospheric concentrations of air particles and gases yielding odor, taste, etc.
	Other Radiation	Frequency, amplitude, direction, etc., of other (not the sun), nonfacility radiation (e.g., nuclear, infra-red, radio, TV, etc.)
Room, Functional Area, Building, Vehicle, Complex	(Same as Station)	(Same as Station).

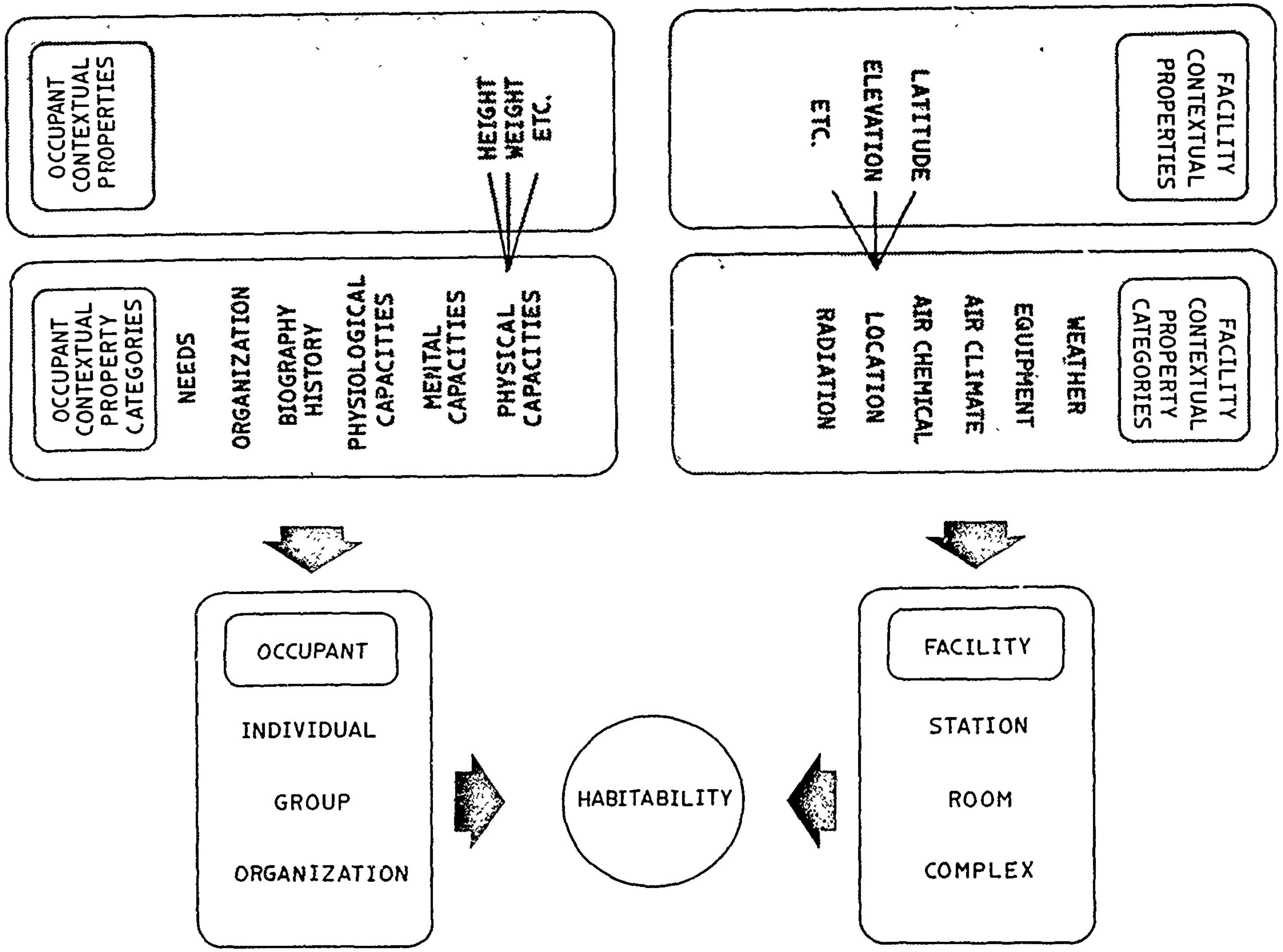


Figure 12. Contextual properties and property categories.

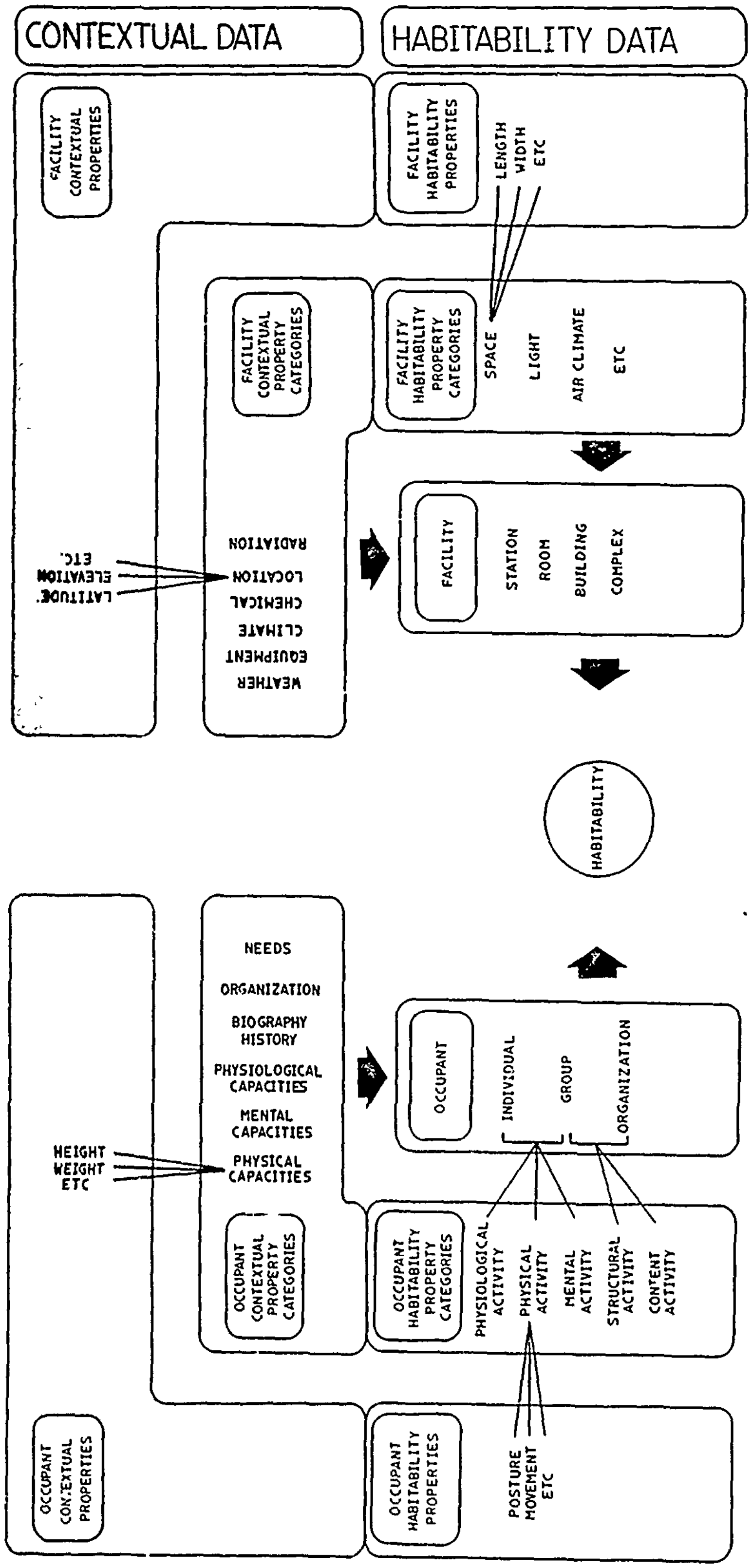


Figure 13. Habitability and contextual properties.

When an occupant property is shown to be the function of several facility properties, the FH subscript i is referred to a table of values of more than one facility property. This is the state of the art today. The most sophisticated habitability expressions occur in air climate, where occupant satisfaction votes in a given context have been shown to be a function of several air climate properties.[14]

A more general case occurs when occupant and facility properties can be expressed as functions of each other in a given context. This represents a situation such as the following:

1. Occupants cold as a function of air temperature.
2. Air temperature raised as a function of occupant body heat.
3. Occupants comfortable as a function of air temperature.

These three interactions can be expressed as follows:

$$f(OH_i) \approx f(FH_i) \qquad \text{[Eq 2]}$$

Again, the subscript i can be replaced by a table of values to indicate more than one property is involved.

The most general case occurs when occupant and facility properties can be expressed as functions of each other in more than one occupant context (OC) and/or facility context (FC):

$$f(OH_i,\ OC_i) \approx f(FH_i,\ FC_i) \qquad \text{[Eq 3]}$$

In the habitability expressions conceptualized in Chapters 4 through 6, the form of Eq 1 is used. Each expression is one-directional and the contextual properties are removed from the expression and stated as an *a priori* condition to it.

Habitability Properties Categories

Continuing the definitions of terms, the "objective definition" called for in the description of research goals above should ultimately express the interaction of *all* occupant properties with *all* facility properties in *all* contexts of *all* Army occupants at their activities in *all* built facilities. This is the situation expressed by Eq 3. The state of the art today is at the level of expressions in the modified form of Eq 1: for a given occupant and facility context, $OH = f(FH_i)$. An example of this expression is: occupant air comfort votes (OH) are a function of facility properties (FH_i) of temperature, humidity, radiation, etc. This example is explained in detail below.

[14] P. O. Fanger, *Thermal Comfort* (Copenhagen: Danish Technical Press, 1970).

To move from the one-directional Eq 1 to the two-directional Eq 2, the habitability properties of occupant activities must be packaged into categories that are compatible with facility habitability property categories. Six of the facility categories are relevant to facility design (space, light, sound, air climate, motion, and structure), and two are more relevant to environmental design (air chemicals and other radiation). The occupant categories suggested above are physical, physiological, and mental. These categories were selected for their utility in categorizing data into a data base rather than for their relevance to the facility categories. Thus 16 categories of occupant habitability properties that are relevant to the eight facility categories must be established--eight for individuals and eight for organizations.

One occupant habitability property category coded in the HDB could be relevant for matching occupant data to facility categories. Occupant activities (not necessarily occupant responses) are coded as shown in Table 5.

Table 5

Occupant Activities

1. Gross motor (body and limbs)
2. Micro motor (digits, facial expressions, etc.)
3. Mental performance
4. Mental opinions, attitudes, and beliefs (OAB's)
5. Physiological performance
6. Perceptual performance
7. Emotions
8. Social structural activity
9. Social content activity

One other category is suggested for individual occupants from a table in Fanger which lists metabolic rates for different levels of activity.[15] A visual inspection of Fanger's table indicates that five categories could represent individual activity levels (see Table 6) which could be used for the development of habitability expressions for air climate.

The two examples suggested in Tables 5 and 6 show that to be relevant to facility habitability properties categories, occupant habitability properties categories must:

[15] P. O. Fanger, *Thermal Comfort* (Copenhagen: Danish Technical Press, 1970), p 24.

Table 6

Metabolic Rates for Occupant Air Climate Categories*

Sedentary

0 60 kcal/hr m^2, e.g., sleeping, seated quietly, standing still, relaxed.

Low

61 - 120 kcal/hr m^2, e.g., walking on the level to 4.0 km/hr, while packing boxes, filling bottles, standing and machine sawing, general lab work, light machine work.

Medium

121 - 180 kcal/hr m^2, e.g., walking on the level to 6.2 km/hr; standing and operating pneumatic hammer; replacing tires, machine fitting, etc.

High

181 - 240 kcal/hr m^2, e.g., standing and sawing by hand, tipping molds in a foundry, heavy machine work, pick and shovel work, etc.

Very High

241-plus kcal/hr m^2, e.g. standing and planing by hand, roughing in foundry, tending furnace, removing slag, digging trenches.

*Information from P. O. Fanger, *Thermal Comfort* (Copenhagen: Danish Technical Press, 1970), p 24.

1. Represent properties of occupant activities
2. Be independent of facility settings
3. Be countable and measurable for all occupant activities and facility settings.

Habitability Expression Strengths

Three categories of habitability expression strengths are suggested: correlations, producer-product, and cause-effect. Correlations are the weakest, and simply mean that there are concomitant variations in both a property of a built facility and in a property of an occupant (e.g., occupant comfort votes varying concomitantly with air temperature). Correlation statements are not involved in causality.

Cause-effect expressions are the strongest, and mean that a property of a built facility is necessary and sufficient for an occupant activity (e.g., under normal atmospheric conditions, striking a bell is necessary and sufficient to produce a ringing). Cause-effect expressions will seldom be available, because the built facility is normally supportive of rather than the cause of occupant activities.

Between the categories of correlations and cause-effect there is a probabilistic or nondeterministic category called producer-product. These expressions can be used for habitability statements specifying necessary built facilities for occupant activities (e.g., artificial illumination in order to read in a windowless room). They are useful to structure habitability expressions, but do not contribute counts or measures to the content of the expressions. In other words, they suggest *which* properties are to be included, but not *how much*.

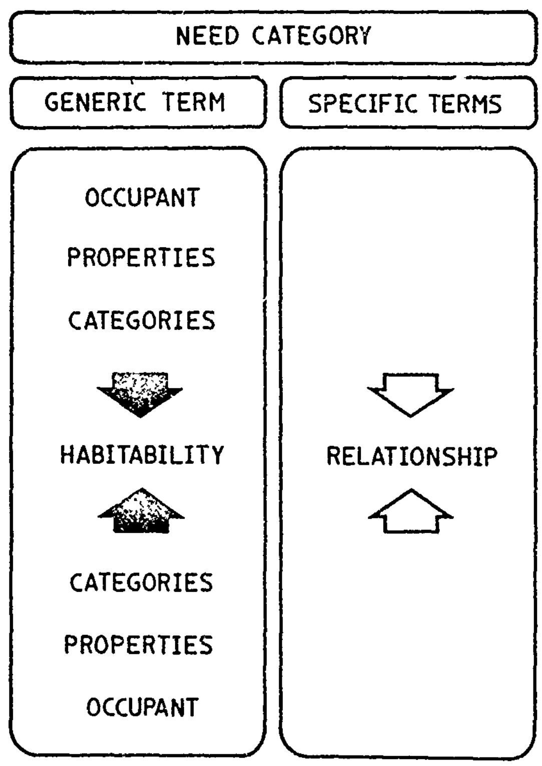
4 HABITABILITY EXPRESSIONS FOR INDIVIDUALS

General

In the discussions of individual habitability below, specific properties of individuals' activities are used as examples. In all four need categories, although specific examples may not be given, there is always the potential of relating physical, physiological, and/or mental properties to facility properties. For the sake of continuity and understanding, the same table format will be used throughout the next three chapters to relate specific terms to generic terms in habitability expressions. The basic format is shown in Table 7.

Table 7

Habitability Expression Form



Health of Individuals

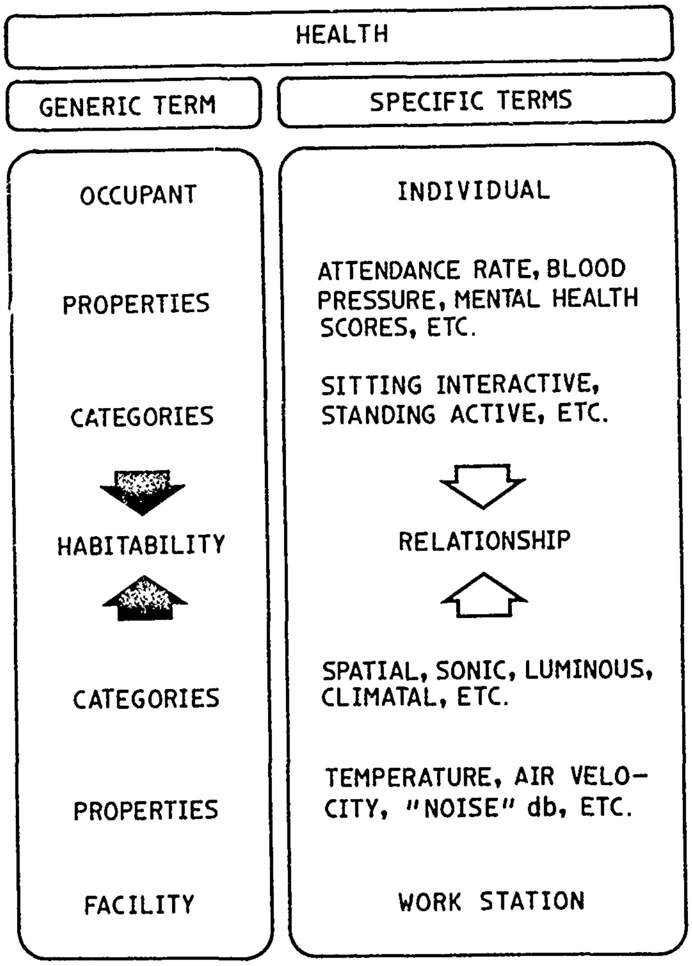
Individual health habitability is depicted in Table 8. For any specific combination of occupant and facility contexts, individual health habitability can also be expressed as a mathematical function corresponding to Eq 1; for example:

$$\text{individual attendance rate, etc.} = f(\text{temperature, air velocity, etc.}) \qquad \text{[Eq 4]}$$

Eq 4 has potential for expressing adverse climatal situations or heavy pollutant conditions, where the attendance rate might be minutes per hour or per day, and the facility properties extreme. Other potential applications include physiological measurements such as blood pressure as a function of background noise or respiration rate as a function of air velocity, polluting gases (ppm), smoke (ppm), etc.

Table 8

Individual Health Habitability



Safety of Individuals

Individual safety habitability is depicted in Table 9. For any specific combination of occupant and facility context, individual safety habitability can be expressed as a mathematical function corresponding to Equation 1; for example:

$$\text{individual accident rate, etc.} = f(\text{lighting levels, noise levels, etc.}) \qquad \text{[Eq 5]}$$

Table 9

Individual Safety Habitability

SAFETY	
GENERIC TERM	SPECIFIC TERMS
OCCUPANT	INDIVIDUAL
PROPERTIES	ACCIDENT RATE, INJURY RATE, SAFETY ATTITUDE SCORES, ETC.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
↓	↓
HABITABILITY	RELATIONSHIP
↑	↑
CATEGORIES	SPATIAL, SONIC, LUMINOUS, CLIMATAL, ETC.
PROPERTIES	CORRIDOR WIDTH, FEET TO WALK LIGHT LEVEL, ETC.
FACILITY	ROOM, FUNCTIONAL AREA, BUILDING.

Performance of Individuals

Performance has to do with the use of a facility for the mission and/or purpose for which it is occupied: to build a cabinet, to learn an increment of knowledge, etc. Thus, there are always two relevant measures of success for the activity: efficiency, which concerns output per time unit; and effectiveness, which concerns the quality of the output. For example, given a person assembling some hardware items, both the number of assemblies completed per time unit (efficiency) and the number that are acceptable (effectiveness) could be influenced by such factors as floor area, light levels, and temperature.

Both efficiency and effectiveness are indicated in Table 10: efficiency by "gross output" and effectiveness by "net output" per time unit. For any specific combination of individual and facility contexts, they can be expressed as a single mathematical function corresponding to Eq 1; for example,

individual output (gross, net)/time unit
= f(floor area, temperature, (light level, etc.)) [Eq 6]

Table 10

Individual Performance Habitability

PERFORMANCE	
GENERIC TERM	SPECIFIC TERMS
OCCUPANT	INDIVIDUAL
PROPERTIES	GROSS AND NET OUTPUT PER TIME UNIT.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
HABITABILITY	RELATIONSHIP
CATEGORIES	SPATIAL, SONIC, ETC.
PROPERTIES	TEMPERATURE, LIGHT LEVEL, FLOOR AREA, ETC.
FACILITY	WORK STATION

Satisfaction of Individuals

Individual satisfaction habitability is depicted in Table 11. For any specific combination of occupant and facility contexts, it can be expressed as a mathematical function as follows; for example,

$$\text{individual votes, etc.} = f(\text{temperature, sound level, light level, etc.}) \quad \text{[Eq 7]}$$

Table 11

Individual Satisfaction Habitability

SATISFACTION	
GENERIC TERM	SPECIFIC TERMS
OCCUPANT	INDIVIDUAL
PROPERTIES	AESTHETIC, COMFORT, ETC. VOTES; PHYSICAL MOVEMENTS, ETC.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
↓	↓
HABITABILITY	RELATIONSHIP
↑	↑
CATEGORIES	SPATIAL, SONIC, ETC.
PROPERTIES	TEMPERATURE, LIGHT LEVEL, FLOOR AREA, ETC.
FACILITY	WORK STATION

The term "satisfaction" is used here to represent responses indicating comforts, aesthetics, and preferences. Much of the current research on habitability elicits satisfaction votes which are used to express occupant opinions, attitudes, and/or beliefs. By way of illustration, Fanger's seven-point psychophysical scale of thermal sensation[16] for individual predicted mean votes is shown in Table 12. From

[16] P. O. Fanger, *Thermal Comfort* (Copenhagen: Danish Technical Press, 1970).

these definitions, satisfaction ranges can be operationally defined as follows:

maximum 2.5 - 5.5
minimum 3.6 - 4.5
average 3.0 - 5.0

Table 12

Thermal Sensation Scale

Individual Thermal Sensation	Aggregating Scale	Aggregate Satisfaction
Cold	1.0 - 1.5	Dissatisfaction
Cool	1.6 - 2.5	More dissatisfaction than satisfaction
Slightly Cool	2.6 - 3.5	More satisfaction than dissatisfaction
Comfortable	3.6 - 4.5	Satisfaction
Slightly Warm	4.6 - 5.5	More satisfaction than dissatisfaction
Warm	5.6 - 6.4	More dissatisfaction than satisfaction
Hot	6.5 - 7.0	Dissatisfaction

To complete the illustration, the following is an example of Eq 7. The example, from Fanger, established the Predicted Mean Vote (PMV) for a large group of persons as a function of the level of their exertion, clothing, air temperature, relative air velocity, and air humidity.[17]

[17] P. O. Fanger, *Thermal Comfort* (Copenhagen: Danish Technical Press, 1970).

$$PMV = \left(0.352\, e - 0.042 \frac{M}{A_{DU}} + 0.032\right) \left[\frac{M}{A_{DU}} (1 - n) - \right.$$

$$0.35 \left[43 - 0.061 \frac{M}{A_{DU}} (1 - n) - Pa\right] -$$

$$0.42 \left[\frac{M}{A_{DU}} (1 - n) - 50\right] -$$

$$0.0023 \frac{M}{A_{DU}} (44 - Pa) - 0.0014 \frac{M}{A_{DU}} (34 - t_a) -$$

$$\left. 3.4 \times 10^{-8} f_{cl} \left[(t_{cl} + 273)^4 - (t_{mrt} + 273)^4\right] - f_{cl}\, h_c (t_{cl} - t_a) \right]$$

where M = metabolic rate

A_{DU} = DuBois area: human body surface area

n = external mechanical body efficiency

P_a = partial pressure of water vapor in ambient air

t_a = air temperature

t_{cl} = mean temperature of outer surface of clothed body

t_{mrt} = mean radiant temperature

f_{cl} = ratio of the surface area of the clothed body to the surface area of the nude body

h_c = convective heat transfer coefficient.

Two other variables used to derive the above equation are:

i_{cl} = thermal resistance from skin to outer surface of the clothed body

V = pulmonary ventilation.

One implication of having expressions like Fanger's available is that habitability requirements can then be expressed in terms of occupant satisfactions; e.g., to provide a facility (i.e., climate and climate-generating equipment) to which the occupants at each station will respond with a mean satisfaction vote on all properties in the range of X to Y on a scale of Z. A second implication is that built facilities can be evaluated directly in terms of properties of an occupant activity rather than by use of a habitability criterion which may limit the range of alternatives in the design of facilities.

Habitability expressions for individual preferences have been reported earlier,[18] and are available for family housing as a computer calculation of predicted occupant satisfaction votes resulting from furniture and equipment selections.

[18] D. L. Dressel, et al., *Predictors of Satisfaction With Housing Interiors*, Technical Report D-48/ADA011187, Vol III (CERL, April 1975).

5 HABITABILITY EXPRESSIONS FOR ORGANIZATIONS

General

As a consequence of restricting the discussion of organization habitability to performance, only one facility modeling unit is relevant. Functional activities take place in space (work stations, rooms, etc.) over time. Considerations of other environmental modeling units such as climate and sound are not relevant to an organization *per se*, but only to the individuals and groups of individuals considered as such.

Performance of Organizations

Performance habitability for organizations is depicted in Table 13. As with individuals, it represents both efficiency and effectiveness measures. For any specific combination of occupant and facility contexts, it can be expressed as a mathematical function as in the following example:

organization gross and/or net output/time unit
= f(number of rooms, stations per room, rooms per building, etc.) [Eq 8]

An example of a mathematical expression of organization training is shown in Table 14, which is a planning formula for determining floor space requirements for an instructional laboratory. But by solving the equation in Table 14 for A, the average number of students (output) in each session (time) can be expressed as a function of practice equipment, floor area per equipment item, floor area per student, and area of laboratory, as follows:

$$A = \frac{BxF}{(BxE)+D}$$

This formula is in the same form as Eq 8.

Table 13

Organization Performance Habitability

PERFORMANCE	
GENERIC TERMS	SPECIFIC TERM
OCCUPANT	ORGANIZATION
PROPERTIES	GROSS OR NET OUTPUT PER TIME UNIT.
CATEGORIES	CLASSROOM INSTRUCTION, AUTO REPAIR, ETC.
↓	↓
HABITABILITY	RELATIONSHIP
↑	↑
CATEGORIES	SPATIAL
	NO. OF ROOMS, STATIONS PER ROOM, AREA PER STATION, ETC.
FACILITY	STATION, ROOM OR BUILDING.

Table 14

Planning Formula for Determining Floor Space Requirements for an Instructional Laboratory*

Definitions	Formula
A = Average number of students in each session.	1. [(B x E) + D] x C = F.
B = Number of students assigned to each item of practice equipment or to each training aid.	2. Add 20 percent allowance to F for instructional changes due to technological advances.
C = Number of items of practice equipment or training aids required = $\frac{A}{B}$.	**NOTES**
D = Square feet of floor area occupied by each item of practice equipment or each training aid (includes critical dimensions and clearances in all directions, safety requirements, aisles and fire exits).	a. A graphic layout should be made. The arithmetical square footage derived by the formula process can be deceiving, particularly where circular or odd-shaped items of practice equipment and training aids are required.
E = Square feet of floor area required for one student working on or around each item of practice equipment or each training aid.	b. Human engineering factors to include safety and lighting should be considered at the outset of the planning process.
F = Net square foot area of instructional laboratory.	c. If the laboratory is to be a separate shop, refer to comments "Circulation areas, walls, service areas," in Appendix A to obtain an established total gross square footage for the Instructional Laboratory.

* Department of the Army, *Construction Space Planning Criteria for U.S. Army Service Schools*, TM 5-843-1 (July 1970).

6 HABITABILITY EXPRESSIONS FOR GROUPS

General

A group of people can be described as the sum of the properties of the individuals who comprise the group. The measurements commonly used include frequency counts of averages, standard deviation, maximums, and minimums. If the group has a formal structure and mission with objectives and procedures, it may be desirable to also describe the performance of the group using the properties of organizations. Both possibilities are conceptualized in the following discussion.

Health of Groups

The health habitability of a group of people is depicted in Table 15. For any specific combination of group and facility contexts, it can also be expressed as a mathematical function; for example,

frequency counts, etc., of group attendance
= f(temperature, air velocity, etc.) rate, etc. [Eq 9]

Table 15

Group Health Habitability

HEALTH	
GENERIC TERMS	SPECIFIC TERM
OCCUPANT	GROUP
PROPERTIES	FREQUENCY DISTRIBUTIONS, ETC., OF ATTENDANCE RATES, SICKNESS RATES, BLOOD PRESSURES, ETC.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
HABITABILITY	RELATIONSHIP
CATEGORIES	SPATIAL, SONIC, ETC.
PROPERTIES	TEMPERATURE, AIR VELOCITY, POLLUTANT, ppm, ETC.
FACILITY	ROOM, BUILDING.

Safety of Groups

The safety habitability of groups of people is depicted in Table 16. For any specific combination of group and facility modeling units, it can also be expressed as a mathematical function; for example,

$$\begin{aligned}&\text{group accident rate, etc.,}\\ &= f(\text{lighting levels, noise levels, etc.})\end{aligned} \qquad \text{[Eq 10]}$$

Table 16

Group Safety Habitability

SAFETY	
GENERIC TERMS	SPECIFIC TERM
OCCUPANT	GROUP
PROPERTIES	FREQUENCY DISTRIBUTIONS, ETC. OF ACCIDENT RATES, EVACUATION RATES, ETC.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
↓	↓
HABITABILITY	RELATIONSHIP
↑	↑
CATEGORIES	SPATIAL, SONIC, ETC.
PROPERTIES	CORRIDOR WIDTH, EXIT DISTANCE, LIGHT LEVEL, ETC.
FACILITY	ROOM, FUNCTIONAL AREA BUILDING

Performance of Group as Sum of Individuals

Task performance habitability of a group of people, as indicated by efficiency and effectiveness measures, is depicted in Table 17. For any specific combination of group and facility contexts, it can also be expressed as a mathematical function:

$$\text{group output (gross, net)/time unit} = f(\text{floor area, temperature, light levels, etc.}) \qquad \text{[Eq 11]}$$

Table 17

Group Performance Habitability

PERFORMANCE	
GENERIC TERMS	SPECIFIC TERM
OCCUPANT	GROUP
PROPERTIES	FREQUENCY DISTRIBUTIONS, ETC. OF GROSS AND NET OUTPUTS PER TIME UNIT.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
HABITABILITY	RELATIONSHIP
CATEGORIES	SPATIAL, SONIC, ETC.
PROPERTIES	TEMPERATURE, LIGHT LEVEL, ETC.
FACILITY	ROOM, FUNCTIONAL AREA BUILDING.

Performance of Group as Organizations

Performance habitability of groups measured as organizational efficiency and effectiveness is depicted in Table 18. For any specific combination of group and facility contexts, it can also be expressed as a mathematical function; for example,

group output (gross, net)/time unit
= f(number of rooms, stations per room, area per station, etc.) [Eq 12]

Table 18

Group Performance Habitability

PERFORMANCE

GENERIC TERMS	SPECIFIC TERM
OCCUPANT	GROUP
PROPERTIES	NUMBER OF GROUPS, POPULATION COUNTS OF EACH, INPUTS, OUTPUTS, TIME, ETC.
CATEGORIES	CLASSROOM INSTRUCTION, ADMINISTRATION, ETC.
HABITABILITY	RELATIONSHIP
CATEGORIES	SPATIAL
PROPERTIES	NUMBER OF ROOMS, STATIONS PER ROOM, ETC.
FACILITY	STATION, ROOM, FUNCTIONAL AREA, BUILDING.

Satisfaction of Groups

The satisfaction habitability of groups of people is depicted in Table 19. For any specific combination of group and facility contexts, it can also be expressed as a mathematical function; for example,

frequency distributions, etc., of group votes, etc.
= f(temperature, sound level, light level, etc.) [Eq 13]

As with individual satisfaction habitability, group satisfaction habitability can be expressed in terms of satisfaction votes, physical movements, and physiological measurements.

Table 19

Group Satisfaction Habitability

SATISFACTION	
GENERIC TERMS	SPECIFIC TERM
OCCUPANT	GROUP
PROPERTIES	FREQUENCY DISTRIBUTIONS, ETC.; PHYSICAL [e.g. VANDALISM RATE], MENTAL OR PHYSIOLOGICAL PROPERTIES.
CATEGORIES	SITTING INTERACTIVE, STANDING ACTIVE, ETC.
HABITABILITY	RELATIONSHIP
CATEGORIES	SPATIAL, SONIC, ETC.
PROPERTIES	TEMPERATURE, LIGHT LEVEL, ETC.
FACILITY	STATION, ROOM, FUNCTIONAL AREA.

7 HABITABILITY COST-EFFECTIVENESS EXPRESSIONS

General

The third application of the habitability expressions conceptualized here is the cost-effective allocation of dollars to the separate properties and/or categories of properties of facilities, either for rehabilitation of existing facilities or planning of new ones. Cost effectiveness (C-E) is defined here as a function of facility dollar costs divided by units of occupant activity; for example,

$$\text{cost-effectiveness} = f\left(\frac{\text{dollar cost of built facilities}}{\text{occupant activity units}}\right) \quad \text{[Eq 14]}$$

The cost-effectiveness ratio which results from the division in Eq 14 can be used at least two ways:

1. Given a fixed budget for a habitability project, properties of facilities can be selected that will be most cost-effective within the budgeted amount.

2. Given the need to build or renovate a facility, priorities can be established for those properties of facilities that are most cost-effective.

Note that cost-effectiveness as defined above is the ratio of the right sides of Eqs 1 through 13 divided by the left sides. Contextual variables would be included in the calculation if their effect were known. Since Eq 14 cost-effectiveness ratios can be used for all occupant needs and for occupants as individuals, organizations, or groups, specific equations are not conceptualized for those categories.

Specific Cost-Effectiveness Expressions

As with habitability expressions, cost-effectiveness expressions can be written for individual properties, categories of properties, and total facilities, as follows:

$$\text{cost-effectiveness of one property} = f\left(\frac{\text{the cost of one property}}{\text{occupant activity units}}\right) \quad \text{[Eq 15]}$$

$$\text{cost-effectiveness of one category of properties} = f\left(\frac{\text{the cost of all properties in one category}}{\text{occupant activity units}}\right) \quad \text{[Eq 16]}$$

$$\text{cost-effectiveness of a facility} = f\left(\frac{\text{the cost of all properties in all categories}}{\text{occupant activity units}}\right) \quad \text{[Eq 17]}$$

An example of the application of Eq 16 can be developed using predictors of satisfaction with housing interiors.[19] Figure 14 shows a "Sample Priority Matrix and Prediction Model Format" for refrigerators, in which number of items to be improved is arrayed against physical improvements. This can be translated into a cost-effectiveness expression by substituting "dollar cost" for "physical improvements," and "units of satisfaction" (distance long the scaling line) for "number of items to be improved." Dollars can then be divided by units of satisfaction, and the cost-effectiveness of each improvement calculated.

As an example of the above, values for the variables in Figure 14 can be assumed as follows:

adequate freezer space = $100
adequate refrigerator space = $250
good repair = $50
increased mean satisfaction: one item = 15 units
increased mean satisfaction: two items = 45 units
increased mean satisfaction: three items = 55 units.

The cost-effectiveness of providing each level of aggregation of items is then as follows:

C-E one item = $100/15 = $6.66/unit of staisfaction
C-E two items = $100 + 250/45 = $7.77/unit of satisfaction
C-E three items = $100 + 250 + 50/55 = $7.36/unit of satisfaction.

Thus, the cost per unit of satisfaction is lowest for one item; i.e., the furnishing of one item is the most cost-effective of the three possibilities.

[19] D. L. Dressel, et al., *Predictors of Satisfaction With Housing Interiors*, Technical Report D-48/ADA011187, Vol III (CERL, April 1975).

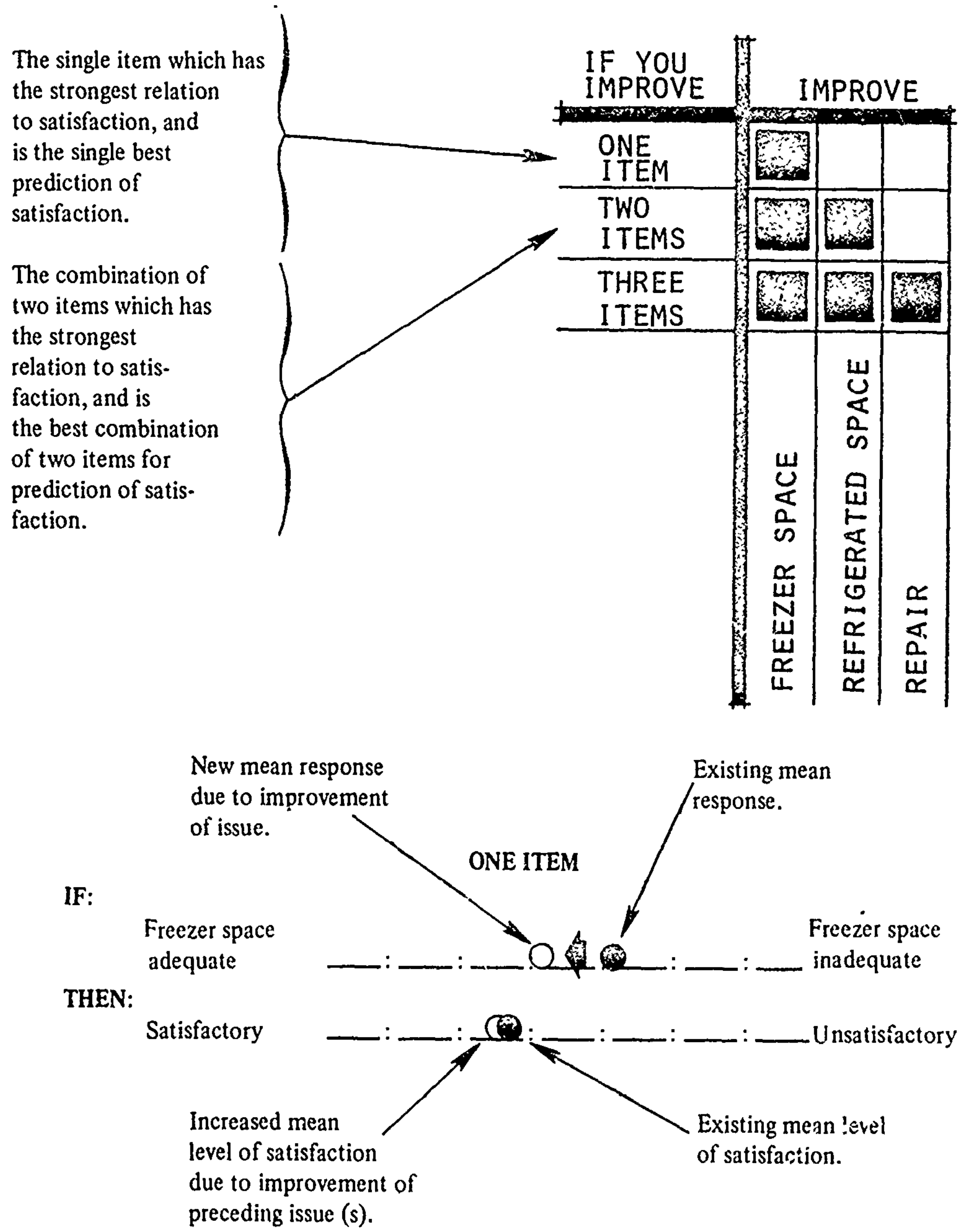


Figure 14. Sample priority matrix and prediction model format. From D. L. Dressel, et al., *Predictors of Satisfaction With Housing Interiors*, Technical Report D-48/ADA011187, Vol III (CERL, April 1975).

TWO ITEMS

IF:

Freezer space adequate ___ : ___ : ___ ○ ◁ ● ___ : ___ : ___ Freezer space inadequate

AND IF:

Refrigerator space adequate ___ : ___ ○ : ◁ ● : ___ : ___ : ___ : ___ Refrigerator space inadequate

THEN:

Satisfactory ___ : ___ ○I● : ___ : ___ : ___ : ___ Unsatisfactory

THREE ITEMS

IF:

Freezer space adequate ___ : ___ : ___ ○ ◁ ● ___ : ___ : ___ Freezer space inadequate

AND IF:

Refrigerator space adequate ___ : ___ ○ : ◁ ● : ___ : ___ : ___ : ___ Refrigerator space inadequate

AND IF:

In good repair ○ ◁ ● : ___ : ___ : ___ : ___ : ___ In poor repair

THEN:

Satisfactory ___ : ___ ○II● : ___ : ___ : ___ : ___ Unsatisfactory

Refrigeration features should include:

1) completely automatic defrosting
2) increased freezer space (as opposed to present size)
3) larger refrigerated space.

Refrigerators should be of the side-by-side, double-door style.

Figure 14 (cont'd)

8 ASSUMPTIONS

Content Assumptions

Habitability is the construct used here to describe the degree of fit (i.e., the quality or effectiveness) of built facilities to Army and Army personnel for: (1) task or functional performance; (2) welfare (health and safety); and (3) satisfactions (comforts, aesthetics, and preferences). To describe this degree of fit in any particular situation, three content assumptions are made:

1. It is assumed that properties of occupant activities and of facility physical objects can be used to express habitability.

2. It is assumed that the minimum contextual properties data needed for facility and occupant is as follows:

   a. Facility descriptions--location, climate, and weather at time of observation.

   b. Occupant descriptions--physical, physiological, and mental capacities; biography; and needs.

3. It is assumed that habitability and contextual properties can be represented in habitability expressions by counts or measurements.

Structural Assumptions

The basic structural assumption is that occupant-facility relationships can be meaningfully studied in the relationship mode as shown in Figure 2. Beyond that, the expressions conceptualized above do not indicate the potential complexity of the interactions between the several properties of a category or between the several categories of properties of a facility as they may be reflected in occupant activities. As an indication of this complexity of interactions, the following assumptions are made, patterned after Klapper's "emerging generalizations" about mass communications.[20] For simplicity, these assumptions do not refer to property categories, but are written only in terms of properties of facilities.

The first assumption states that each property of a facility has maximums and minimums above and below which the property will be perceived as unsatisfactory for human use:

[20] J. T. Klapper, "What We Know About the Effects of Mass Communications: The Brink of Hope," *Communication and Culture,* A. G. Smith, ed. (Holt, Rinehart, and Winston, 1966).

1. There are extreme conditions (too much or too little) in which any property of a facility can be a direct cause for occupant discomfort or disfunction.

The next two assumptions state that the built facility is only one of many factors which make up the total context of a functional setting, and that it interacts with the other factors toward a steady (predictable) state:

2. The built facility does not ordinarily serve as a necessary and sufficient cause for occupant performance and comfort, but instead, acts among and/or through a complex of mediating factors that make up the total context of a setting.

3. These mediating factors are such that they typically render the built facility a contributory agent, but not the sole cause, in a process of reinforcing existing conditions (rather than changing them).

The next assumption states that when the built facility does not contribute to change, either the other mediating factors will not be acting or there will be a "snowballing" effect:

4. When the built facility does function as an agent of perceived change, one of two conditions is likely to exist. Either (1) the mediating factors to that perception will have been rendered inoperative by the agent of change; or (2) the mediating factors will also be impelling toward change.

The final assumption states that the separate properties of a facility are independent variables which interact with each other:

5. The role of the built facility either as a contributory agent or as a direct affect or effect on human performance and comfort is influenced by the interaction between the several properties of a facility.

Each property of a facility is thus described as working independently among several other properties acting on an individual at any one time: it may cause unsatisfactory affects or effects in extreme situations, but it normally acts only as a necessary but not sufficient contributor to human satisfactions.

Technical Assumptions

The approach taken here is a further development of the author's statement of theoretical considerations regarding the evaluation of built environments in terms of human comforts and satisfactions.[21] Four basic technical assumptions which apply to the manipulation of opinion, attitude, and belief properties of occupants are as follows:

1. It is assumed that humans are able to match the degree of intensity of facility properties (e.g., air warmth) to words representing subjective feelings (e.g., a scale from cold to hot).[22]

2. It is assumed that the words representing degrees of intensity of subjective feelings can be expressed as frequency counts that will form binomial distributions of satisfaction or comfort[23] as shown in Figure 15.

3. It is assumed that an interval scale can be arrayed beside the words representing degrees of intensity of subjective feelings, and that the resulting numerical expressions can be equated to facility stimuli algebraically.[24]

4. It is assumed that the numerical expressions of intensity of subjective feelings will be additive for any single variable.[25]

[21] T. A. Davis, "Evaluating for Environmental Measures," *Proceedings of the 2nd Annual Environmental Design Research Association Conference, EDRA II*, Archea and Eastman, eds. (1970).

[22] S. S. Stevens, "Ratio Scales of Opinion," *Handbook of Measurement Assessment in Behavioral Sciences* (Addison-Wesley, 1968).

[23] L. E. Weaver, "The Quality Rating of Color Television Pictures," *Journal of the Society of Motion Picture and Television Engineers*, Vol 77 (June 1968), p 610.

[24] Stevens.

[25] Weaver.

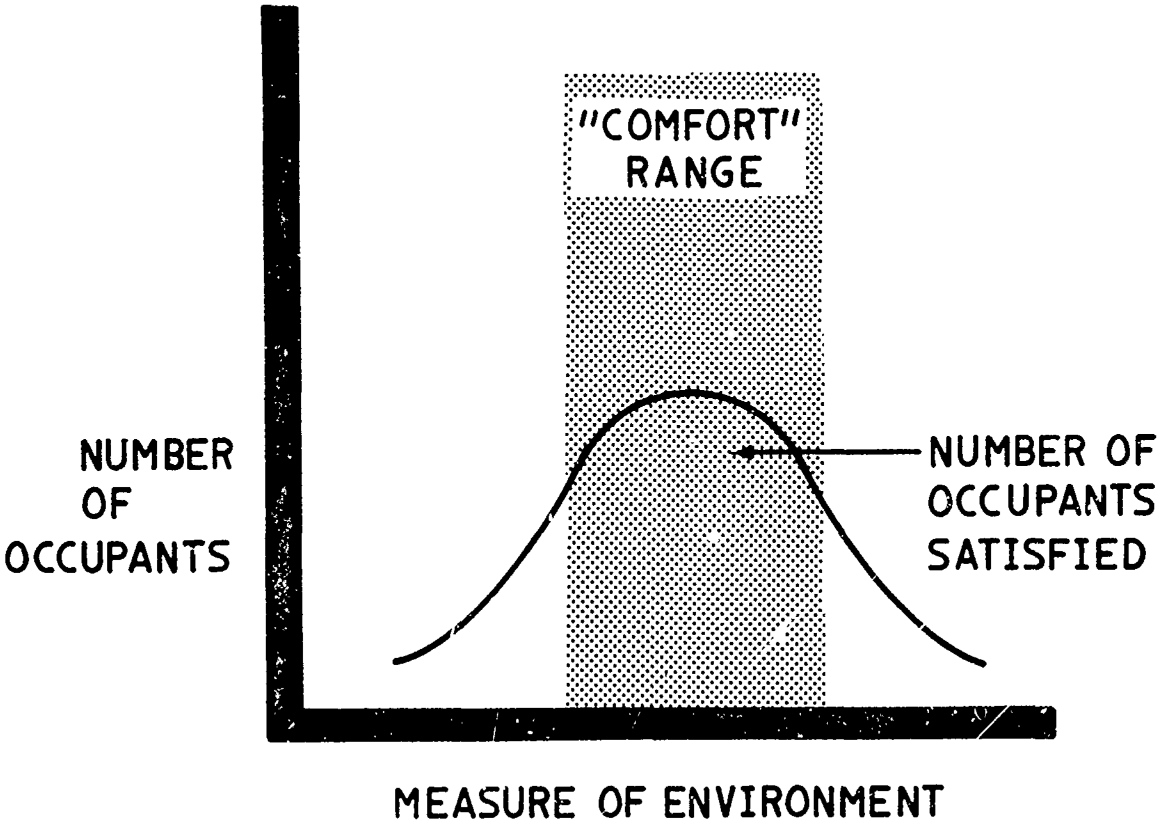


Figure 15. Comfort frequency count.

9 SUMMARY AND RECOMMENDATIONS

Summary

The purpose of this report was to conceptualize an approach to an objective definition of Army and Army personnel facility habitability for application in the planning, programming, design, and occupancy of Army facilities. Basic terms have been defined; content, structural, and technical assumptions stated; and examples cited where possible. This concludes the conceptual phase of habitability expression development.

Recommendations

It is recommended that the development of habitability expressions be continued through the prototype phase as follows:

1. Review habitability Eqs 4 through 17, comparing them to the procedures and activities of the Corps' facility delivery process.

2. Select those habitability expressions most relevant to Corps facility planning, programming, design, and evaluation.

3. Establish a priority list of habitability expressions for development into prototype expressions.

4. Develop prototype expressions.

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