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Building Accessibility in Relation to Door Hardware, Door Users, and Door Use

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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, *Secretary*
Jordan J. Baruch, *Assistant Secretary for Productivity, Technology, and Innovation*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

As part of a National Bureau of Standards (NBS) effort to develop comprehensive accessibility guidelines for building professionals, NBS proposed to the Architectural and Transportation Barriers Compliance Board (ATBCB) a project entitled "Development of Architectural Accessibility Guidelines." The proposed project, which is in three phases, focuses on accessibility research on doors. The first phase, now completed, addressed problem identification. This report is a product of the first phase. The second phase will emphasize research and the development of comprehensive, rational accessibility guidelines. The third phase will be a continuing activity of research, demonstration, and public participation to improve the accessibility guidelines and to promote their adoption.

ABSTRACT

This report reviews the technical literature related to doors as architectural barriers. It examines the concept of disability and the associated concepts of impairment and handicap. It is concluded that these terms lack consensus of meaning. The concept of functional capacity is recommended as an alternative because of the more direct linkage between functional capacity and performance. A review of the conceptual literature on functional capacity and its measurement leads to the conclusion that functional capacities relevant to building accessibility generally have been identified but more precise specifications and improved ergonomic procedures for testing functional capacities of the disabled are required. Furthermore, a distinction is drawn between functional capacity and door use patterns. The latter refers to how functional capacities are applied during actual door use. Last, door systems are examined, particularly locking and latching mechanisms, door openers, and door closers. The existing literature on these raises questions about the adequacy of current accessibility codes and standards with regard to these components. Based on unresolved problems and current needs, research addressing accessibility-relevant objectives is recommended.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

The Architectural and Transportation Barriers Compliance Board (ATBCB) was created by the Congress to assure compliance with Federal standards which were developed to make building and transportation facilities accessible and usable by handicapped persons. Since 1973, when the ATBCB was created, a number of accessibility guides and codes have been developed at the State and Federal levels and by consensus standards groups (e.g., ANSI 117.1-1979). However, these standards and codes are not in full agreement with each other on common elements, vary in their scope, and vary in the empirical support they can muster for their specifications. Fortunately, the Congress has provided the ATBCB an opportunity to clarify this situation through the 1978 Amendments to the Rehabilitation Act of 1973. These Amendments provide the ATBCB with authority to "develop standards... with respect to overcoming architectural, transportation, and communication barriers" [new section 503(d)(3)].

One building system addressed by codes which requires reappraisal is the door system. The door is the manipulable building feature which all users of a building must use. It is inherent to building use. Doors must be negotiated at entry points and at other points throughout buildings. Doors, particularly manually operated doors with closers, are a pervasive obstacle to the disabled.

Doubtless every citizen has experienced at one time or another a door that was difficult, if not impossible, to open or close. This difficulty can result from (1) improper installation, (2) insufficient maintenance, such as an improper closer adjustment, (3) an unusual climatic condition, such as extreme wind acting on the door, or (4) a characteristic of the door's design or construction, such as the door's weight, size, or placement.

There is another reason why doors can become obstacles to ease of access and use. This reason is less obvious, very pervasive, and difficult to resolve. Doors serve multiple functions, such as access, life safety, security, privacy, and climate control/energy conservation. Doors also serve ceremonial and symbolic functions -- witness the immense doors on courts of law. These functions may be dictated by public policy (such as life safety), tradition (such as privacy), national interest (such as energy conservation through climatic control), or financial interest (such as security precautions required by an insurance carrier). These functions are expressed through the characteristics of the door system such as the location of doors, the design and construction of doors, door operation, and door size, weight, materials, and hardware. Conflicts among functions all too often have been resolved so as to create accessibility problems for the disabled.

Examples will illustrate how the life safety, security, energy conservation, and ceremonial functions, respectively, have conflicts with and affect the accessibility function. (1) A recently revised national consensus standard on building accessibility (ANSI 117.1-1979) specifies that exterior doors must open in response to no more than 8 1/2 lbf (38 N),[1] to enable persons with stamina or coordination limitations to use these doors easily. However, it is widely believed by persons concerned about life safety functions of doors that this criterion would sharply reduce the ability of the doors to self-close and self-latch effectively. Presumably current codes that specify higher levels than 8 1/2 lbf (38 N) for exterior doors are doing so for life safety reasons.[2] (2) Disabled persons with limited mobility or who may be bed-ridden realize that they are vulnerable to intruders (burglars, robbers), a point also emphasized by the police. For example, if locks are used for physical security, locked doors can prevent friends from entering domiciles, thus limiting opportunities for the disabled to affiliate or to get needed help in medical emergencies (Lipchez and Winslow, 1979, p. 67). Moreover, high security locks require finer motor coordination for their use, a potential problem for persons with coordination difficulties (J. Stroik, personal communication, September 1979). (3) Interest in energy conservation has led to weatherstripping of exterior doors to minimize air infiltration. However, the weatherstripping also increases the inertial force required to overcome opening resistance. Moreover, weatherstripping can lead to binding of the bolt against the strike plate hole, further creating difficulties with using the door (R. Hudnut, personal communication, July 1979). (4) Some public buildings have huge, heavy, manually operated doors. The size and weight of these doors express their ceremonial and symbolic status; they give the building an aura of importance and awesomeness. However, such doors can be an obstacle to access, even for ostensibly able-bodied people. These four examples illustrate conflicts between accessibility and other door functions. Clearly, these conflicts must be addressed directly and the alternatives carefully weighed in any consideration of requirements for doors affecting door use.[3]

Conflicts among functions involving the door also can be aggravated if building regulations or standards do not agree on levels of door performance. This can be illustrated with conflicts between life safety and security, respectively, and accessibility. The Life Safety Code specifies that the force to fully open doors shall not exceed 50 lbf (222 N) applied at the latch stile (Sharry, 1978, p. 48). Similarly, security concerns may require a door to have a very tight fit, similar to the effect of a tightly weather-stripped door. A tight fit may significantly increase the difficulty of unlocking the door and of opening it from a near-latch position (Cohn, 1978, p. 3-17). These examples illustrate opening resistances that can fall beyond the ability of many handicapped individuals (Johnson, 1979; see note 6). In sum, building features can be obstacles to building access and use.

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[1] SI and conventional units are rounded, unless indicated. N = lbf x 4.448

[2] Point made by the Panel on Egress during the Conference on Fire Safety for the Handicapped, November 1979, Gaithersburg, MD.

[3] These conflicts are a concern of model code writing organizations such as BOCA, ICBO, SBCC. (S. Trant, personal communication, fall 1979).

The idea that building features can be obstacles to access to or use of buildings for all of us, at one time or another, is discussed by Jones (1978, p. ix).

> If we consider that the environment has traditionally been designed for the average, "able-bodied" adult (of average height, weight, hearing, eyesight, stamina and reaction time), then the rest of the population which does not match up to this standard is, by definition, handicapped. It is estimated that 60 percent of the total population of the United States is handicapped at any one time in their use of the environment.

He goes on to note that

> While the environment poses problems to all citizens, the effects of architectural barriers on the severely disabled are manifested more tragically.

He concludes that

> Any changes that are made to the environment to aid the severely handicapped population will also help all people to lead easier and safer lives.

That is, building designs and building products, in principle, can be made responsive to the capacities of both handicapped users and the general population so that both benefit from improved accessibility.

In this report, the problem of accessibility focuses on the user and the door system and the relation between them. This relation is based on several assumptions. First, successful door use requires a fit between (1) a user's functional capacities and (2) how these functional capacities are employed in using a door with (3) the physical characteristics of and forces created by the use of the door. Second, these three factors are interrelated. Third, the contribution of each factor can be studied. Last, studies of these factors should relate the human and the engineering elements to one another and should provide a technical basis for accessibility standards.

The choice of specific topics for this report draws on expert opinion, including the recommendations for further research by the contributors to the ATBCB/NBS Conference on Accessibility Standards, and on an appraisal of current research on door use.[4]

[4] Surprisingly, studies of the needs of the disabled did not prove to be useful. An extensive search for such studies resulted in only one "large scale" study (Panel on Building Design Criteria for the Disabled, 1977) [henceforth to be designated as "the Panel"]. However, the presentation of the Panel's results limited their usefulness. For example, the size of the sample whose responses are reported is unstated and the data is qualitatively, not quantitatively, summarized thus making it impossible to determine the relative importance of particular responses.

2. THE DOOR USER

This section addresses four topics: the concept of disability, disability versus functional capacity as an index of human performance, the identification and measurement of functional capacity, and patterns of door use. These four topics represent the human side of the user-door equation.

2.1 THE CONCEPT OF DISABILITY

According to a major review of uses of terms such as disability, handicap, and impairment, there is a lack of consensus on meanings. However, there is a general sense of agreement on what the terms, taken collectively, have as their referent (Urban Institute, 1975). There also is disagreement about what is meant by the various degrees of a condition (e.g., what "severely disabled" means). Again, these disagreements tend to vanish when dealing with extreme, hence obvious, cases. These definitional problems stem from the different uses of these terms, with medical and scientific usage at one extreme and policy-related usage associated with program administration or service delivery, for example, at the other. Moreover, some meanings narrowly focus on limited use of extremities and sensory deficits as disabilities. Other meanings encompass developmental disabilities, emotional disabilities, and medical conditions, such as severe heart conditions, which can be more incapacitating and restricting than blindness or paraplegia. Last, people differ in their response to medical conditions and traumas and in their ability to cope. These differences also affect how terms like disability are applied.

What, then, are reasonable uses for terms like disability and handicap? The thoughtful analysis of the Urban Institute (1975, pp. 21-38) offers the following suggestions:

> The residual limitation resulting from congenital defect, disease, or injury [should be called] an <u>impairment</u>. A person with an impairment, then, may or may not have a <u>disability</u>, an inability to perform some key life functions [particularly roles related to work]. When the ability is such that the environment imposes impediments to the individual's goals for travel or work, for example, the individual has a <u>handicap</u> (p. 25).

The Urban Institute's report indicates that these definitions create problems for analyses of existing data on the disabled because most surveys limit the definition of disability to whether the respondent's condition limits the kind or amount of work the person can do. Using a work criterion means that the retired elderly, for example, regardless of their physical status would not be counted among the disabled, hence among the handicapped.

It is the view of the Urban Institute's report that an impairment is a necessary but not a sufficient condition for a disability. Thus, the use of diagnostic labels such as paraplegia, blindness, and epilepsy as proxies for the terms disability and handicap is conceptually objectionable because "people with some kinds of disability are better equipped than others to tackle the trials of life" (Goldsmith, 1967, p. 43).

As reasonable as the proposed definitions are, they still raise a problem. Handicaps may be based on inabilities that are not rooted in a congenital defect, disease, or injury. The young or elderly ambulatory person may encounter environmental barriers to access because of their age and physical development. So long as the capabilities of the able-bodied adult serve as the implicit standard for designing environments, others who do not match this standard are likely to be stigmatized with the label "handicapped". It would be preferable to recognize and accept changing capabilities across the stages in human development. Moreover, since people infer handicaps from failures to master environmental obstacles, it could just as easily be said that environments handicap people rather than that people have handicaps. This view does not deny the variability in human capabilities. Rather, it would stigmatize settings for imposing their limitations on their users.

2.2 DISABILITY VERSUS FUNCTIONAL CAPACITY AS AN INDEX OF HUMAN PERFORMANCE

Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell (1979) favor the use of functional ability as the basis for discussing environmental barriers. They state the case clearly.

> Environmental barriers have specific impacts upon people with specific limitations to functional abilities. For example, the width of a door is only critical to people who use wheelchairs and walking aids. It does not affect use of a building by a person with severe impairments of vision. Thus, each barrier-free design feature may, in fact, have a different beneficiary population (Steinfeld et al., 1979, p. 27).

There are several advantages to emphasizing functional ability or capacity. First, the phrase emphasizes what _is_ whereas disability, limitation, and handicap emphasize what _isn't_ or what _was_. Second, it has a broad scope since it applies to conditions such as extremes of size and weight which are not necessarily rooted in defects, disease, or injury. Third, it is applicable to the able-bodied and to acute conditions, such as a broken leg, that can have consequences for the use of the environment. Fourth, as Steinfeld et al. argue, functional capacity is likely to be more closely linked with how and how well the individual actually uses the environment than are diagnostic categories, which are the current emphasis. This does not mean that there will be a direct correspondence between functional capacity and performance. Performance can be affected by other factors such as the individual's motivation, training and other available services, family support, environmental setting, and the like (Jeffreys, Millard, Hyman, and Warren, 1969).

Functional capacity is what Jones (1978) meant when he noted that the able-bodied adult of average height, weight, hearing, eyesight, stamina, coordination, and reaction time is the standard used for designing environments and those not sharing these characteristics and capabilities are, by definition, handicapped.

In any event, if functional capacity (or functional limitation, a synonym), whatever its basis or duration, is used as the indicator of or criterion for assessing handicaps, these functional capacities must be identifiable, measurable, and have established contributions to building accessibility (Urban Institute, 1975).

Survey data on people with physical limitations offers an estimate of how many people could profit from user-responsive accessibility standards and regulations. Such data are summarized in the Panel's report (1977, pp. 178-179) and in Steinfeld et al. (1979, pp. 21-42). Readers will find additional information in Brown and Redden (1979) and the Urban Institute report (1975, pp. 56-88). The information in the Urban Institute report tends to be based on diagnostic categories (e.g., cardiovascular disorder, musculoskeletal disorder) and severity of disability rather than on functional limitations.

Appendix 1 has summary tables from the Panel's report (1977, pp. 178-179) and from Steinfeld et al. (1979, pp. 29-30). Steinfeld et al. (1979), addressing the question "Who benefits from accessibility?", have reviewed the available data and have concluded that 2.2 percent to 11.6 percent of the U.S. population has functional limitations. These percentages are based on the noninstitutionalized population. There are no figures specifically for beneficiaries of barrier-free door provisions. Door provisions should result in lower percentages because not all functional limitations affect door use (see Steinfeld et al., 1979, pp. 29, 80).

A comparison of the summary tables in appendix 1 suggests that the number of beneficiaries of barrier-free design would depend on whose survey data is used. For example, the Panel's (1977) report states a much higher incidence of stamina problems (60 million cases, see p. 178) than Steinfeld et al. do (5 million cases, see p. 29). Improved estimates will require a survey that uses measures of functional capacity in a manner that provides complete statistics on who would benefit from the removal of a class of environmental barriers (Steinfeld et al., 1979, p. 27).

2.3 THE IDENTIFICATION AND MEASUREMENT OF FUNCTIONAL CAPACITY

The relationship between functional capacity and the performance of door users was systematically studied by Steinfeld in his research for updating ANSI 117.1 (see, e.g., Steinfeld et al., 1979; Steinfeld, Schroeder, and Bishop, 1979).

2.3.1 The Work of Steinfeld and His Associates on Identifying Functional Capacity

Steinfeld et al. (1979) have identified 14 characteristics of individuals that are particularly important for using the physical environment. They are listed and defined in table 1 and are presented diagrammatically as a

Table 1. A List of Functional Limitations and Definitions That Are Particularly Important for Using the Physical Environment:

A. Difficulty in Interpreting Information - individuals who have impaired abilities to read or reason and/or who have limited abilities to interpret complex information.
B. Severe Loss of Sight - individuals who cannot read ordinary newspaper print with eye glasses, who have legal blindness (20/200), or vision field defect of 10 percent or less.
C. Severe Loss of Hearing - individuals who cannot understand usable speech with or without amplification.
D. Prevalence of Fainting, Dizziness or Poor Balance - e.g., individuals with Meniere's disease, hemiplegia, etc.
E. Incoordination - individuals who have difficulty in controlling and placing or directing their extremities, e.g., those with cerebral palsy or other neurological disorders.
F. Limitations of Stamina - individuals who become short of breath and/or experience an abnormal elevation in blood pressure from physical exertion, e.g., those with cardiopulmonary disorders or severe hypertension.
G. Difficulty in Moving Head - individuals limited in looking up and down or side to side.
H. Difficulty in Lifting and Reaching with Arms - individuals with decreased range of motion and strength of upper extremities.
I. Difficulty in Handling or Fingering - individuals who have difficulty performing functional activities with hands, e.g., one who has severe arthritis or fixed contractures from an injury such as a third-degree burn.
J. Inability to Perform Upper Extremity Skills - individuals with complete paralysis, lack of coordination or absence of upper extremities.
K. Difficulty in Bending, Turning Sitting or Kneeling - e.g., individuals with severe arthritis of the spine or those in back braces and plaster body casts.
L. Reliance on Walking Aids - individuals who use leg braces or artificial legs and those who need crutches, canes or walkers.
M. Inability to Use Lower Extremities - individuals who are unable to move about except by use of a wheelchair.
N. Extremes of Size and Weight - individuals who are extremely tall, extremely short or extremely overweight.

Source: Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, pp. 27-28.

schematic figure of a person called The Enabler (see figure 1). The characteristics include cognitive or mental functioning (difficulty in interpreting information), the senses (sight and hearing), "internal" regulation (balance, coordination, stamina), motor abilities (e.g., head, arm, hand, finger, and leg movement), and bodily dimensions (size and weight).

Using the Enabler, Steinfeld et al. (1979) analyzed building and site elements to determine environmental conditions that have an impact on access and use for people. Then, Steinfeld and his colleagues determined the contribution of each characteristic of the Enabler to access to and use of the identified elements. They also indicated the severity of the problem that might arise from each characteristic, but without specifying the Enabler's level of functional capacity. The resulting evaluations are called Problem Identification Matrices. Two, dealing with door use, appear as figures 2 and 3. They focus on doors and on hardware.

2.3.1.1 <u>Advantages and Limitations to This Approach</u>

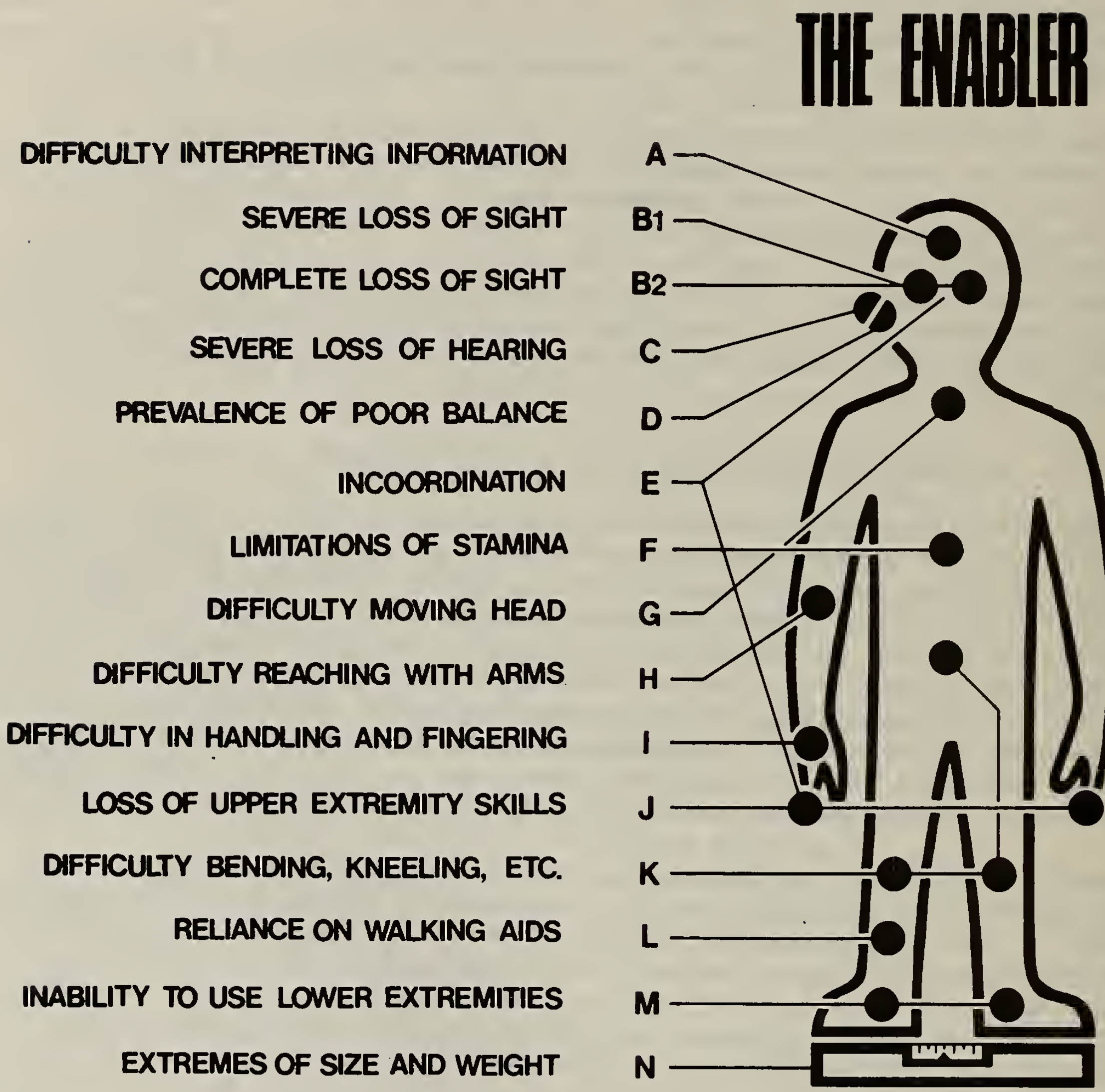
Among the principal advantages are the following three. First, it demonstrates the nature and pervasiveness of the impact of an incapacity on accessibility. This can raise the consciousness of uninformed individuals. Second, it ties specific functional characteristics to accessibility and use. This approach satisfies two of the three criteria posed by the Urban Institute (1975) for using functional limitations as indicators for assessing handicap. These two criteria are identifying the functional capacity and establishing its contribution to the handicap. The third criterion, measurement, is discussed below. Last, Steinfeld et al.'s approach encourages an analysis of accessibility conflicts between people with different functional limitations (see table 2).

There are also several limitations to the approach. For example, the procedures that Steinfeld and his associates employed for generating the list of functional characteristics and determining their contribution to accessibility and use do not appear in Steinfeld et al. (1979). The analysis could have been an empirical or a logical analysis. If it was a logical analysis, it may or may not have received independent (outside, expert) confirmation of the contribution of each characteristic to the use of environmental elements. Whatever may have been the procedure, the approach is useful and the examples are reasonable. In addition, the level of functional capacity is a determinant of the impact of a particular environmental element on access and use. However, as noted above, the matrices do not address the level of functional capacity. Moreover, the matrices do not take explicit account of multiple functional limitations and their joint impact on a person's performance.

2.3.2 Steinfeld's Diagnostic Interview for Measuring Functional Capacity

Accepting the Problem Identification Matrices, the issue of measuring, in contrast to identifying, functional capacity remains. A Diagnostic Interview, designed for self-report, was developed to assess functional capacity (Steinfeld, Schroeder, and Bishop, 1979, p. 6). The Diagnostic Interview

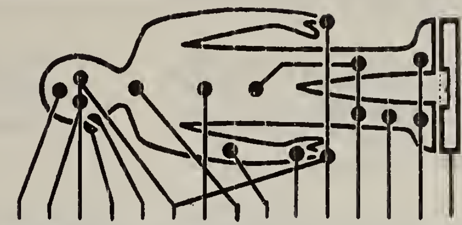
Figure 1. The Enabler



Source: Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, p. 75.

Figure 2. Problem Identification Matrix

- • potential problem
- o problem
- O severe problem
- ● impossibility

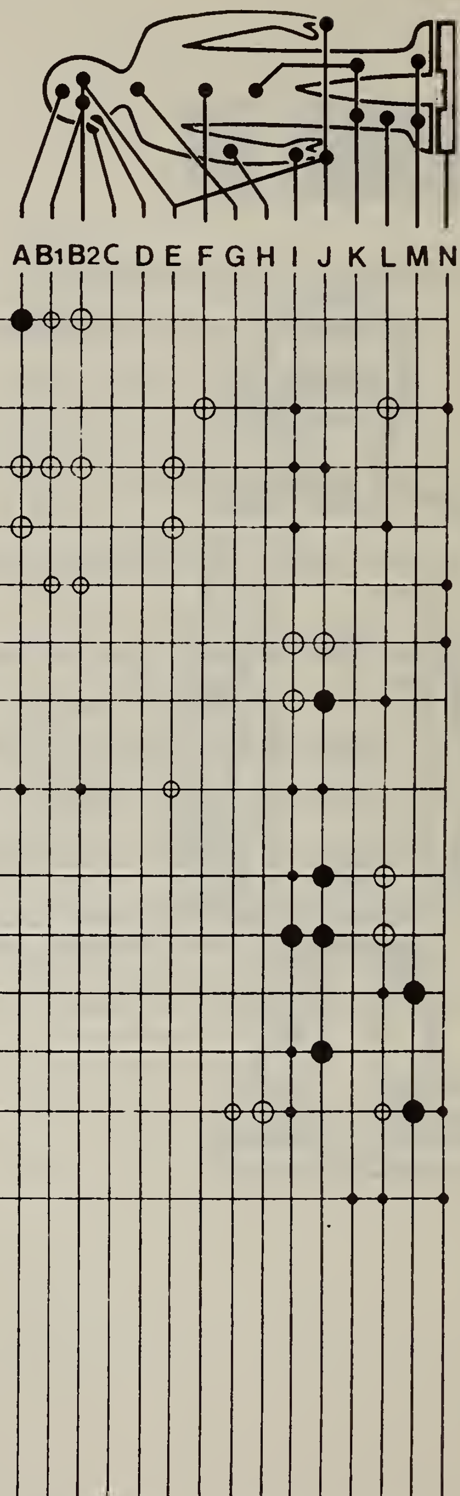


Entrances, Exits and Doorways	A	B1	B2	C	D	E	F	G	H	I	J	K	L	M	N
1. Extremely narrow door openings													●	●	•
2. High thresholds or stairs at entrance/exit		O	O		O	O		•					O	●	
3. Not enough maneuvering space in front of doors													O	●	•
4. Door swings that partially obstruct use													•	●	•
5. No level space in front of entry doors													O	O	
6. Directions unclear or poorly marked	O	O	O				•						•	•	•
7. Illogical opening procedure	●	•	O			O									
8. Great force needed to open doors					O	O	O		O		●		O	O	•
9. Stairs in path of travel to an emergency exit or place of refuge		•	•										O	●	
10. Revolving doors on turnstiles		o	o										●	●	

Source: Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, p. 82.

Figure 3. Problem Identification Matrix

- • potential problem
- ○ problem
- ◯ severe problem
- ● impossibility



Controls and Operable Hardware*

1. Counter-intuitive means of activation
2. High force of activation
3. Ultra-sensitive activation
4. Fine motor control required to use
5. Very small size
6. Very large size
7. Activation requires turning motion of wrist
8. Use requires complex manipulation (more than a single movement)
9. Use requires two hands
10. Use requires hands
11. Use requires feet
12. Use requires fingers
13. Controls and hardware located in very high position
14. Controls and hardware located in very low position

*Includes controls and hardware on appliances and fixtures.

Source: Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, p. 90.

Table 2. Accessibility Conflicts and Recommended Solutions

Condition	Conflict	Recommended Solution
1. Curbs at intersections	Elimination of curbs is helpful for wheelchair users but is dangerous to blind people.	Provide a texture change for the curb to define the edge of the street.
2. Warning signals	Visual signals are good for deaf people, but cannot be seen by blind people; audio signals are good for blind people, but cannot be heard by deaf people.	Use both visual and audio modes for warning signals.
3. Controls and hardware	Hand operated controls and hardware are good for wheelchair and walking aid users, but cannot be used by people who have no use of hands.	Sometimes both hand and foot/leg controls or hardware can be used; in other cases only hand controls can be provided (e.g., window or door locks) and this problem can only be solved by electronic means.
4. Control heights	Low heights are good for wheelchair users and people who cannot reach very high, but are a potential problem for very tall people and those who cannot bend easily.	Use compromise height.
5. Height of work surfaces	Low work surfaces are good for people who sit while working but a severe problem for those who stand and have difficulty bending.	Use adjustable or adaptable heights in residences and work places or alternate heights in public places.
6. Overhanging objects	Good way to provide access to equipment for wheelchair users, but dangerous to blind people if the object projects into a circulation area.	Keep objects out of circulation paths.
7. Grab bar mounting height	Low heights help people without use of legs to have leverage while transferring; people who use walking aids, have poor balance or bending and stamina problems use high bars to pull themselves up.	Use compromise height in public facilities and provide alternate heights in residential locations.

Source: Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, p. 94.

addressed many of the functional capacities in table 1, often in terms of mastering daily activities (e.g., "Can you fasten buttons?"). It was used to select volunteers for the research project to revise ANSI 117.1-1961 and specifically to "find people within each [disability] category that reflected a range of functional abilities" (p. 6).

The Diagnostic Interview yields "valid indications of functional ability" (Steinfeld, Schroeder, and Bishop, 1979, p. 6). Also, it yields accurate reports. Specifically, answers to the interview by 20 respondents over the telephone accurately reflected their actual condition, as determined by a subsequent visit to the respondents' homes by a physical therapist. However, a comparison of self-reports with performance measures of functional capacities taken in the laboratory by Steinfeld and his associates, often a month or longer after the interview, indicated that some volunteers inaccurately judged certain abilities and that some volunteers had experienced an improvement or deterioration in their physical status. In all, approximately 25 percent of the volunteers demonstrated discrepancies between self-reports and performance. The two areas of self-report that had the weakest predictive validity were difficulty reaching and lifting and limitations of stamina (Steinfeld, Schroeder, and Bishop, 1979, p. 8). Last, Steinfeld, Schroeder, and Bishop (1979) do not report how the Diagnostic Interview was scored in order to establish the functional ability level or functional ability profile of a person or what these level were for each disability category (see Steinfeld, Schroeder, and Bishop, 1979, p. 9). Different levels were meant to represent decreasing degrees of independence in daily activity, ending with the lowest level that would allow such independence (Steinfeld, Schroeder, and Bishop, 1979, p. 6). The authors do not report what the different degrees of independence are.

2.3.3 Other Measures of Functional Capacity

Steinfeld included static and dynamic anthropometric measurement procedures as part of his research. These procedures can be used in conjunction with an instrument like the Diagnostic Interview or in lieu of it to establish levels of functional capacity. Such use requires having or developing anthropometric measurement procedures that do what they claim to do <u>and</u> also are relevant to building use. Whether such procedures are currently available is a matter of debate. Developing them is a difficult, expensive, time-consuming task.

An obvious source of other measures of functional capacity would be other studies of building accessibility in which the functional capacities of volunteers were assessed. However, only one other study was located which relied on anthropometric measurements (Johnson, 1979). It is discussed in section 2.4.4.

Another obvious source is the medical, rehabilitation, and service delivery literatures. These should be reviewed systematically to determine if instruments, in addition to the Diagnostic Interview, have been developed. An initial search suggests that such instruments have been developed (e.g., Jeffreys, Millard, Hyman, and Warren, 1969). There remains the task of assessing the technical adequacy of the instruments, particularly with regard to building access, egress, and use as criteria.

2.3.4 Ergonomic Measurement

Two basic assumptions underlie ergonomic measurement and data.

(1) People vary in their physical characteristics. The physical characteristics of individuals change over the years (cf. the child with the adult). Individuals also differ from one another. Often these differences are associated with group membership, such as size and weight differences between males and females. There appear to be differences across generations. Generational differences can affect the future applicability of current anthropometric data. There also are sources of variability in daily life including day-to-day fluctuations in height and weight and the effects of clothing on body size and joint movement (Annis, 1978).

(2) The measurement of the human body encompasses a variety of procedures for determining an almost limitless number of human characteristics. There seems to be a lack of consensus, worldwide, on measurement procedures. In some cases procedural differences result in measurement differences greater than what can be attributed to measurement error (McConville and Laubach, 1978). Moreover, procedures must be carefully chosen to fit the problem. Thus, if building accessibility is the interest, then the measured characteristics must be relevant to accessibility. For example, Johnson (1979) reports a near zero correlation between static measures of strength and successful door performance. This suggests that his particular static test does not measure a functional capacity of individuals relevant to this aspect of building use.

Ergonomic data permit you to compare specific individuals with appropriate reference populations for whom there are ergonomic measurements. Also, you can determine the percentage of a population falling at, between, or below certain values on a measured characteristic. For example, a sitting height of 35.8 in (90.9 cm) includes at least 95 percent of the 5,800 military fliers on whom this measurement was made (McConville and Laubach, 1978, p. III-20).

Steinfeld et al. (1979, pp. 102-122) review the available ergonomic literature. Their review covers functional anthropometry or the measurement of physical features of the body. Size and reach are examples of static anthropometry; range of movement, accuracy of motion, and speed of response, reaction, or limb movement are examples of dynamic anthropometry. It also covers strength and endurance which are examples of biomechanics. [This categorization differs from that of Steinfeld et al. (1979).] Detailed ergonomic data can be found in Hertzberg (1972), Jones and Fechter (1980), and Webb Associates (1978a). Body size and reach data also can be found in Webb Associates (1978b) and Diffrient, Tilley, and Badagjy (1974).

Erogonomic data are based on able-bodied adults, by and large. Applications of ergonomic data to disabled groups are found in the Panel's report (1977, pp. 141-180) and in Jones (1978, pp. 7-31). The Panel's (1977) report also includes data on environmental features affecting the disabled. These data, for example on door spring force, are usually based on user considerations. Steinfeld et al. (1979) review additional sources of ergonomic data (see pp. 102-122).

The usefulness of anthropometric data on joint motion, muscular strength, velocity of limb movement, and response time based on able-bodied persons for problems of disabled groups generally is assumed. This assumption must be critically evaluated. It must be determined whether the procedures used to measure able-bodied groups are appropriate for disabled groups and whether the data for able-bodied people, based on these procedures, can be generalized to disabled populations.

Steinfeld et al. (1979) discuss another aspect of generalizing ergonomic data. They point out that most ergonomic measurement was not done with building use in mind. However, to the extent that negotiating the built environment is a task with features in common with tasks that have been well studied by human factors psychologists, they believe that the resulting data can be transferred across tasks.

Based on their review, Steinfeld et al. cite seven limitations of available ergonomic data.

1. There is a lack of comprehensive dynamic anthropometric research.

2. There are little data on people over 50 years old, women, and disabled people but there are increasing data on children.

3. Some data, such as size measurements, may be out of date. However, correction factors make this a less serious problem than it might otherwise be.

4. Few data have been taken during actual activities of the kind useful to building designers and building component manufacturers.

5. Most of the data have been gathered using posed body positions. The representativeness of this data for situations involving natural body movements has not been determined. Lack of representativeness would be a serious problem.

   The usefulness of other data bases, such as speed of movement and strength, is limited because of the nature of the tasks that were studied when able-bodied users were measured (see Steinfeld et al., 1979, pp. 109-111).

6. The data are not comprehensive on the effects of encumbrances, prosthetic devices, etc.

7. There are few studies that compare different disabled groups or disabled with able-bodied groups.

According to Steinfeld et al. (1979, p. 106), "focusing specifically on anthropometric data for people with disabilities, there is not a definitive study." Available data tend to focus on wheelchair users. Often these data are no more than generalizations from data on able-bodied persons. Too many studies do not include descriptions of research procedures or sampling, thereby undercutting an opportunity to critically evaluate the quality of the data. Nevertheless, some studies of actual human performance have provided useful information for building design guidelines (e.g., best dimensions for a door).

Steinfeld et al. (1979, pp. 120-122) also note methodological shortcomings of ergonomic measurement and they suggest ways of overcoming them. They recommend testing in the field or accurate simulations of real-world tasks and environments in contrast to overreliance on laboratory-based research. They also recommend representative selection of volunteers, but only when this is necessary.[5]

As for which functional capacities are relevant to door use and, therefore, are appropriate for ergonomic measurement, suggestions are found in Jones (1978) and Steinfeld et al. (1979). Jones (1978), for example, notes the importance of end-positions of the hand for door use. These end-positions are (1) power grip, for grasping a door handle, (2) precision grip, for grasping a key, and (3) open hand, for pushing on the face of a hinged door. (Twisting skills could be added to this list.) These manipulative abilities determine whether door use will be easy, difficult, or impossible (Jones, 1978, p. 19). Steinfeld et al. (1979) discuss information needs in designing accessible buildings. These needs are stated in terms of environmental factors, such as force of activation (see p. 103), which have user counterparts in muscular strength, joint movement, and stamina. Thus, an analysis of information needs in terms of user counterparts could guide the evaluation of available ergonomic data and, by implication, the determination of needed ergonomic data.

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[5] For example, in determining a lower limit, such as a minimum width for an opening, the researcher may only have to test the widest users and the widest mobility aids expected in a building. It may not be necessary to test a representative sample of users.

2.4 PATTERNS OF DOOR USE

Door use refers here to gross body movement patterns people use in unlocking, unlatching, opening, passing through, and closing doors. Social and psychological factors that can impact on door use could be added. One well-studied social factor is the effect of the presence or absence of an audience on an individual's motor performance. Researchers are currently trying to establish the most adequate explanation of this effect (see the reviews by Geen and Gange, 1977; Landers and McCullagh, 1976; and Marten, 1974). Another social factor is the presence and assistance of a personal aide. Psychological factors include expectations about the difficulty of opening a door which, in turn, may derive from inferences about the door based on the door's appearance (e.g., the massiveness of the door).

Patterns of door use can be viewed from two perspectives: ideal patterns and actual patterns. Both perspectives acknowledge the actual functional capacities of the individual as well as the age and rehabilitation training of the person. Ideal patterns are based on expert judgment and include patterns of use which rehabilitation specialists recommend and teach to their clients. Presumably, there is a better or best way for a person to use their functional capacities in order to open a particular door. Actual patterns refer to what people actually do when using a door.

The principal questions about door use patterns are whether the ideal and actual use patterns are comparable and, if these are different, why this is the case and what can be done about it? Brown and Redden (1979) offer two possible reasons for noncomparability. The use patterns that the disabled are being taught may "not fit their individual needs [or, perhaps,] the person has not been taught well how to use [them]" (Brown and Redden, 1979, p. 2). In this regard, to establish ideal use patterns, the ergonomic implications of actual use patterns, in terms of body position, reach, stamina, strength, etc., must be understood. What are the forces a person generates using his or her body in a particular way? Can a different pattern generate higher forces more easily for the person?

Little attention has been paid by researchers to actual door use patterns. Only four studies involving door use patterns were located (Cohn, 1978; Johnson, 1979; the NBS door safety study; Seaton, 1979).[6] Two focus on

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[6] Byron Johnson's study was conducted for the National Research Council of Canada. I wish to thank Mr. Johnson and the National Research Council of Canada for permission to cite the unpublished reports of Johnson, Seaton, and Cotton and Dainty (see section 2.4.4). The reports by Seaton and by Cotton and Dainty were done under contracts from the National Research Council of Canada. They are available from the Canadian Institute of Scientific and Technical Information. A published version of Mr. Johnson's report under the title "Door Use Study" is forthcoming. The NBS door safety study is unpublished. Inquiries about it may be addressed to the author.

building accessibility (Johnson's and Seaton's). The other studies are concerned either with physical security, specifically with emergency exiting from secure spaces (Cohn, 1978), or with user safety (the NBS door safety study).

2.4.1 The NBS Door Safety Study

As part of a door safety project, door use was videotaped. The aim of this videotape study was to capture and analyze actual use and misuse of doors as these occurred under typical conditions of use in a variety of settings.

Eight hours of videotape of door use was collected. Users were ostensibly able-bodied adults and children. Doors in six different settings across five sites were studied. The five sites were a shopping center, a university medical center, a university student union, a university-based preschool, and other university buildings. Presumably, different door sites had different user groups.

Videotaping was employed because, like filming, it is a useful method of data collection for behavioral data. It can record naturally occurring behavior unobtrusively. Moreover, having a videotaped record permits a detailed examination of recorded activities, including an estimation of the proportion of all recorded events involving a designated critical event.

The NBS analysis of the videotape focused on what were called misuse patterns and behavior patterns. The misuse patterns are observed actions thought to be closely linked to factors that a previous analysis of Consumer Product Safety Commission (CPSC) in-depth accident reports suggested caused or contributed to door-related accidents. The behavior patterns are observed actions that indicate a door is inconvenient or even difficult to operate due to a poor fit between user and door characteristics. A model of door and stair accidents by Johnson, Archea, and Steel (1975) determined which behavior patterns to expect.

The study of behavior patterns may have applicability to user aspects of accessibility. Examples of behavior patterns include leaning toward or away from a door while opening or holding it, using both hands in the process of opening or holding a door, bumping or crowding another while going through a doorway, pushing or pulling a door handle the wrong way, and touching a door at least one time after initially touching or contacting a door.

The behavior pattern of leaning toward or away from a door while opening or holding it will be used to illustrate the potential applicability of the concept of behavior patterns to accessibility. In its study of door safety, the NBS researchers reasoned that this pattern resulted from a poor fit between the physical strength of the user and the force required to open the door. Consistent with this, the group most likely to lean were preschoolers using the metal door to their classroom. Thirty-five percent of the preschoolers (N=40) leaned compared with an average of six percent of the other 280 users at the other six door sites. Preschoolers are both smaller in size and lighter in weight than adults. Put differently, preschoolers are an example of an extreme size and weight group, a category in Steinfeld et al.'s ideogram of functional limitations. Thus, a behavior pattern analysis may provide a basis for describing how people with different functional capacities manage potential environmental barriers. This supports the contention that analyzing behavior patterns as part of a study of door use patterns of disabled persons could be valuable.

2.4.2 Cohn's (1978) Study of Emergency Exiting from Secure Spaces

As part of a study of emergency exiting from secure areas, Cohn did a logical analysis, it appears, of the operations a user had to go through to use locks and latches. He found that, depending on the hardware, more than one step might be required (see table 3). With certain multi-step procedures, more than one movement will be required (see section 3.1.2). Cohn's analysis of hardware use coupled with the Jones's (1978) analysis of hand end-positions and the analysis of functional limitations of users by Steinfeld et al. (1979, esp. ch. 5) could provide a foundation for subsequent analyses of lock and latch use.

2.4.3 Seaton's (1979) Study of the Manual Operation of Doors

Seaton studied door use and errors in door use on a university campus. Functional capacity and disability were not studied. Events were recorded by observers as they occurred; they were not videotaped or filmed.

Seaton (1979, p. 7) reports that over 60 percent (483 of 802 persons) used their right hand to open a door, which is not surprising since most people are right-handed. By comparison, less than 10 percent used either both arms (4.9 percent or 39 of 802 persons) or their shoulders (4.7 percent or 38 of 802 persons) to open doors. Those who used both hands tended to be unencumbered (72 percent or 28 of 39 carried nothing) and those who used their shoulders most often had both hands encumbered (45 percent or 17 of 38 had both hands encumbered). Seaton seems to indicate that the unencumbered individuals may have been older (see Seaton, 1979, p. 7). In regard to age, Cohn (1978) reports that anthropometric norms for older persons (over age 50 years) may be two-thirds of the value for younger males. This study suggests that certain behavior patterns indicate how environmental barriers are managed by people with temporary limitations, such as encumbrances, or age-related limitations.

2.4.4 Johnson's (1979) Study of Door Use

Byron Johnson, of the National Research Council of Canada, undertook an extensive study of door use. The study addressed three aspects of door use: unlatching and pushing open the door, passing through the door, and closing the door when needed. Volunteers were studied in a laboratory setting (much as Steinfeld and his associates did). Emphasis was placed on opening resistance caused by door closers and air pressure differentials. There were 4 volunteer groups totalling 24 individuals with varying but unspecified physical abilities: a minor or no disability group, children (under age 13 years), and 2 disability groups (see Johnson, 1979, p. 10). The use of one door

Table 3. Number of Steps in the Opening of Doors

Description	No. of Steps	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
No lock or latch	1	push/pull					
Panic hardware	1	push(inside)					
Electric opening	1	step on mat					
Electric opening	1	press button					
Electric opening	1	insert magnetic card					
Latch or deadbolt	2	turn knob	push/pull				
Latch only	2	depress handle	push/pull				
Latch only	2	depress thumb latch	push/pull				
Deadbolt only	2	slide bolt	push/pull				
Deadbolt and panic hardware	2	slide bolt	push(inside)				
Barrier bar and panic hardware	2	remove bar	push(inside)				
Electric latch	2	press button	push/pull				
Remote electric latch	2	telephone guard	push/pull				
Electric latch	2	punch code	push/pull				
Electric latch	2	insert magnetic card	push/pull				
Emergency release	3[a]	break glass	turn lever	push/pull			
Deadbolt and latch	3	turn/slide deadbolt	turn knob	push/pull			
Barricade bar and latch	3	remove bar	turn knob	push/pull			
Deadbolt or latch	3	insert key	turn key	push/pull			
High-security	3	insert magnetic card	punch code	push/pull			
Deadbolt or latch	4	insert key	turn knob	push/pull			
Key in break-glass box	6[a]	break glass	remove key	insert key	turn key	turn knob	push/pull

[a] Cohn classifies breaking glass as one step; it can also be conceived as one step in a multi-step activity.

under varying air pressure differentials was videotaped. Three other doors were mounted with closers. The use of one of these three doors was filmed, and a force platform was used to measure triaxial ground reaction forces while volunteers opened the other two (Cotton and Dainty, 1978). The 16 mm film was used to measure behavior patterns and other use patterns (Johnson, 1979, p. 12). A control group of 17 able-bodied individuals from a local university, most of whom were staff members in the physical education department, took part in ergonomic testing of door hardware (Johnson, 1979, p. 20).

Johnson studied the relationship between door use patterns and success at opening and keeping open doors. He noted, for example, that depending on a person's functional capacities, force could be generated by walking (forward movement), angular momentum (while moving), leaning (assuming the person can balance), or from pushing or pulling with shoulders and hands. His volunteers were usually successful at opening the doors and often against higher opening resistances than Steinfeld, Schroeder, and Bishop's (1979) volunteers. However, it appears that Johnson's volunteers were more functionally capable than Steinfeld's volunteers. Moreover, Johnson's volunteers, unlike Steinfeld's, treated the testing as a challenge and "their performance was very similar to what it might have been in an emergency situation" (p. 10; emphasis added). It is necessary to limit comparisons of the subject populations of Johnson's and Steinfeld's studies because neither report (Johnson, 1979; Steinfeld, Schroeder, and Bishop, 1979) precisely states the functional capacities of their samples or subsamples. This points to a need for developing and using technically adequate and comparable measures of functional capacity in accessibility studies of disabled groups so that their results can be compared and accumulated.

Last, Johnson (1979, pp. 25-27) presents a preliminary model to predict the difficulty of door use for a user. His aim is to develop a model that has a few, easy-to-measure variables that will predict door use successfully. His current model includes four variables: maximum (static) push, the person's weight, the person's height, and the cosine of the shoulder angle which is Johnson's indicator of angular velocity.[7] These correlated +0.49 with force at failure, his performance measure. Note that this model includes three anthropometric measures (push, weight, and height). Shoulder angle is a door use variable which, like a behavior pattern, describes how people with different functional capacities manage potential environmental barriers.

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[7] Johnson (personal communication, August 1979) describes the shoulder angle as the angle whose sides are a horizontal line passing through the ankle and a line connecting the shoulder to the ankle. Johnson (1979) does not discuss the applicability of this model to wheelchair users. The proper models for hand-operated and powered wheelchair users are not patently obvious. The question, then, is what the proper models will be for wheelchair users and whether they will be comparable with models, such as Johnson's, for standing (ambulatory) door users.

In all, Johnson's study illustrates the importance of considering patterns of door use. In personal conversation (September 1979), he notes that work has to be done to determine which aspects of door use contribute significantly to successful passage and to determine the proper techniques for observing and measuring these aspects.

2.5 THE DOOR USER: SUMMARY AND CONCLUSIONS

The concept of disability and related concepts like impairment and handicap lack consensus of meaning. In part, this is because some definitions reflect regulatory in contrast to scientific requirements. One view defines impairment as residual limitations, disability as impairments resulting in inability to perform key life roles, and handicaps as environmentally-imposed impediments resulting from impairments. However, even these relatively reasonable definitions raise conceptual problems. One can argue for limitations which are not residuals of injury, illness, or trauma. Functional limitations (or, stated positively, functional capacities) are likely to be better indicators of human performance than disabilities are because functional capacities are direct antecedents of performance. Disabilities, by comparison, are indirect indicators of functional capacities. However, to make an approach based on functional capacities workable, they must be identifiable, measurable, and have established contributions to building accessibility.

Although functional capacities relevant to building accessibility have been identified generally, they must be more precisely specified and improved ergonomic measurement procedures for them are needed. In the absence of meeting these goals, the evaluation of specific research studies and the comparison of studies on building accessibility by people with functional limitations will be undermined. This will result in conflict and confusion about what is, in fact, the case. As for available ergonomic data, it is usually based on able-bodied adults and often in relation to tasks other than building accessibility. Questions have been raised about the generalizability of results from able-bodied subjects to disabled subjects. However, a case has been made for generalization of results across tasks with essential features in common. If building accessibility is a task which shares characteristics with other well-studied tasks, then results from those studies should be applicable to building accessibility, other factors equal. Nevertheless, the available ergonomic data, overall, are not fully suited for understanding accessibility by disabled people.

Assuming functional capacities can be identified and measured, then their contributions to building accessibility would be determined, in part, by how the abilities were actually employed. This is the topic of patterns of door use. It is clear that these patterns vary. The questions, then, become (1) which patterns, for given groups and given types of doors, are the most effective, (2) are they being used, and (3) if not, why not? It is assumed that if ideal patterns were known, they could be taught as part of rehabilitation training.

3. THE DOOR SYSTEM

The physical forms of buildings and their components, such as the door system, derive from custom, regulations, research, and the creativity of designers. These forms also reflect the multiple functions that a building component may serve. Because functions may be in conflict (see section 1), research that could affect the performance of door system components should take explicit account of the multiple functions served by the door components.

This section will address three components of the door system as they relate to handicapped users: the locking and latching components, door openers, and door closers. Each component raises questions about the adequacy of current standards governing accessibility. Each has engineering and behavioral implications.

3.1 THE LOCKING AND LATCHING COMPONENTS

There are two approaches to the handicapped and their use of locking and latching components. One emphasizes adaptive solutions such as the use of adaptive devices by the handicapped. The other emphasizes product designs that meet the needs of users which is the emphasis in this section. Adaptation is a reasonable approach. However, some situations make adaptation difficult. For example, Prof. K. Mallik, a rehabilitation specialist (personal communication, July 1979) describes the problem of disabled travelers. They find a variety of locks and keys at motels and hotels. Keys tend to have plastic identifiers to assure their return. However, these identifiers often make it difficult to use conventional key extenders. Furthermore, there is currently no key adaptor which can be used across motels and hotels. In addition, many motel and hotel doors tend to automatically lock when closed, increasing the potential for room key use.

3.1.1 Door Handles

There are different types of door handles such as door knobs and push plates. Although strongly held preferences for particular types of handles are common, often based on personal experience or observation, there is little systematic research on door handles. In one recently completed study on this topic there were no differences between different types of handles in their effectiveness (Johnson, 1979). Johnson used 24 disabled people to compare a lever, a knob, a pull bar, and a push plate. Although levers allowed greater strength to be exerted than knobs, as advocates of levers have been suggesting, volunteers who were able to effectively use the lever also effectively used a knob. Thus, based on force alone, levers are not essential to accessibility. Moreover, the force levels generated by Johnson's disabled volunteers easily exceeded the levels required by the door handles that Cohn (1978) measured in his field study of door components. Johnson also found, contrary to expectation, that the pushing and pulling maxima for his 24 disabled volunteers did not differ. There were two additional comparisons. The 24 volunteers used a panic bar and a paddle-type unlatching device to unlatch a door and a knob and a handle to close a door. All 24 volunteers apparently were used in both comparisons (see Johnson, 1979, pp. 23, 24). The results did not favor one type of door handle over the other in either comparison. Based on this finding and other considerations, Johnson recommends the paddle-type unlatching device to unlatch a door. If a door has a knob, Johnson does not recommend the addition of a handle for closing a door (Johnson, 1979, pp. 19-24). Like Lipchez and Winslow (1979, p. 61), Johnson believes that although strength can affect the use of hardware, it should not be the sole determinant of the choice of hardware.

3.1.2 Number of Steps

Rehabilitation specialists have complained about forcing the disabled to simultaneously turn a key, work a handle, and push a door. Cohn (1978) analyzed the number of steps required to actuate exit door hardware. The results are in table 3. Cohn notes that some of the multiple step operations are discontinuous. For example, turning a knob and pushing a door may be done without shifting the hand whereas removing a bar and pushing a door will probably require two distinct movements. He goes on to conclude that "the modes of operation requiring more than two steps [see table 3] typically will require the shifting of hands" (p. 4-4). Although Cohn feels such hardware may still be simple to use, the consequences of multiple steps and multiple movements on persons with different functional limitations does not appear to have been addressed in research with the disabled.

3.1.3 Locks

Two characteristics of cylinder locks that can affect individuals with certain functional limitations are key insertion difficulty and key opening force. For example, locks with multiple bolts may require a higher key opening force. A factor that may lower the needed key opening force is the smoothness of the operation of the lock, a factor that is associated with the quality of a lock. A delination of lock characteristics is required in order to determine the contribution of each characteristic to opening resistance and to key insertion difficulty.

An alternative to the keyed mechanical lock, particularly the cylinder lock discussed above, is the electro-mechanical lock, particularly the electronically encoded lock. Electronically encoded locks substitute an encoded card which is read when inserted in a slot or held in front of a sensor for a cut key which is inserted in a cylinder and turned (see table 3). If electronic locks grow in popularity, then their use by persons with functional limitations should be considered. This suggests the need for a determination of the use-related advantages and disadvantages of cylinder and electronic locks of different types for groups with different functional limitations.

In summary, there is preliminary work on handles and apparently no research on locks or latching mechanisms with regard to the functional capacity of disabled users. If one accepts the design alternative as a basis for removing barriers, research on these components will be required.

3.2 DOOR OPENERS

Door openers refer to power-operated and power-assisted devices that replace or supplement user force in the opening of a door. These devices vary in their durability, reliability, and safety features. These sources of product variability do not necessarily create problems for the handicapped. However, if a door opener fails, which is a reliability issue, then there must be back-up procedures to meet the needs of the handicapped user. A failure could be especially serious during an emergency situation requiring egress. An emergency situation itself can create an electrical failure, making power features inoperative, thereby compounding the emergency. Back-up power systems or assurances that the failed doors can be opened by or for handicapped people would solve this problem.

3.2.1 Opening Resistance Under Normal and Emergency Conditions

The current standard for power-operated doors (BHMA 1601-1977) stipulates that sliding and swinging power-operated doors, during a power failure, will be capable of manual opening and panic breakout with a force no greater than 50 lbf (222 N). These values appear to be consistent with the 50 lbf (222 N) limit recommended by the Life Safety Code to fully open exist doors during emergency egress (Sharry, 1978, p. 48). However, a 50 lbf (222 N) maximum may be too high for disabled users. According to Johnson (1979, p. 12), a rapid impact against a door created 36 lbf (160 N) for a wood door and 40 lbf (180 N) for a steel door. In tests with a push plate, the average maximum push force for a sample of 24 disabled persons was 27 lbf (121 N); this group's maximum pull force was 34 lbf (153 N). For a control group of 17 individuals, largely physical education staff from a local university, the forces were correspondingly higher: 45 lbf (201 N) for maximum push and 57 lbf (252 N) for maximum pull (see Johnson's table 5, p. 20). Put differently, for both groups combined, approximately 2 persons in 10 could achieve a maximum push of 45 lbf (200 N) or higher (see Johnson's figure 15). These results suggest that BHMA 1601's 50 lbf (222 N) limit for emergency exiting might not be met by disabled persons with the functional capacities of Johnson's sample, a sample that not only may be more capable than the individuals studied by Steinfeld and his associates (see Steinfeld, Schroeder, and Bishop, 1979, p. 9) but who, according to Johnson, may have been treating his tests as a challenge and and who may have been performing as they would have under emergency conditions (see section 2.4.4 of this report). This comparison underscores the contention, in the preceding paragraph, that there must be provisions for persons with functional limitations who might otherwise face doors whose power has failed, particularly during situations requiring emergency egress.

This discussion underscores the importance of addressing a building element, such as a door system, holistically--that is, with its many functions, such as accessibility and life safety, in mind.

3.3 DOOR CLOSERS

Doors frequently have closers. There are many reasons for having closers on doors. For example, environmental conditions acting on an open door may prevent it from closing; the proper sized closer will overcome this source of resistance and close the door. There is a consequence for the user of having closers on manually operated doors. Closers increase the opening resistance of the door. Specifically, the closing force of a door closer, because of its mechanical inefficiency, is generally 60 to 70 percent of the opening force. Because door closing forces can become a barrier to access, this problem is often the subject of regulation. One approach to regulation has been reducing the closing forces so as to create opening resistances at managable levels. This approach is discussed in section 3.3.1 on door closer forces. Another, often complementary, approach is to slow or delay the action of the closer, thereby giving the user enough time to get through the door. This approach is discussed in section 3.3.2.

3.3.1 Door Closer Forces

This topic raises the most contentious issues involving door hardware. The contentiousness reflects conflicting findings and recommendations which, in turn, reflects problems of measuring and of sampling the disabled. In addition, this topic clearly distinguishes the engineering and behavioral approaches to door closer standards.

An indication of conflict among recommendations comes from an unpublished comparison of 19 standards and codes addressing building accessibility by Mr. Sanford Alder of NBS. A summary of standards and codes that have door opening force requirements appears in table 4. As mentioned above, opening force maxima set an upper limit on door closer forces. For exterior doors, for the codes with quantitative criteria, six codes specify an 8 or 8.5 lbf (36 or 38 N) limit and five codes allow a 15 lbf (67 N) limit. For interior doors, for the codes with quantitative criteria, four codes specify a 5 lbf (22 N) limit, another seven codes specify an 8 lbf (36 N) limit and one code specifies a 15 lbf (67 N) limit. Many factors determine the limits a code will set for door opening resistance, including research on functional capacities of disabled users, the state of door closer technology, the status of measurement methodologies for testing opening resistance, interpretations of what "accessible" means, and the like. The code to be addressed here will be the ANSI 117.1-1979 recommendations (exterior doors: 8.5 lbf or 38 N; interior doors: 5 lbf or 22 N).

Steinfeld and his associates conducted research on which to base their revision of ANSI 117.1-1961. The research included a study of push-pull forces (Steinfeld, Schroeder, and Bishop, 1979, pp. 42-44), the results of which were to be the basis for recommendations for door opening force, and by implication, for door closer performance. For a number of reasons, Steinfeld and his associates decided to use current technology to establish door closer specifications. "Operating forces for opening doors ... should be as low as technology allows..." (Steinfeld, Schroeder, and Bishop, 1979, p. 42). According to Prof. Steinfeld, if the door closer specification had been based

Table 4. Door Opening Forces (Maxima for Hinged, Manually Operated Doors)

	No Quantitative Criterion	8 lbf (36 N)	15 lbf (62 N)
Exterior Doors	3 codes Michigan, Minnesota, North Carolina-New Construction Code These codes tend to require that the door be operable with a single effort, and using one hand.	6 codes ANSI[a]; U.S. Department of Health, Education and Welfare, U.S. Postal Service, New Jersey, Texas; Australia ANSI actually specifies 8.5 lbf (38 N)	5 codes U.S. Department of Defense; Illinois, Massachusetts, New Hampshire, North Carolina-Rehabilitation Code
Interior Doors	3 codes Michigan, Minnesota, North Carolina-New Construction Code Three codes require interior doors to be operable with a single effort.	7 codes U.S. Department of Health, Education and Welfare, General Services Administration, U.S. Postal Service; Illinois, Massachusetts, New Hampshire, New Jersey **5 lbf (22 N)** 4 codes ANSI; U.S. Department of Defense; Texas; Australia	1 code North Carolina-Rehabilitation Code

For this set of criteria, individual codes may have had one or more of the following qualifiers:

1. Whether a self closing feature is part of the door system (interior doors only) (e.g., Massachusetts).
2. Whether the force to retract the latch set is excluded (ANSI specifically excludes this).
3. Whether force applies to push and pull operations (ANSI, U.S. Department of Defense specifically include both).
4. Whether door also must be operable with a single effort and/or with a single arm (see, e.g., U.S. Postal Service, Massachusetts).
5. Statement of where on the door the force is/should be applied (see Illinois).
6. Whether door is on ingress or egress path (see, e.g., Massachusetts).
7. Provision if force is exceeded (see, e.g., Massachusetts, Illinois, New Hampshire).
8. Whether door is hinged (see ANSI).
9. Whether there is a preferred in addition to a maximum force (see U.S. Department of Health, Education and Welfare).

[a] ANSI refers to ANSI 117.1-1979, section 4.13.11.
Codes and standards are listed alphabetically within categories: Consensus standard; federal; state; foreign.

on his ergonomic research, the requirement for exterior doors might have been as low as 5 lbf (22 N), not 8.5 lbf (38 N) (E. Steinfeld, personal communication, February 1980). At this point, it will be useful to summarize Steinfeld's data and compare it to Johnson's (1979) data on push-pull forces in order to highlight the role of methodological differences in the creation of conflicting results.

Steinfeld's instrument for measuring pushing and pulling forces was workable but not sophisticated. There was no opportunity to test the adequacy of the testing rig as a simulation of actual door use (E. Steinfeld, personal communication, February 1980). Two large samples were used: 53 wheelchair users and 108 persons with other disabilities. The latter group included four wheelchair users with "exceptionally good abilities" (Steinfeld, Schroeder, and Bishop, 1979, p. 11: table 1) as well as persons with reaching, standing, handling, and balance problems and also persons using walking aids other than wheelchairs. An additional sample of able-bodied volunteers were tested but their results are not reported in Steinfeld, Schroeder, and Bishop (1979). The results, reported in Steinfeld, Schroeder, and Bishop (1979, p. 44) as percentages of individuals within class intervals (measured in lbf), have been converted into averages in newtons (see table 5A). [This required using the midpoint of each class as the representative value and, for open-ended categories, using a value 2.5 lbf (11 N) below the upper limit or above the lower limit, for whichever limit was given in the original table.] There appear to be consistencies in table 5A across tasks (pushing and pulling with left and right hands) and groups (wheelchair users versus other disabled persons), with average values falling between 11 lbf (50 N) and 14 lbf (64 N). By comparison, Johnson (1979) (see table 5B) reports higher values for pull than for push forces and the averages double those reported by Steinfeld, Schroeder, and Bishop (compare tables 5A and 5B). Differences in testing procedures, testing instruments, and functional capacities of volunteers probably account for these differences.

A comparison of the results for able-bodied groups in tables 5B and 5C underscores the contention that differences among studies may be the reason for conflicting results across studies. Table 5B presents results for the able-bodied adults most of whom were physical education staff at a university. Table 5C presents the results of studies with six-year old males (Brown and Buchanan, 1973) and stewardesses (Reynolds and Allgood, 1975). The results for Johnson's (1979) physical education group approximate the results for six-year old males (Brown and Buchanan, 1973) and is almost half that of stewardesses (Reynolds and Allgood, 1975). A detailed comparison of these studies is difficult. One reason is limitations in the discussion of testing procedures in Johnson (1979). Nevertheless, it is likely that differences in testing instruments and procedures, resulting from different methodological approaches to shared conceptions of strength or from different conceptions of strength, account for these unexpected differences in results.

This discussion implies that as long as researchers do not agree on testing and measurement standards for push-pull strength and on how to measure and sample people with different functional capacities, noncomparability of studies will remain a problem and decisions based on different studies will

Table 5. Push and Pull Strength Testing Results
(In pounds force, and newtons in parentheses)

(A) Based on Steinfeld, Schroeder, and Bishop (1979, p. 44: Table 10).
(see text for explanation)

	PUSH		PULL	
	Left	Right	Left	Right
	(Estimated average measured force)			
Wheelchair users (n = 53)	14 (62)	13 (59)	13 (59)	11 (50)
Other disabilities[a] (n = 108)	14 (61)	14 (63)	13.5 (60)	14 (64)

[a] Includes 4 wheelchair users with "exceptionally good abilities".

(B) Results from Johnson (1979, p. 20).

	PUSH	PULL
	(Average Maximum force)	
Disabled[b] (n = 24)	27 (121)	34 (153)
Able-bodied (n = 17)	45 (201)	57 (252)

[b] See text for a description of the group.

(C) Other Studies

	PUSH		PULL	
	Female	Male	Female	Male
	(Average maximum force)			
6-yr. old males[c] (n = 51)	39 (175)	47 (209)	50 (224)	56 (250)
	MAX. PEAK PUSH		AVG. PLATEAU FOR PUSH	
Stewardesses[d] (n = 152)	97 (432)		67 (297)	

c Source: Brown and Buchanan, 1973.

d Source: Reynolds and Allgood, 1975. These subjects used two hands for pushing.

create irreconcilable conflict. Not surprisingly, both Steinfeld and Johnson recognize the problem under discussion and they agree that improvements in sampling and testing are needed.

As for door closer standards, the industry standard (ANSI A156.4-1972, American National Standard Door Controls-Closers),[8] sponsored by the Builders Hardware Manufacturers Association, covers product performance tests for adjustable closing speed, closing force, closer efficiency, degree of dead stop, degree of opening, etc. (see ANSI A156.4-1972, section PT 10.1, p. 22). The test for closer force requires a minimum value to be met. Any value in excess of the minimum presumably is acceptable. By comparison, the behavioral standard in ANSI 117.1-1979 establishes a maximum value. Nevertheless, the two standards have a relationship because opening force is a function of closing force and closer efficiency.

3.3.2 Closer Delay Intervals and Time to Close

An open door with a standard, mechanical closer will begin to close as soon as the door is released by the user. Thus, even if functionally limited users can exert the required opening force, the closer's time to close may pose a problem for the users. Specifically, the users may not have sufficient time to pass through the door after releasing it without having the closing door impede or stop their progress. There have been two approaches to creating adequate time for users. One approach is to delay the closing action of the door. The other is to increase the time it takes the door to close. Time to close refers to how long it will take a door to move a prescribed distance after the door has been released by the user. It is assumed that the closing speed will remain constant with an adjustable closure (see ANSI 156.4-1972, sections PT 11-2 and PT 11-6, on pp. 23 and 24, respectively).[9] Delayed action refers either to how long an opened door will remain stationary or almost stationary (i.e., move very slowly) after being released by the user.

The delayed action interval and time to close are independent measures and are additive, with the time to close beginning when the delayed action interval, if any, ends. Delayed action and time to close are also mechanically independent, each regulated (adjusted) separately on the closer.

A specific delayed action interval (e.g., 5 seconds) and a specific closing time (e.g., 5 seconds) have different consequences for the user because the door is stationary in the former case and it is closing in the latter. Therefore, depending on how much space a user needs, there will be some point

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[8] This standard is being revised.

[9] A closer with a latch speed regulator would accelerate the door when the door was between 2 in (51 mm) and 12 in (305 mm) of its closed position (see ANSI 156.4-1972, p. 23, section PT 11-3). However, a door's speed at this point does not bear on the discussion.

during the closing time when the location of closing door will coincide with the location of a user who has not cleared the path of the door. At this point, the door may impede or stop the user's progress or may require an activity, like secondary touching, which permits the user to resume progress.

Door closers create trade offs between accessibility and other door functions. For example, the longer a door remains open (because of delayed action and the closing time), the greater the infiltration, hence energy consumption, in the case of exterior doors and the greater the threat of fire or smoke spread in the case of interior doors. The issue, then, is the amount of time needed by handicapped users.

Table 6 provides on indication of how much time is needed. It is based on an unpublished comparison of 19 accessibility standards and codes by Mr. Sanford Adler of NBS. Table 6 summarizes the codes and standards that addressed delayed action intervals and closing times for doors with closers. According to table 6, one standard (ANSI 117.1-1979) only addressed time to close; eight standards and codes presented quantitative criteria for delayed action intervals; and one standard addressed both delayed action and time to close (the Illinois standard). A minimum delayed action interval of 3 or 4 seconds is common. The two standards that addressed time to close recommended a minimum of 3 seconds. (These two standards, however, specify different distances for the door to move during the 3 seconds, hence different total times to close; see table 6).

There appears to be little research on delayed action intervals and closing time requirements. The author located only one study and it was on delayed action intervals. In this study, by Steinfeld, Schroeder, and Bishop (1979), these researchers installed spring-loaded closers adjusted to 5 lbf (22 N) on each of three manually-operated, hinged doors with 32 in (813 mm) clear widths (Steinfeld, Schroeder, and Bishop, 1979, p. 133). The door opening force and the clear widths are the values subsequently specified in ANSI 117.1-1979 (see ASNI's sections 4.13.5 and 4.13.11).

Eleven volunteers, all of whom were wheelchair users, attempted to pass through the door using a direct forward approach. Seven of the eleven subjects (64 percent) got through the door with the closer set at a 3 second delay. Of the four subjects who failed under the 3 second condition, none got through the door with the closer set at a 5 second delay and one of the four got through the door with the closer set at an 11 second delay (Steinfeld, Schroeder, and Bishop, 1979, p. 138). These four people "all had severe disabilities restricting strength and arm movements" (Steinfeld, Schroeder, and Bishop, 1979, p. 135). Volunteers were given more than one opportunity to pass through a door successfully if there was an indication that they might succeed (E. Steinfeld, personal communication, July 1980). Thus, the meaning of success or failure under each condition is less equivocal than if an individual had had only a single attempt.

Table 6. Automatic Door Closers: Time to Close and Delayed Action Intervals*

	No Quantitative Criterion	Quantitative Criteria (in seconds)
Time to close		2 codes ANSI: 3 second minimum for a door to move from an open position of 70° to a point 3 in (75 mm) from the latch, measured to the leading edge.[a] Illinois: 3 second minimum for a door to move from an open position of 70° to a closed position.
Delayed Action Interval	4 codes Michigan, Minnesota; Australia, Canada	9 codes 3-6 seconds: Utah 4-6 seconds: U.S. Dept. of Health, Education and Welfare (HEW); New York, Ohio, Texas 4 seconds: General Services Administration (GSA) 5 seconds: U.S. Postal Service; Illinois Up to 12 seconds: North Carolina-New Construction Code

Among the qualifiers of door closer requirements are

1. It should limit (not increase) the opening resistance of the door (GSA, HEW; Minnesota, North Carolina Rehabilitation Code, Ohio, Washington; Canada).
2. The closer's pressure should be adjustable (Ohio).
3. The closers should comply with ANSI 156.4-1972.

GSA recommends smoke-or-heat sensitive door closers on fire doors on trafficked routes so these doors can be left open during nonemergency conditions.

Michigan permits doors in series to have delayed-action closers.

* includes entrances

a ANSI refers to ANSI 117.1-1979, section 4.13.10.

An examination by the author of these results using the binomial test (Siegel, 1956) established the likelihood of the obtained results. For example, although 7 of 11 volunteers succeeded under a 3 second closing time, statistically speaking one cannot say that significantly more volunteers succeeded than failed. The probability of 7 of 11 persons succeeding is 0.548.[10] Generally, for differences to be regarded as statistically significant, the probability of the obtained results should be 0.10 or, preferably, 0.05 or smaller. With this in mind, the probability of 4 of 4 persons failing in the 5 second condition was 0.125 and the probability of 3 of 4 persons failing in the 11 second condition was 0.625. The results do not reach customary levels of statistical significance, even though the outcomes appear to be clear-cut, because of the effects of very small sample sizes on binomial probabilities. In this regard, the probability of being unsuccessful in both the 5- and 11-second conditions, given a failure in the 3 second condition, is 0.078 which is the product of the binomial probabilities for the obtained results of the 5- and 11-second conditions.

Based on the aforementioned results, the author agrees with Steinfeld, Schroeder, and Bishop (1979) that "door closers are not recommended for interior locations" (p. 135), so long as it is assumed that this also is appropriate for reasons other than accessibility. There are several reasons reasons for the author's concurrence. First, the number of volunteers succeeding with a 3 second closing time was not statistically different than those failing. Even if one additional success with the 11 second closing time was added to create 8 of 11 successes (73 percent), the difference between successes and failures still would not be statistically significant ($p = .226$). Second, those failing at 3 seconds continued to fail at longer closing times. However, all 11 volunteers succeeded passing through these doors with the closers removed (see Steinfeld, Schroeder, and Bishop, 1979, p. 138: table 36). Clearly, the closer is the problem.

In lieu of supporting data, Steinfeld's recommendation of a 3 second minimum closing time for all doors with closers in ANSI 117.1-1979 is a reasonable interim criterion. He included this recommendation based on his belief that, given a door with a closer, it is prudent to have a closing time specified. The ANSI 117.1-1979 recommendation (see ANSI's section 4.13.10) actually is more generous than it appears. It allows a 3 second minimum for a door to move 70 degrees to a point 3 in (75 mm) from the latch (see table 6). This is equivalent to about a 5 second minimum for the door to actually close (E. Steinfeld, personal communication, July 1980). A 5 second minimum is consistent with other recommendations in table 6. It also appears to be consistent with recommended practice in the door hardware industry. For example, ANSI 156.4-1972 (section PT 11-6, p. 24), in its cycle test of closers, stipulates 4 to 6 seconds for a door's time to actually close from a 90 degree open position. In conclusion, information is still needed on

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[10] For this test and for the other statistical tests on this data in this section, two-tail probabilities are reported because the outcomes were not predicted in advance.

how much time different handicapped user groups need to pass through a door with a closer. Moreover, there should be a determination of whether the preferable approach is a longer closing time or the addition of a delayed action interval. The decision may turn on the behavior patterns of users. Not all users may open a door wide enough to engage the operation of the door mechanism that controls delayed action. With some closers, the door must be opened more than 60 degrees to engage this feature. Steinfeld (personal communication, July 1980) suggests that user groups only may open a door wide enough to pass through and that the resulting position of the door may not be sufficient to engage a delayed action mechanism. Moreover, user strength and stamina also may be an issue. If a door closer has a back check feature, to make it less likely that a user will slam the door into a wall or other objects when opened widely, this feature when engaged will increase the door's opening resistance. On some closers, the door must be opened beyond the point at which the back check feature engages before the delayed action feature is activated. This combination may create barriers to access for functionally limited user groups with strength or stamina problems. Thus an examination of door closers must include the strength and stamina of users with regard to unlatching and opening a door, their behavior patterns with regard to how widely the door is opened, and the relation of these to the design and operation of door closers on manually-operated, hinged doors. Last, door closers with delayed action features are priced higher than standard door closers, other factors equal. Whether the benefits of delayed action are commensurate with their greater costs also should be examined.

3.3.3 Two Questions Posed by Closers

Closers pose two related research questions. First, what are reasonable accessibility maxima for door closers' closing forces, given 60 to 70 percent closer efficiency for exterior and interior doors? Second, can technology and environmental design overcome problems that now require high closing forces? For example, if environmental conditions, such as wind loads acting on a door, are the reason for increasing the closing force, then environmental design solutions like wind screens or better choices of door location might be better solutions than stronger closers. As for technological improvements, there are now smoke- and heat-sensitive closers for fire doors on trafficked routes. Consequently, these doors can be left open during nonemergency conditions. There are now pneumatic assists that control the opening force of doors with mechanical closers by "overriding" the closer and lowering opening forces to 5 lbf (22 N) or less. So long as these assists are reliable and durable and their user-operated controls conform to the abilities of the handicapped (see Faste, 1977, p. 53), these pneumatic assists represent a useful approach to separating door opening and door closing functions as far as the role of the door closer is concerned.

3.4 THE DOOR SYSTEM: SUMMARY AND CONCLUSIONS

Three door hardware components that relate to handicapped users are discussed. The components are the locking and latching mechanisms, door openers, and door closers. Each raises questions about the adequacy of current codes and standards as these apply to persons with functional limitations. There have been few studies of locking and latching components. It is not clear from the available literature how serious the problems posed by these door components are for functionally limited individuals. Door openers provide barrier-free access and egress. However, if the power systems fail, these door can be barriers. This would be especially serious if the failure happened during an emergency requiring building egress. Door closer forces, closing time, and delayed action intervals lack firm empirical support.

Since these door components, with the exception of locking and latching mechanisms, are frequently included in building accessibility standards and codes, a sound empirical basis for standard-setting remains to be established.

4. GENERAL SUMMARY AND RECOMMENDATIONS

4.1 SUMMARY

One building system addressed by accessibility codes and guides developed at the State and Federal levels and by consensus standards groups is the door system. However, these standards and codes do not agree on levels of performance or on scope and they vary in their empirical support. This holds for accessibility codes as a whole and for their sections on the door system. The sections of accessibility codes on the door system require reappraisal.

Doors can be obstacles to building access and use. The reasons may be obvious and include improper installation and unusual climatic conditions such as a strong wind acting on a door. The reasons also can be less obvious. A pervasive example are conflicts among the multiple functions that doors serve. These functions include life safety, security, access, and energy conservation. Doors as obstacles pose problems for all citizens. Jones (1978) has estimated that 60 percent of the total U.S. population is handicapped at any one time in their use of the environment. However, the effects of architectural barriers are greater for the severely disabled.

The concept of disability and related concepts like impairment and handicap lack a consensus of meaning. In part this is because some definitions reflect regulatory requirements and others reflect scientific requirements. It is suggested (in chapter 1) that the concept of functional capacity (or, in its negative form, functional limitation) be used. This concept is likely to be a better indicator of human performance than disability because functional capacity, unlike disability, is a direct antecedent of performance. To make an approach based on functional capacity workable, the abilities must be identifiable, measurable, and have established relevance to building accessibility.

Although functional capacities relevant to building accessibility have been identified, generally speaking, they must be more precisely specified. They need improved and standardized ergonomic measurement procedures. This is likely to require a major research effort. Not meeting these goals will undermine the evaluation and comparison of building accessibility studies using volunteers varying in functional capacity. This will result in conflict and confusion about what, in fact, are the facts. Moreover, there are questions about the suitability of applying ergonomic data from able-bodied people to persons with functional limitations. Because of these problems, chapter 2 discusses suggestions for improving the existing ergonomic data base to make it more suitable to building accessibility for the functionally limited.

There is a distinction between functional capacity and door use patterns. The latter refers to how abilities are actually employed during door use. These patterns vary. This raises three questions. Which patterns are the most effective for given groups and given doors? Are these patterns being used? If not, then under what conditions would they be used?

The door user is one aspect of the person-environment system. The other is the door system itself. Among the components of the door system is the hardware: locking and latching mechanisms, door openers, and door closers. Each of these is discussed. (Other components, such as door size and weight, and clear widths, are not discussed in this report.) For each of the components (discussed in chapter 3), questions are raised about the adequacy of current accessibility codes and standards as they apply to persons with functional limitations. For example, it is not clear from the available literature how serious the problems posed by these components are to handicapped individuals. Door openers provide barrier-free access and egress. However, if power systems fail, these doors can become barriers. This could be particularly serious if the failure was due to an emergency requiring building evacuation. Door closer forces, closing times, and delayed action intervals lack firm empirical suport. The available data have methodological problems (e.g., small sample sizes) that limit their usefulness. Since these components, with the exception of locking and latching mechanisms, are frequently included in building accessibility standards and codes, a technically sound basis for such standards remains to be established.

4.2 RECOMMENDATIONS

Based on the information that was reviewed, research in three related areas is recommended. These are the ergonomic measurement of human capacities, the specification of door use patterns, and the creation of engineering-based standards (tests and measures) for accessibility.

The ergonomic measurement project should initially address two objectives: (1) the selection and development of a basis for characterizing the functional capacities of users, and (2) the selection and development of instruments and procedures to measure these functional capacities. Work by Steinfeld and his associates on characterizing functional capacity, discussed in chapter 2, is a recommended building block for this effort.

The door use pattern project should initially pursue the objective of characterizing and measuring ideal and actual door use patterns. Following the lead of Johnson (1979), the project also should address how these patterns can and do contribute to successful door use.

The third project should pursue the objective of developing engineering-based standards for accessibility. A second objective would be to develop and test new technologies for building accessibility with possible emphasis on door opener, door closer, and latching and locking technologies. The aim of producing engineering-based tests and measures is to have available for door and door hardware manufacturers tests and measures that would predict behaviorally-relevant door performance. The purpose of developing new technologies would be to make buildings more accessible and to reduce the cost of so doing.

Cost is a factor that must not be ignored. As matters stand now, the estimated increase in construction costs for making buildings accessible is generally less than one percent of total construction costs (Schroeder and Steinfeld, 1979, pp. 148, 150). As a rule, accessibility is less costly in new construction than in renovation and in nonresidential than in residential buildings (Schroeder and Steinfeld, 1979, chap. 11; Jones, 1978, p. ix). Costs depend on what items are included in a particular building. An elevator, for example, can be an expensive addition (see Schroeder and Steinfeld, 1979, p. 142, cost estimate for the public branch library) and so can power-assist door features (R. Hudnut, personal communication, July 1979). In short, researchers must consider the cost to the public of proposed standards, improvements, innovations, and technologies. One aim of researchers should be the development of new technologies which will reduce the cost of making buildings accessibile.

In closing, the three recommended projects were selected because available research suggests that each represents an area with unresolved problems or unmet needs. Answers provided by these projects can bear directly on accessibility criteria for door components and on future research on building accessibility and with functionally limited groups.

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APPENDIX 1

ESTIMATES OF THE NUMBER OF PEOPLE IN THE UNITED STATES WITH FUNCTIONAL LIMITATIONS WHO WOULD BENEFIT FROM ACCESSIBLE BUILDINGS

PREVALENCE OF FUNCTIONAL LIMITATIONS IN THE NONINSTITUTIONALIZED U.S. POPULATION (in millions)

Limitation	Date	Estimate (in millions)	Age Group	Source
A. Difficulty in Interpreting Information	(No Data Available)			
B. Severe Loss of Sight	1970	1.7	All	American Foundation for the Blind
C. Severe Loss of Hearing	1974	6.8	All	National Association for the Deaf
D. Prevalance of Fainting, Dizziness or Poor Balance	1970	2.9	18 & Over	Nagi (fainting spells, dizziness, sick feelings)
E. Incoordination	(No Data Available)			
F. Limitations of Stamina	1953-1965	5.0		NHIS (limited activity[1] due to asthma-hay fever, heart conditions, hypertension & other respiratory conditions)[2]
G. Difficulty Moving Head	(No Data Available)			
H. Difficulty in Lifting and Reaching with Arm	1970	11.8	18 & Over	Nagi (great difficulty lifting 10 lb weight or reaching with arms)
I. Difficulty in Handling or Fingering	(No Data Available)			
J. Inability to Perform Upper Extremity Skills	1963-1965	3.6	All	NHIS (limited activity due to impairment of upper extremity and shoulder)[1,2]
K. Difficulty in Bending, Turning, Sitting or Kneeling	1970	10.0	18 & Over	Nagi (great difficulty stooping, kneeling & crouching)
L. Reliance on Walking Aids	1969	6.6	All	NHIS (use of crutches, braces, canes, walkers, artificial limbs)
M. Inability to Use Lower Extremities	1969	0.4	All	NHIS (wheelchair users)
N. Extremes of Size and Weight	(No Data Available)			

[1] Includes both those "limited in amount and kind of major activity" as well as "unable to carry on major activity."

[2] Does not include paralysis and absence of limbs.

From Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, p. 29.

BENEFICIARIES[1] OF BARRIER ELIMINATION WHO WOULD BENEFIT DUE TO INCREASED INDEPENDENCE IN PERSONAL CARE AND MOBILITY USING NHIS AND SSN DATA[2]

Age	% of U.S. Population	Date	Source
Under 17	0.04	1965-1967	NHIS (limitation of mobility such that "needs help getting around")
18 - 64	1.7	1966	SSN (severely disabled and needing help with personal care or mobility, plus severely disabled with visual impairments)
65 plus	0.5	1965-1967	NHIS (limitation of mobility such that "needs help getting around")
Total	2.2		

[1] Noninstitutionalized people only.

[2] NHIS refers to the National Health Interview Survey of the National Center for Health Statistics.
SSN refers to Social Security Survey of Noninstitutionalized Adults.

Source: Steinfeld, Schroeder, Duncan, Faste, Chollet, Bishop, Wirth, and Cardell, 1979, p. 30.

Based on its review of a number of data sources, the Panel concludes that the following represents a reasonable approximation of the makeup of the disabled population:[1]

Disabilities	Population
Difficulty in Interpreting Information	13,983,000
Severe Loss of Sight	1,768,000
Severe Loss of Hearing	6,800,000
Prevalence of Fainting, Dizziness, or Poor Balance	3,599,000
Incoordination	2,700,000
Limitations of Stamina	60,203,000
Difficulty in Moving Head	2,652,000
Difficulty in Lifting and Reaching with Arms	11,978,000
Difficulty in Handling or Fingering	2,642,000
Inability to Perform Upper Extremity Skills	3,244,000
Difficulty in Bending, Turning, Sitting, or Kneeling	10,097,000
Reliance on Walking Aids	6,935,000
Inability to Use Lower Extremities	430,000
Extremes of Size and Weight	4,160,000

The Department of Health, Education, and Welfare (1972c) provides the following concerning the number of persons using special aids:[2]

Number of Persons Using Mobility Aids (in thousands)

		Brace					Artificial Limb		
Special Shoes	Cane or Walking Stick	Leg or Foot	Other	Crutches	Wheel-chair	Walker	Leg or Foot	Arm or Hand	Other Aid for Getting Around
2,377	2,156	233	869	443	409	404	126	46	140

Population data obtained from Trends (1974) are as follows:

1.2 million blind or severely visually impaired
7.6 million suffering from heart condition
6.2 million (non-institutional) using orthopedic aids--wheelchairs, braces, crutches, etc.
1.8 million deaf
18.3 million hard of hearing
14.5 million respiratory ailments
18.3 million arthritics
409,000 Americans are in wheelchairs
1,102,000 use heavy leg braces
172,000 artificial limbs
2,156,000 use canes
404,000 use walkers
443,000 use crutches
20,000,000 are over 65.

As estimated by Sally Bedow of Little People of America,[3] there are approximately 100,000 small adults in the United States.

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[1] There is great difficulty in obtaining consistent and reliable data concerning numbers of individuals possessing specific disabilities and degrees of disability and even more difficulty in determining the numbers of individuals possessing more than one disability who are, thus, being counted more than once. As a consequence, in all probability it is unrealistic to arrive at total numbers of reported individuals with given disabilities.

[2] Data are based on household interviews of the civilian noninstitutional population. The survey design, general qualifications, and information on the reliability of the estimates are given in Appendix I of the cited DHEW publication; definitions of terms are given in Appendix II of [the Panel's report].

[3] Private communication

Source: Panel on Building Design Criteria for the Disabled, 1977, pp. 177-179.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report reviews the technical literature related to doors as architectural barriers. It examines the concept of disability and the associated concepts of impairment and handicap. It is concluded that these terms lack consensus of meaning. The concept of functional capacity is recommended as an alternative because of the more direct linkage between capacity and performance. A review of the conceptual literature on functional capacity and its measurement leads to the conclusion that functional capacities relevant to building accessibility generally have been identified, but more precise specifications and improved ergonomic procedures for testing capacities of the disabled are required. Furthermore, a distinction is drawn between functional capacity and door use patterns. The latter refers to how capacities are applied during actual door use. Last, door systems are examined, particularly locking and latching mechanisms, door openers and door closers. The existing literature on these raises questions about the adequacy of current accessibility codes and standards with regard to these components. Based on unresolved problems and current needs, research addressing accessibility relevant objectives is recommended.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Architectural barriers; building accessibility; codes and standards; disability; doors; door closers; door openers; ergonomics; functional capacity; handicap; locks

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