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MOBILITY

FOR SPINAL-CORD-IMPAIRED PEOPLE

Report Of A Workshop
February 22-24, 1974



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M O B I L I T Y
FOR
SPINAL-CORD-IMPAIRED PEOPLE

Report of a Workshop
February 22-24, 1974

held at the
Rancho Los Amigos Hospital, Inc.
Downey, California

NATIONAL ACADEMY OF SCIENCES
1975



Invited speakers, groupleaders and other participants presenting their ideas to improve mobility for spinal-cord-impaired people.

NOTICE

The project which is the subject of this report was approved by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to undertake this project and prepare this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

Each report issuing from a study committee of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved, by the President of the Academy, upon satisfactory completion of the review process.

This report was prepared as part of the work under Contract V101(134)P-75 between the Veterans Administration and the National Academy of Sciences, and Contract No. SRS 72-7 between the Social and Rehabilitation Service, Department of Health, Education, and Welfare, and the National Academy of Sciences.

PREFACE

In May 1973 the Committee on Prosthetics Research and Development conducted a Workshop on the Role of Engineering in Spinal-Cord-Injury Programs. Held at Castle Point Veterans Administration Hospital, its purpose, implicit in the title, was to define those areas in which it was felt that engineering could be most helpful in the management of patients with an impaired spinal cord. One of the areas that stood out clearly, and one in which it seemed that considerable progress might be made in the relatively near future, was mobility aids. Virtually all of these patients are confined to bed and wheelchair, and the latter devices, while being quite versatile, are considered to be "behind the times." Good ideas have been put forth from time to time concerning improved orthoses, more useful wheelchairs, and other devices, but for reasons that are not clear there has been no widespread acceptance of the designs.

There are also problems not solved in adapting automobiles for use by paraplegics to say nothing of the problems associated with providing vehicular controls for the quadriplegic patient.

Architectural barriers still exist, despite some programs resulting from heroic efforts by a number of groups throughout the world.

For this reason, CPRD elected to organize and conduct a "Workshop on Mobility Aids for the Spinal-Cord Impaired." Maurice LeBlanc, Staff Engineer of CPRD, was assigned the major staff responsibility. During the late summer and fall of 1973, by interviewing personally many people here and in Europe, Mr. LeBlanc gathered together as much pertinent information as possible for consideration by a steering committee consisting of Colin A. McLaurin, Martin Prast, James B. Reswick, Thomas R. Shuxrles, and Warren G. Stamp.

The steering committee met in Washington, D.C., on November 21, 1973, at which time a tentative structure for the meeting was established and Dr. Reswick was selected to be chairman of the workshop.

The final arrangement called for a presentation of selected papers in plenary session to be followed by five panels meeting simultaneously to develop design criteria for mobility aids to meet the various needs respectively of five different classes of patients. The needs were classified as mobility in the home or at work, in the immediate neighborhood, and intercity travel.

The selected papers published here provide a good overview of the problems facing the designers, clinicians, and patients, and the reports of the panels provide the designers with rather specific goals, while offering some suggestions how they may be met.

It is hoped that the workshop proved to be stimulating to those in attendance, and that this report will provide readers incentive to either engage in the work recommended or support those who offer sound proposals.

*A. Bennett Wilson, Jr.
May 13, 1974*

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S Y N T H E S I S

1. The number of people requiring special consideration in mobility is growing due to the improved care received by individuals subjected to trauma and suffering from birth defects.
2. The manually operated wheelchair that has evolved through the years has many good features, but its usefulness could be increased considerably by a few easily incorporated design changes. Consideration should also be given to providing more function by design changes that probably involve sophistication and ingenuity. Care must be exercised so that none of the positive features of the present designs is compromised in the zeal to provide a new function.
3. The use of exoskeletal orthoses, with and without external power, with and without electrical stimulation of the neuromuscular system, should be explored thoroughly.
4. Work on electrical stimulation of the neuromuscular system to preserve function and muscle force as well as provide function should be expanded and accelerated.
5. The modular concept should be considered in the development of a mobility system useful in the home, in the immediate neighborhood, within the city, and between widely separated points. A system built around a customized, readily detachable seat that can be easily transferred along with the occupant, from chassis to chassis and on to other vehicles that contain safe attachments, should be studied. The design of other systems should be encouraged also.
6. Studies involving the effect of pressure on soft tissue with respect to the prevention and management of decubitus

ulcers should be expanded and accelerated. This work should include the development of improved seating and bedding and effective techniques in their application. The body of knowledge already accumulated in prevention and management of ulcers should be made available widely by publication and formal education programs.

7. Present movements to remove so-called architectural barriers and to make public transportation more available should be supported and accelerated.

PURPOSE AND GOALS OF THE WORKSHOP

James B. Reswick

After life-saving efforts and medical stabilization of injuries and complications, the first-priority need for the spinal-injured patient is mobility. In a very real sense, the world first begins to open up again for him on the day he can be transferred to a prone gurney or wheelchair, either motorized or self-propelled. On this day he can demonstrate to himself that some day he will be able to move about in his home, leave his home for limited excursions in the immediate environment, and eventually go to work and even travel throughout the world. Much has been accomplished in the United States and other countries toward providing spinal-injured patients with the necessary equipment to achieve these goals. Attention has been paid to architectural barriers and even to public transportation. But much more is yet to be done, and it was the purpose of this workshop to bring together concerned people--users, suppliers, developers, government agency representatives, architects and counselors--to assess the state of present affairs and to define and give priority to what must be done in the future.

WORKSHOP ACTIVITY

On the first day of the workshop, papers were presented by invited speakers, which ranged from technical details of wheelchair design through government activities and architectural considerations in the home and in public, to psychosocial and learning considerations in using mobility systems. Several of the speakers are themselves users of wheelchairs.

James B. Reswick

For the second day of workshop activity, the main body was divided into five separate groups which met by themselves and worked through the day. These groups dealt with the problems of various categories of disability as follows:

- Group I - People with no lower-limb function
- Group II - People with no lower- or upper-limb function
- Group III - People with no lower- and partial upper-limb function
- Group IV - People with partial lower- and partial upper-limb function
- Group V - People with special problems; i.e., cerebral palsy, spina bifida, muscular dystrophy, and multiple sclerosis

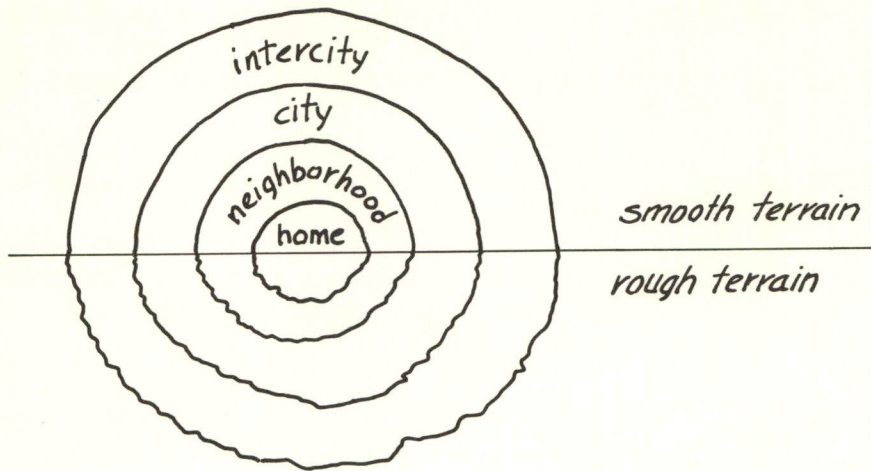
Each group attempted to answer the following questions:

1. How is each category characterized in terms of functional disability?
2. What is the patient population of each category?
3. What are the needs of each group? That is, general problems were to be translated into precise statements of functional need.
4. In following patients in each category through the various spheres of activity, what problems are encountered in:
 - a. Ambulation
 - b. Positioning and seating
 - c. Transfer
 - d. Use of nonlicensed vehicles
 - e. Use of licensed vehicles
 - f. Public transportation
 - g. Architectural limitations
 - h. Other

In considering these questions, a "sphere of activity" was defined to identify the range of problems from those within the home environment to intercity

Purpose and Goals of the Workshop

transportation. The figure below illustrates this sphere of activity and indicates that at all levels the difference between rough terrain and smooth terrain markedly affects the effectiveness of wheel-chair users.



The reports of each group were presented by group recorders on the third day of the workshop. These reports, along with the first day's position papers, comprise the total workshop report which follows.

SECTION I. INTEREST AND ROLE OF:

VETERANS ADMINISTRATION

SOCIAL AND REHABILITATION SERVICE,
DEPARTMENT OF HEALTH, EDUCATION,
AND WELFARE

DEPARTMENT OF TRANSPORTATION

INTEREST AND ROLE OF THE VETERANS ADMINISTRATION

Eugene F. Murphy

The Veterans Administration (VA) welcomes the action of the Committee on Prosthetics Research and Development (CPRD) in arranging this conference on an important subject. I also have a personal "old-alumnus" interest, having spent about nine months, including a semester at school, in an old wooden three-wheeled chair after polio in 1924, and a brief period in a small chair of the type publicized by "Sunrise at Campobello" after injuring an ankle at Warm Springs.

The Veterans Administration, of course, has several areas of responsibility for wheelchairs and automotive adaptive equipment. The listing of workshop groups implies a somewhat broader interest than spinal-cord impairment (SCI) alone, so perhaps it is fair to note the widespread use of wheelchairs (and walkers) in hospitals for patients of many categories. Most of these devices are simple, relatively standard items procured through a supply depot and used concurrently by many patients. Typically, hospital wheelchairs are propelled by the occupant, mostly by hand rims or perhaps by one foot in the case of an amputee or some hemiplegics, but sometimes an attendant pushes the chair. A relatively few power-driven wheelchairs are used in VA Hospitals, primarily for quadriplegics. Hospitals are usually free of architectural barriers to wheelchairs.

The VA prosthetics program, in contrast, primarily supplies prescription wheelchairs personalized for individuals--usually outpatients who face a wide variety of difficulties if not barriers. Sometimes a hospital-type chair is prescribed, but often special features such as special sizes, removable arm rests, reclining backs, elevating leg rests, power and

Eugene F. Murphy

control features, etc., are needed. In addition to attempting to eliminate architectural barriers, it is only realistic to attempt to develop devices to manage some of the barriers that remain.

The Veterans Administration also serves patients who have a variety of handicaps that entitle them by law to allowances for automobiles, generally with special adaptive equipment such as hand controls, automatic transmissions, power steering and brakes, manual dimmer switch, etc. It is appropriate that this conference consider the problems of registered motor vehicles for use by the physically impaired.

Under a VA research contract, the University of California is continuing refinement of a wheelchair with special features developed partially under Social and Rehabilitation Service (SRS) support. Mobility engineering is developing driver and passenger safety appliances, especially seats and restraints, for vehicles for the handicapped, particularly vans for quadriplegics. Texas A&M University, with the cooperation of Texas Transportation Institute, is testing existing automotive adaptive equipment, drafting safety regulations, and developing new controls. Prast Research Associates are just starting a contract for development of a crutchless walking device for paraplegics.

Dr. Peizer will sketch the extensive program in mobility aids being carried out by the VA Prosthetics Center.

INTEREST AND ROLE OF THE VETERANS ADMINISTRATION PROSTHETICS CENTER

Edward Peizer

We are particularly pleased that the medical and rehabilitation problems of the SCI, discussed at the CPRD meeting at Castle Point VA Hospital, have led so rapidly to this workshop on mobility--one of the most critical elements in the rehabilitation of SCI patients. We think Rancho a most fitting place for this conference since it is among the most advanced SCI treatment centers in the United States.

About four years ago, VAPC became responsible for supporting the SCI treatment programs in VA centers. Our initial efforts were focused on evaluating and improving existing mobility aids--a charge not too dissimilar from the one we have in prosthetics and orthotics. However, VAPC is not a hospital and to deal with these matters systematically our role grew to include close cooperation with and responsibility for supporting the services of 12 VA SCI centers.

Our concept of mobility for SCI patients is very broad. It is based on the notion that SCI makes the bed the normal habitat of the patient: he needs human or mechanical intervention to displace himself or, in the case of the quadriplegic, to displace or manipulate objects in his environment. We define the quadriplegic's needs in terms of both mobility and manipulation. We conduct a multifaceted program which includes:

1. Development projects in our own laboratories to devise new or improve older appliances as the need is brought to our attention by clinicians and patients.
2. Evaluation programs to determine the utility of the widest possible array of devices developed by others. This program includes both laboratory and clinical testing.

Edward Peizer

3. Support of and cooperation with other groups which are developing devices for the SCI patient.
4. Rapid deployment of useful devices into SCI treatment centers and to outpatients--a program coordinated through the 12 participating VA SCI centers.
5. Development of standards and specifications that cover the safety, durability, and performance of appliances.
6. Close coordination through CPRD with non-VA SCI centers, such as Rancho, for mutual support in development and evaluation.

The problem of mobility for patients prior to medical stabilization, that is, immediately after injury, has not been acute in the VA because those coming under our care have usually been through military hospitals. Nor have mobility problems associated with employment been acute because of benefits the VA provides eligible veterans. Nevertheless, we believe these are vital problems and should be attacked with the same zeal as others.

We are now either working on or supporting work in the following areas:

1. Reestablishment of the Walking Function

Conventional mechanical orthoses and axillary crutch systems for paraplegics are relatively heavy, consume too much energy, and provide an unesthetic gait.

- a. With CPRD we are planning an evaluation of the ILC pneumatic orthoses ("Ortho-Walk").
- b. VAPC engineers are working on the design of an electromechanical exoskeletal brace system.
- c. We are cooperating with VA clinicians who are exploring the application of functional electrical stimulation (FES) to restore certain walking patterns.

Interest and Role of VAPC

- d. Being discussed at this time, with a view toward developing a project with several surgeons, is the possibility of spinal bridging--obtaining electrical information from the proximal portion of the cord and feeding it--conditioned or raw--either to the distal, truncated cord or to certain spinal roots.

2. Nonwalking Mobility Aids

Certain paraplegics and almost all quadriplegics are "trapped" in bed and require help to be taken out of bed and placed in a chair which is either pushed by an attendant or driven electrically.

- a. We have developed, in the sense of packaging the best features of several, a high-performance powered wheelchair system which is to be evaluated in cooperation with CPRD.
- b. We are supporting the development of a bed operated by the patient which can be converted into a type of chair for indoor use.
- c. We are evaluating a class of intermediate "vehicles" which are neither conventional wheelchairs to which power elements have been added nor licensed vehicles. Somewhat akin to the golf cart, they offer faster speeds, longer range, and greater hill-climbing capacity.
- d. We are developing and cooperating with others in the development of remote manipulators for SCI patients. This is a form of mobility in that it gives the patient control over the movement of objects, doors, windows, food, switches, etc. We have developed our own, and we are evaluating several other such environmental control systems.

Edward Peizer

- e. We have developed tentative standards and specifications for hand controls for driving automobiles, and I think it fair to say that this is an area wide open for development of more adequate devices.
- f. We have purchased and continue to purchase vans equipped with elevators and hand controls. These vans are turned over to SCI centers for evaluation and for training veterans to drive. This program has already demonstrated the need for safe driving seats or chairs which perhaps should be part of the system.
- g. We are developing a safe hold-down system for wheelchair users who may be passengers in a van.

Without going into further detail, I would like to conclude my remarks on the VAPC program by adding that we are contracting with the Paralyzed Veterans Association to conduct a nationwide survey to determine the functional needs of quadriplegics who are living at home.

We are sure this conference will provide valuable insights to these problems and suggest useful approaches to their solutions.

INTEREST AND ROLE OF THE SOCIAL AND REHABILITATION SERVICE

Joseph E. Traub

As a result of substantial advancements in technology over the past several years, and the apparent potential for the realistic adaptation and cost beneficial application of these technologies to the needs of the handicapped, the Social and Rehabilitation Service in FY-1972 undertook a major program commitment in this area. This new program is called Rehabilitation Engineering and has been designed to combine the efforts of medicine, engineering, and related sciences to improve the vocational and self-care goals of severely handicapped.

BACKGROUND

In 1954, the Office of Vocational Rehabilitation (OVR), through the Rehabilitation Act of that year, began the support of research and training activities in the fields of prosthetics, orthotics, and sensory aids. These research and training programs were responsive to the needs of the State-Federal program in Vocational Rehabilitation which had for years purchased devices and services for their clients locally with little or no assurance of quality or effectiveness. In this respect, the OVR joined with the Veterans Administration, the Army, the Navy, the National Institutes of Health, the Children's Bureau, and the Office of Education, in a closely coordinated program of research and training. The program was designed at that time to focus major emphasis on the problems of the amputee.

The total Federal program has been closely coordinated over many years through the consultation and advice provided all agencies by the National Academy of Sciences' Committee on Prosthetics Research and Development. As progress was made in certain areas, i.e., artificial limbs, and the manpower was developed

Joseph E. Traub

to undertake other problem areas, the program was expanded to include orthopaedic bracing, mobility devices (wheelchairs, etc.), and sensory aids (hearing aids, reading machines for the blind, etc.). The total program has been quite successful in spite of the very limited resources available and the difficulty of coordinating and fully integrating research, manpower development, and the delivery of clinical services. The ultimate goal has been the improved delivery of more effective services to people.

During the middle 1960s, a concentrated effort was made by SRS to utilize wherever possible the advanced technology developed in the U.S. space and defense programs. A joint program was developed with the National Aeronautics and Space Administration (NASA) whereby unclassified technology would be made available to rehabilitation specialists for use in resolving complex rehabilitation problems.

Under this agreement a number of rehabilitation centers were identified and agreed to participate. NASA organized five Biomedical Applications Technology teams. The B.A.T. teams of NASA visited each participating rehabilitation center and consulted with clinicians to identify problems which modern technological information stored in NASA computers could help to solve. Once the problem was identified, the B.A.T. team would return to their base and search the computers for existing technology which could be expected to provide a reasonable solution. When this technology was located, a package of written materials was prepared and forwarded to the rehabilitation center for their evaluation and possible application.

After eight years' experience, the program proved to be of no substantial benefit to rehabilitation. Failure of engineers and clinicians to communicate effectively their problems and solutions to each other blocked the successful transfer

Interest and Role of SRS

of available technology to rehabilitation practice. A more realistic approach placed engineers, physicians, and related scientists together physically in a clinical setting to work on patient problems, establishing the necessary teamwork at a level of expenditure that would produce cost-effective results and improve communications between the disciplines.

Since well-defined and realistic accomplishments were produced by the SRS research and training program utilizing the team approach, this program was established as the core area for an expanded program called Rehabilitation Engineering. Through working level meetings, the following specific areas of interest were delineated to distinguish between the Biomedical Engineering Program of the National Institutes of Health and the Rehabilitation Engineering Program of the Social and Rehabilitation Service:

SOCIAL AND REHABILITATION SERVICE

1. Artificial limbs--both internal and external prosthetic replacements
2. Orthopaedic braces--both internal and external orthopaedic assistive systems
3. Amputation and reconstructive surgery
4. Mobility aids for orthopaedically disabled persons--wheelchairs, automotive systems, etc.
5. Mobility and communication aids for the blind and deaf
6. Architectural barrier removal for the severely disabled
7. Fundamental studies directly goal-oriented to rehabilitation in the above areas.

NATIONAL INSTITUTES OF HEALTH

1. Life-saving devices, i.e., artificial hearts, renal dialysis, heart-lung machines, etc.
2. Facility engineering--automated hospitals and patient monitoring equipment

Joseph E. Traub

3. Surgical and medical instrumentation, etc.
4. Implantation materials for vessel and organ synthetic grafts, coverings for electrode implants, etc.

In order to avoid any but planned duplication, these working-level relationships must continue. This unofficial arrangement has encouraged excellent rapport between the agencies and has eliminated much of the past unnecessary duplication of research. In addition, many areas of SRS research utilize products of the NIH program, such as materials for maxillofacial prostheses, artificial kidney machines, etc.

In the past year, similar arrangements have been worked out with the National Science Foundation (NSF) and its Research Applied to National Needs (RANN) program, as well as with the Department of Transportation and the Department of Housing and Urban Development (DOT and HUD).

RESEARCH AND DEVELOPMENT STRATEGY AND LONG-RANGE PLANS

Since the multiplicity of problems confronted by Rehabilitation Engineering is so great, and it has been proven that closely coordinated project grant research can be very productive, it follows that both the Rehabilitation Engineering Centers program and the project research grants program are deserving of support.

As a result, the research issues developed in both the Fiscal 1972 and 1973 Research Strategies proposed a broad-scale attack upon many problems of the target populations of SRS. The Rehabilitation Engineering Centers and project grant research program together are seen as a reasonable administrative approach. The strategy has been developed to be responsive to the (goals of the) Long Range Plan for 1975-79 developed by the Rehabilitation Services Administration which states as follows:

Interest and Role of SRS

Goal 1 (Supports SRS Self-Support Goal)

To provide services to all disabled persons where such services can lead to full or partial participation in the labor force.

Goal 2 (Supports SRS Community-Based Alternative Goal)

To assist the States to develop and implement a comprehensive interagency plan to improve and expand supportive community services, improve quality of residential care, and provide community-based alternatives to institutional care for the developmentally disabled. Included is a 1/3 reduction in the DD institutionalized population by 1979.

Goal 3 (Supports SRS Self-Support Goal)

To assist other public and private agencies to eliminate or reduce the impact of barriers in architecture, housing, transportation, job opportunities, and recreation so that the handicapped may participate more fully in society, contribute as citizens, and, to the extent individually possible, become productive in the economy.

Goal 4 (Supports SRS Self-Care/Family-Care Goal)

To provide services to those severely disabled persons not expected to be able to enter the labor force which will permit them to function more effectively as individuals and which will reduce their dependency on society.

The research strategy for FY 1972 Rehabilitation Engineering develops the following variables for study:

- a. Physical and vocational requirements of the disabled
 - b. Available technologies and how they can be adapted to the needs of disabled
 - c. Evaluation systems
 - d. Service delivery systems
- (1) a and b above require high concentration of effort immediately to determine what the disabled need, can accept, and can use.

Joseph E. Traub

- (2) Evaluation systems are necessary to identify successful research and move it as soon as possible toward the service providers.
- (3) New and improved service delivery systems must be designed that will provide the ultimate in rehabilitation potential while at the same time reducing costs of individual programs in order that the total population in need of these services can have them available.

TARGET POPULATION (Figures represent number of persons located throughout the country)

- a. The Spinal-Cord Disabled--there are various estimates as to the number of spinal-cord disabled in the U.S. with no positive data. However, best estimates based on several surveys place the numbers in this group between 500,000 and 1,000,000 persons.
- b. Amputees-- 375,000
- c. Paralyzed and/or Deformed--3,000,000
- d. Blind-- 1,280,000
- e. Deaf-- 1,705,000
- f. Deaf-Blind-- 40,000

GENERAL SYSTEMS QUESTIONS TO BE STUDIED

- a. Can the establishment of a national system of Rehabilitation Engineering Centers in combination with project grants in Rehabilitation Engineering produce a business plan for the movement of research developments through clinical evaluation and professional continuing education programs directly to service delivery programs where technology for the handicapped can be beneficial to their needs?
- b. Can the orderly application of modern technology to the needs of the handicapped produce a truly cost-effective service delivery system, and make available the benefits of high technology to a substantial number of the population?

Interest and Role of SRS

- c. What ways can be demonstrated to make market potentials attractive to industry so that technological developments can be applied to the needs of the disabled at reasonable cost?
- d. How can Rehabilitation Engineering technology be utilized in the vocational rehabilitation of the disabled so that those benefiting from the services are rendered more employable?

SPECIFIC RESEARCH GOALS

- To develop cost-benefit data on the use of Rehabilitation Engineering technology in the rehabilitation of the disabled.
- To demonstrate the use of Rehabilitation Engineering as a means to permit the disabled to become employable and to remain employed.
- To develop modular adjustable prosthetic and orthotic systems which will be more cosmetic, lighter in weight, interchangeable, and less expensive.
- To develop neuromuscular pattern-recognition techniques that will be applied to the disabled to produce the control of externally powered devices which function to perform tasks at the patient's will.
- To utilize the technique of functional electrical stimulation of muscles and nerves to overcome both motor and sensory disability through the use of the remaining neuromuscular system, including the control of spasticity.
- To develop devices and systems to reduce the disabling conditions associated with chronic back pain.
- To develop reading machines for the blind--to convert ink print to audible phonetic speech.

Joseph E. Traub

- To develop mobility devices for the blind and the deaf that will enable them to move safely and efficiently in the total environment.
- To replace disabled or destroyed anatomical joints in the body with artificial joints that are implanted and are biomechanically and biochemically functional.
- To replace diseased or destroyed muscles and tendons with synthetically produced substitutes which will drive the remaining anatomical structure and be both biomechanically and biochemically functional.
- To develop communication systems for the deaf-blind which will allow them to lead independent and vocationally successful lives.
- To develop improved external orthotic systems which will be more cosmetic, lighter in weight, interchangeable and less expensive.

INTEREST IN PERSONAL MOBILITY DEPARTMENT OF TRANSPORTATION

Ira Laster, Jr.

For many of this nation's handicapped population, the unavailability together with the inaccessibility of transportation, either public or private, severely limits their ability to find and hold jobs, to obtain regular medical care, further their education, shop at competitively priced markets, and enjoy the everyday social and recreational opportunities available to the rest of the population.

While we in the Department of Transportation (DOT) are firmly committed to actions which will stimulate the country to provide transportation which responds to the needs of all citizens, we bear a special responsibility for improving transportation for the mobility-limited, many of whom cannot or do not drive, have limited financial resources, and whose needs for mobility may not be served by existing means or modes of transportation. The work that has been done by DOT to date represents a mere beginning of efforts to provide suitable, economical transportation for this nation's handicapped population.

ACTIVITIES OF DOT

The U.S. Department of Transportation's first major action to improve transportation for the physically handicapped was taken in 1969 with the funding of a study of the transportation needs of the handicapped. The study, which was conducted for the Department by Abt Associates of Cambridge, Mass., represented the first serious attempt to identify barriers to travel by the mobility-limited, and to recommend approaches to overcoming those barriers. The study report, entitled *Travel Barriers: Transportation Needs of the Handicapped*, has been widely circulated among transportation planners and individuals,

Ira Laster, Jr.

and groups concerned about improving transportation services for the handicapped.

Since release of the Travel Barriers report in 1969, the Department has supported a variety of research and demonstration projects aimed at making public transportation more accessible to the mobility-limited. Research and development activities have focused on equipment design, and the modification of related facilities aimed at eliminating barriers which impede mobility in those modes of transportation for which the Department has a responsibility. For example, the Department's Urban Mass Transportation Administration (UMTA) has supported research which has resulted in the modification of rail rapid cars and station facilities and in the modification of buses of various sizes, so as to increase their accessibility to the infirm and aged. In addition, UMTA has supported a variety of demonstrations aimed at discovering new service approaches for responding to the special needs of the handicapped and elderly. Miss Cass will present a more detailed description of the urban Mass Transportation Administration's activities to improve equipment and services for these population groups.

With respect to aviation, the Federal Aviation Administration (FAA) within the Department of Transportation has published an *Airport Medical Design Guide* which, if used in conjunction with a previously published advisory circular on eliminating barriers in airport terminals, provides the airport operator with the necessary information for designing airports which are fully accessible to the physically handicapped. The FAA has a rulemaking action under review directed toward developing uniform criteria for transporting mobility-restricted persons in civil air carriers. FAA expects to finalize the rulemaking process by issuing a regulation sometime during the first half of this year.

Interest in Personal Mobility - DOT

The Federal Railroad Administration (FRA) is working cooperatively with Amtrak to assure that new equipment and new or renovated terminals include provisions for facilitating movement of mobility-limited persons. For example, in a recently awarded contract for the design of a suburban train station just outside of Washington, D.C., the contractor has been given instructions to take into consideration the special needs of the physically handicapped. In addition, the special needs of the handicapped continue to receive attention at the FRA test center in Pueblo, Colorado. A major activity of the center is the testing of the capabilities of conventional and advanced-design passenger equipment.

With funds provided by the National Highway Traffic Safety Administration, 13 states have driver-education projects for the handicapped as a part of their highway safety programs. The projects cover a number of different facets of training handicapped drivers, such as curriculum development and evaluation, purchase of prosthetic devices, audiovisual equipment, and software (e.g., captioned films for deaf students). Also, there are projects which include mobile simulators, modification of driving-range equipment, and in-service teacher-training workshops. Further, with respect to highways, the Federal Highway Administration encourages states to build highway rest-area facilities so as to accommodate persons confined to wheelchairs.

LEGISLATION

In the area of legislation, the Federal-Aid Highway Act of 1973 contains several provisions which augment the Department's ability to improve transportation for the mobility-limited. The provisions which offer the greatest opportunities for improving transportation services for the physically handicapped are as follows:

Ira Laster, Jr.

One provision, amending the Urban Mass Transportation Act, authorizes the Secretary of Transportation to make grants and loans to private nonprofit corporations and associations for the specific purpose of assisting them in meeting the special needs of elderly and handicapped persons for whom mass transportation services otherwise provided are unavailable, insufficient, or inappropriate. This is a significant enlargement of the Department's authority to help the private sector supplement public transportation services for the handicapped.

A second provision requires that state highway safety programs submitted for departmental approval must provide adequate access for the safe and convenient movement of physically handicapped persons across curb cuts constructed or replaced after July 1, 1976.

A third provision in the statute authorizes a rural public transportation demonstration program which provides an opportunity for addressing the transportation problems of the rural handicapped population.

DOT INDIVIDUAL MOBILITY ACTIVITIES

The Department of Transportation's activities to improve transportation services for the handicapped and elderly have been directed primarily at making transportation systems accessible to these population groups. However, for a little more than a year and a half, the Department has received inquiries from individuals and institutions about possible financial assistance for support of research and development aimed at designing, building, and evaluating individual mobility devices or pedestrian aids which can be used by severely disabled individuals to enable them to move about, either under their own auspices or with minimal assistance from able-bodied attendants. The types of individual mobility

Interest in Personal Mobility - DOT

devices for which aid has been sought include: powered wheelchairs with special control switches, automobiles that have been modified so as to accommodate drivers who desire to remain in their wheelchairs, and wheelchairs that will climb and descend stairs.

As a result of the inquiries mentioned above, together with a general awareness and concern among departmental officials that we have a responsibility to provide safe, efficient, and convenient transportation for as many of the population as can effectively utilize it, a departmental task force was formed last summer to examine whether and to what extent the Department should become involved in activities to facilitate mobility of individuals, as distinguished from the features of transportation systems which accommodate the systems to such individuals. The task force's assignment was: first, to determine whether the Department had the legal authority to deal with the problem of mobility of individuals; second, to examine the dimensions of the problem; and third, to assess what has already been done in this area. Our presence here represents one among a variety of efforts to accomplish the lastmentioned task.

Our present view is that we want to be helpful to DHEW and VA in their efforts with respect to individual aids while we continue our efforts with respect to transportation systems and the accessibility to these systems. In some cases, we might be undertaking research on individual aids in selected cases, primarily in relation to transportation systems (e.g., how viable is a stair-climbing wheelchair as an alternative to an elevator or an inclinor in a subway station?). We would also hope to be of assistance to DHEW and VA with respect to their efforts regarding the safety of devices for handicapped in automobiles.

I hope that this workshop will assist us to work with all concerned in facilitating mobility of the severely disabled.

SECTION II. SELECTED PAPERS ON:

MOBILITY

AMBULATION

POSITIONING AND SEATING

PERSONAL VEHICLES

OTHER NONLICENSED VEHICLES

LICENSED VEHICLES

MOBILITY FOR SPINAL-CORD-IMPAIRED PATIENTS

W. M. Motloch

The mobility system discussed in this paper is designed primarily for paraplegics. Considered are not only the physical attributes of the patient and characteristics of the terrains and distances involved, but also, and perhaps more important, the methods of donning and removal, transfer to and from devices, and compatibility of components within the overall system.

INTERCONNECTING LINKS

For the most part, the modular concept has not been applied to the mobility and transportation problems of the physically handicapped. Isolated all-purpose units have been sought without much attention being paid to interconnection of compatible units to meet the various needs of individual patients. To be useful, these compatible units, or modules need to be equipped with connectors that can be operated effectively by the patient.

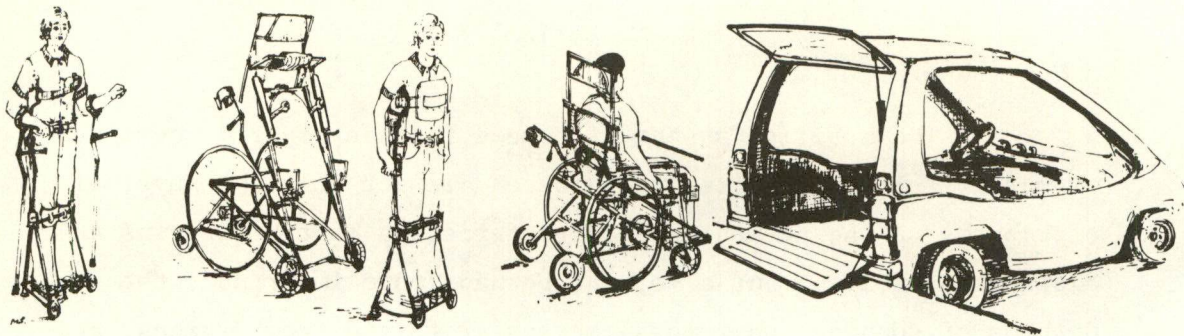
MODULE I--SHORT-RANGE MOBILITY

Walking, even short distances, with current devices is not practical for virtually all patients with spinal-cord impairment. The patient's ability to maneuver is limited to a small area. The fine movements which are required to locate oneself within the reach of an object, be it located low, high, or in an obstructed position, are often unattainable. To date our concept of Module I can be represented by a crutchless, standing orthosis, with pivot-walker and crutches (Fig. 1). An arrangement of this type allows the patient to maneuver in confined areas and narrow passageways, and see and work from a standing position. While pivot-walking without crutches is possible in spaces like bathrooms, or kitchens, the rougher terrain and longer distances have to be transversed with the use of crutches. This type of Module I

SHORT RANGE

INTERIM RANGE

LONG RANGE



MODULE I

MODULE II

MODULE III

DISTANCE -FEET
TIME -SECONDS.
SPACE -ROOM, OFFICE.
(CONFINED)
MODE -UPRIGHT.
DEXTERITY -FINE. PRECISE.

-YARDS.
-MINUTES.
-HOME, NEIGHBOURHOOD.
-SIT/STAND.
-GROSS (NOT TOO PRECISE)

-MILES.
-HOURS.
-CITY, INTERCITY.
-SITTING.
-PRESENT FORMS OF
PUBLIC TRANSPORT.

Fig. 1. Ambulation

is not only versatile in short-range activity but offers a wide choice for connecting directly with other modules. It thus should be possible for the patient to remove himself from a wheeled transporter--Module II (Fig. 1), place the transporter in the trunk of a car, and then move to the seat of the car. This kind of freedom to interconnect with different components in the transportation system in fact is utilized by the able-bodied all the time. We walk to our car (short-range activity), drive the car to the airport's parking lot (long-range activity), and then walk (short-range activity) to the airport shuttle bus, which moves us across the interim distance so that we are within walking distance of the ticket counter.

HUMAN MODULE

The mobility units should receive the human frame as a living organism with many physiological, psychological, and biological needs--not as if it were a static object. The person

Mobility for SCI Patients

and his machines should form a dynamic mobility system which facilitates such functions as programmed relief of weight-bearing areas, exercising, general changes in posture, and other movements that play a great part in maintaining a good physical state and healthy mental attitude.

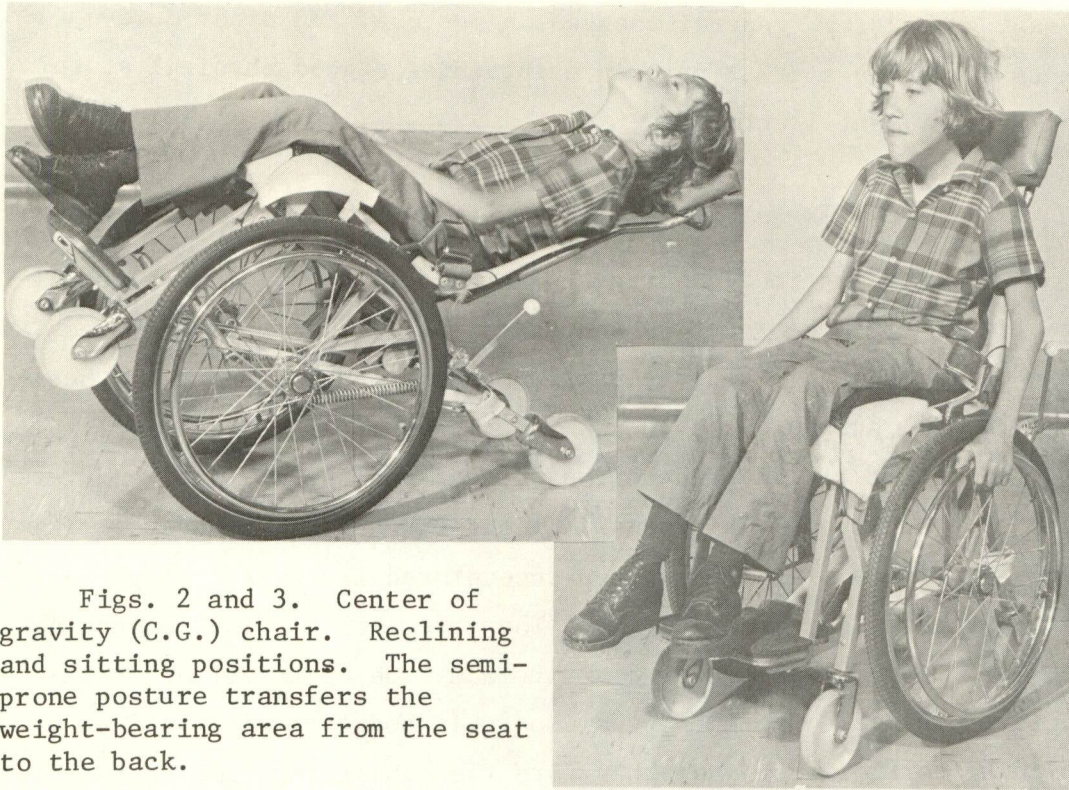
MODULE II--INTERIM-RANGE ACTIVITY

The intermediate range of transport (Fig. 1) involves bridging the gap between the short and "public" transport systems. Most often Module II would consist of a wheeled transporter (wheelchair, cart, scooter, etc.). Whether the unit is externally powered or not will depend on the patient and the distance and terrain to be covered. This usually limits the range to several city blocks. The barriers most often encountered are curbs, steps, narrow passages, and rough terrain. The interesting point concerning Module II is that while the distance and time to travel are relatively short, the patient often uses this module as a base from which to work or rest, and therefore the ambulation time represents only a small portion of the actual usage time.

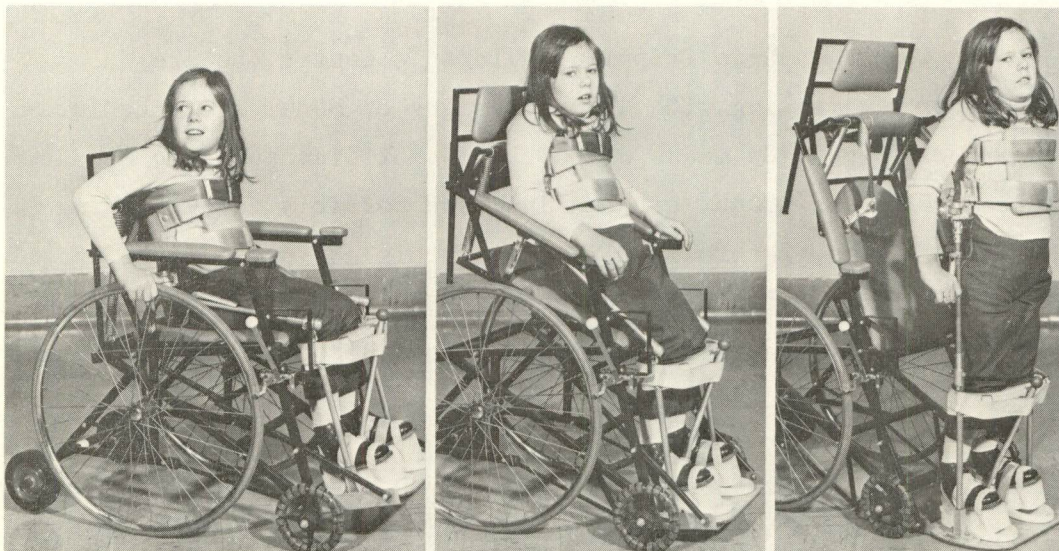
At the Ontario Crippled Children's Centre, we are presently experimenting with unique designs of Module II, the functions of which provide means of quick connect/disconnect to Module I, and include sit/stand, sit/recline, and possibly curb-climbing attachments (Figs. 2 through 6). All of this equipment is being developed primarily for the teenage spina bifida patients, but obviously it or variations should be useful to other types of patients.

MODULE III--LONG-RANGE ACTIVITY

Generally, mobility for long-range activity (Fig. 1) will be provided by Module III (car, boat, plane, etc.) along the existing routes of "public" transport (highways, railroads, airways). It may be necessary to standardize or even modify, in some instances, both "public" transport and the system for the handicapped to make



Figs. 2 and 3. Center of gravity (C.G.) chair. Reclining and sitting positions. The semi-prone posture transfers the weight-bearing area from the seat to the back.



Figs. 4, 5, and 6. The OCCC stand-up chair. The functions of sit/stand, sit/recline, quick connect/disconnect and possibly curb climbing will be built into this wheeled transporter.

Mobility for SCI Patients

them compatible. Devising methods for connection to systems for the able-bodied is of great importance--it would certainly remove any barriers to independence.

SUMMARY

It is my opinion that a person's life-style revolves around the ability to manipulate the environment at close range and, while a mammoth task remains in the area of connecting to "public" transport and creating ingenious Module II-type devices, very little benefit will be realized by the patients until the Module I-type device and the mobility provided is meaningfully integrated into the total, modular system of mobility.

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POSITIONING AND SEATING

John Rogers

Because the results of most of the research on pressure on soft tissues is well documented, I feel that it will only be necessary to bring you up to date on the problem of tissue-trauma brought about by excessive pressure, and then emphasize the relationship between patient-positioning and breakdown of tissue.

About six years ago, our efforts in measuring pressures developed in artificial-limb sockets led to the development of special solid-state transducers and then on to a simple pneumatic transducer which has proven to be useful in measuring pressures in the conduct of our Tissue Trauma Pressure Clinic.

The Tissue Trauma Study Group (TTSG) has been expanded from one engineer to a team which includes a plastic surgeon, three orthopedic surgeons, one orthopedic resident, three physical therapists, one research assistant, and a rehabilitation engineer.

A typical pressure sore that has developed on the trochanter because side positioning occurred beyond the time allowable is shown in Figure 1. This is typical of the pressure sores that we see. They usually develop from sitting or lying on one spot so long that the blood flow is affected, but they may occur in some types of peripheral vascular disease.

The pneumatic transducer shown in Figure 2, originally developed in the prosthetics program to determine interface pressures, is made up of a grid of contact points, and is placed under the ischium or over large bony prominences. This simple transducer has been used extensively in our Pressure Clinic, and is critical to the success of the Clinic.



Fig. 1



Fig. 2

A hand-held read-out device indicates peak pressure (Fig. 3) between the sole of the foot and a shoe insert (Fig. 4). A pneumatic transducer with the readout (Fig. 5) is especially designed to monitor the interface pressure under bandages and casts (Fig. 6). Because of the ability to monitor pressures objectively and to define suitable pressure-relief paddings, the Pressure Clinic directed

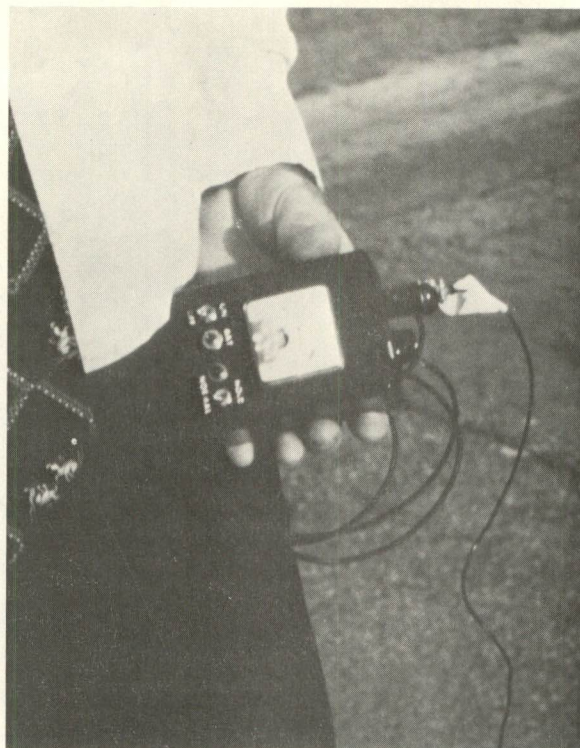


Fig. 3

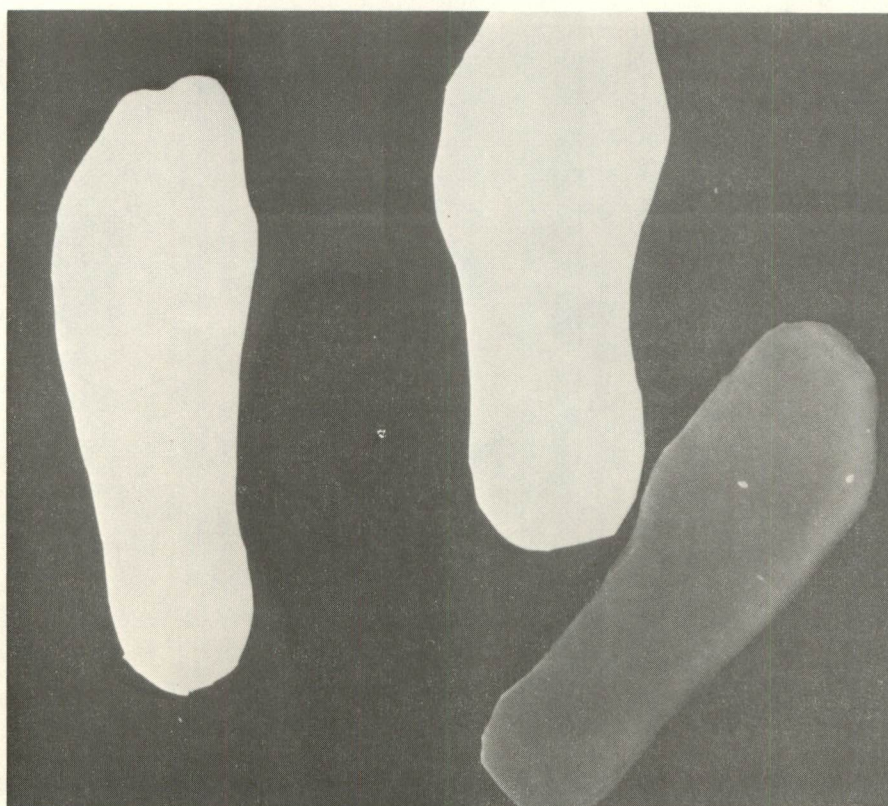


Fig. 4

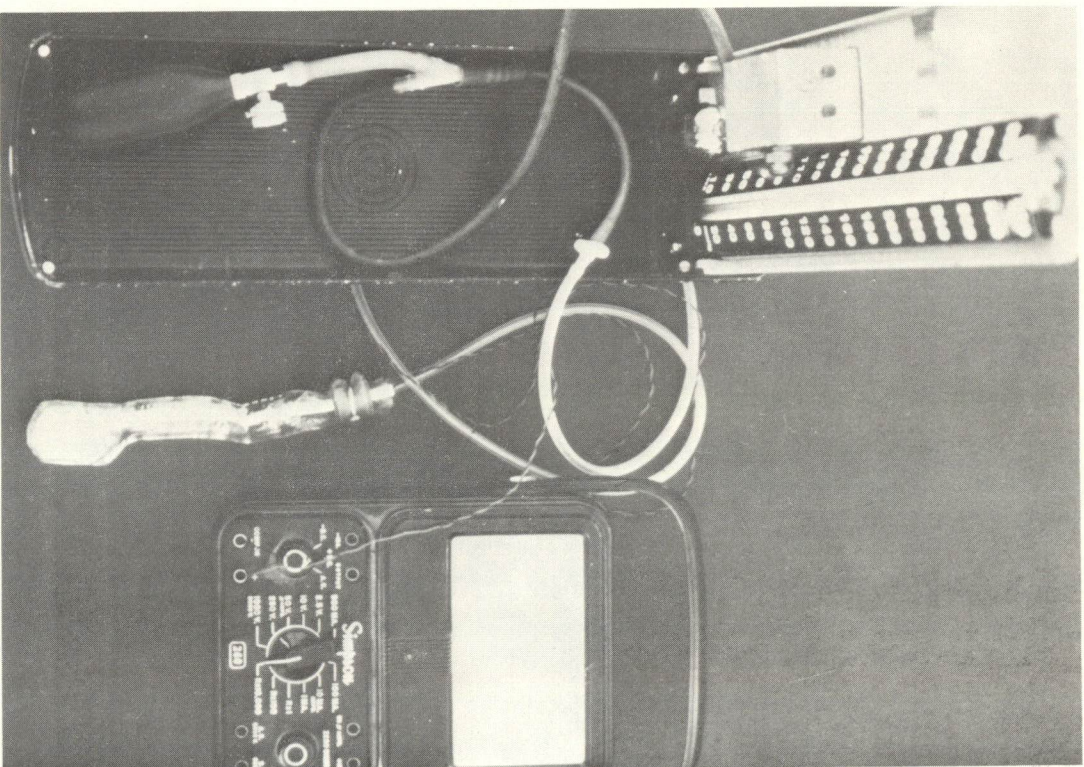


Fig. 5

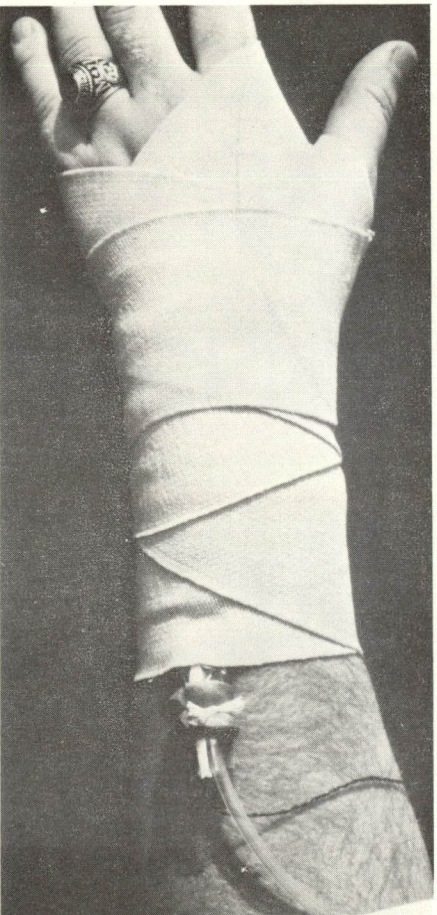


Fig. 6

John Rogers

by a physical therapist was established. A typical scene involving seating and positioning is shown in Figure 7.



Fig. 7

Positioning and Seating

A report of a study that was conducted several years ago, evaluating various types of cushions for wheelchairs, has been published in the *Bulletin of Prosthetics Research* (2). A report on positioning and the findings that we have obtained from the Pressure Clinic will appear in the first revision to the *Orthopaedic Appliances Atlas, Vol. 1*, to be published in 1975. (A copy of the manuscript can be made available.) Another article to appear in the same publication will discuss hand controls for the handicapped which can be used to determine transportation requirements for patients (5), and copy is available. A three-year follow-up study of a special cushion was conducted by an orthopedic resident and is available from the Rancho library. Another device reported upon by TTSG is the trunk support. An article on this item appeared in the *American Journal of Occupational Therapy* last year (1). In addition to these reports, the periodic reports of the Rehabilitation Engineering Center contain details of the methods used by TTSG.

Some of the work we have done to date on quantitating some of the variables used for fitting patients is discussed below.

As you all probably know, Dr. Paul Brand has been studying breakdown of tissue of patients with leprosy in India and in Carville, Louisiana. Through his efforts and those of Mr. Tuck in England, Plastazote was introduced as part of a method to distribute forces over tissue. Dr. Brand is also responsible for first using temperature differentials to indicate the viability of tissue. From these initial concepts the Tissue Trauma Study Group has conducted studies with specially designed temperature/pressure probes (TEMPRESS).

Figure 8 illustrates differential temperature changes resulting from pressures of 700 mmHg applied for approximately 20 min. and then released. This differential-temperature response

has been correlated somewhat with the pressure versus time allowed before breakdown (Fig. 9) in Figure 10. It should be noted that as pressure is maintained for longer periods of time the differential temperature tends to remain elevated when pressure is removed, indicating potential breakdown. For example, at 100 mm the patient can quite reasonably be expected to be able to sit for two hours without risk.

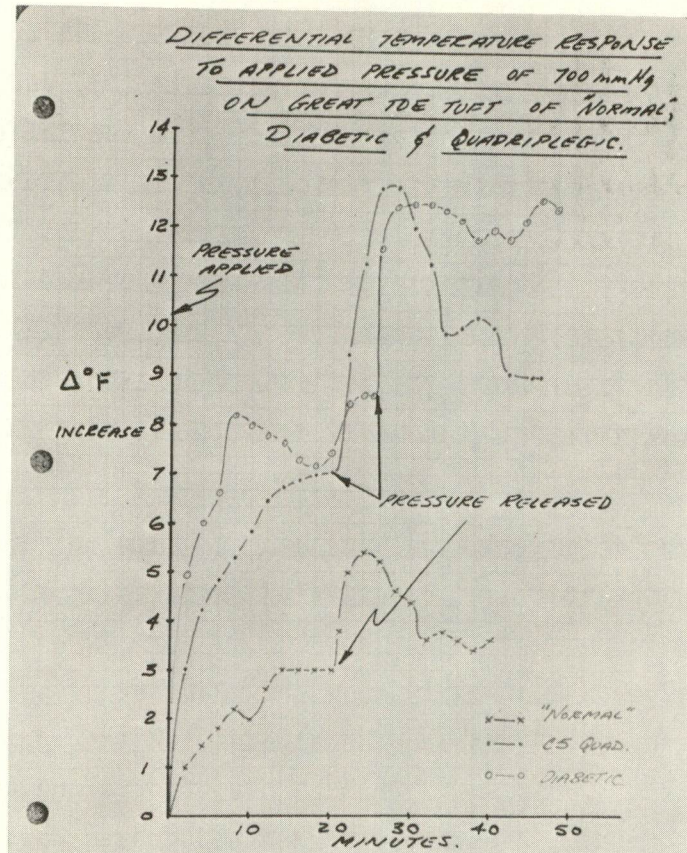


Fig. 8

We haven't found all the answers. We are busily engaged in investigation of correlation of temperature differentials with various aspects of tissue breakdown so that we can define those limits beyond which tissues begin to break down; and, of course, we are correlating those findings with thermographic and other pressure studies. Shoe inserts, bed pads, wheelchair cushions, and other types of padding or interfacing

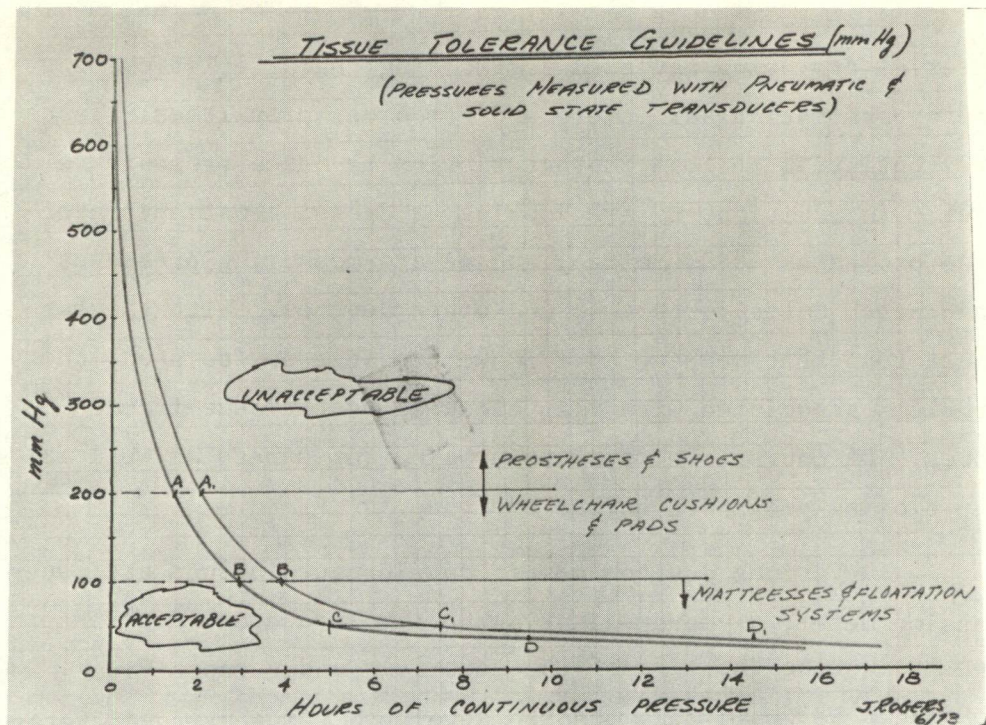


Fig. 9

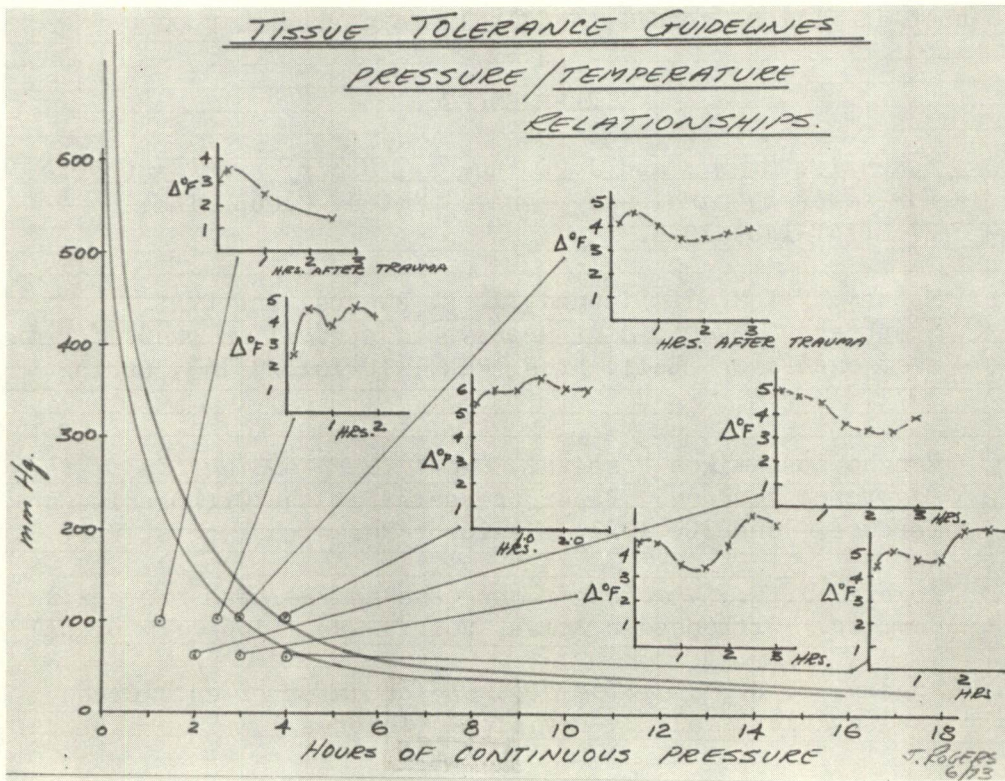


Fig. 10

material are being reviewed for molding characteristics, for energy-absorption abilities, and for other properties. Tests are continuing on foam characteristics to match pressure relief. In addition, we are looking at dressing-patient interface pressures (5-30 mm Hg), and we are measuring pressures underneath casts, orthoses, and other devices. With the surgical team that we have in TTSG we are able now to study the problems associated with flap closures over tissue-trauma sores. Of course, we worry about lines of stress as well as the closing pressures across the flap.

Various devices now in development include a tissue-tension meter, a vacuum-limiting device, and a cycling tester for evaluating the life of the materials under repetitive loading. We would like also to develop a temperature-differential readout device that will be more suitable for clinical use so that it will be readily available to everyone.

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LEFT TO YOUR OWN DEVICES:

The State of the Art of Wheelchair Design

Ralf Hotchkiss

An ideal mobility device should enable a person to use all of his strength and coordination to carry out every part of living that is theoretically possible. If one has a fair degree of arm strength, for example, the problem is not a lack of power but a lack of a way to apply that power. In this case, a good machine should enable the occupant to move about freely on a smooth surface or past any array of obstacles while carrying at least one pot full of hot tea; kneel down under the sink to fix the plumbing; lean over the engine compartment to do repairs; or stand up to the top shelf so quickly as to not mind picking up everything you drop; pay surprise visits to friends on the third floor with narrow doors; chug through the snow; or hike in the woods.

The main problem in realizing all this is that there is little serious work going on in the development of the necessary hardware. Many independent inventors are tackling one or another basic deficiency of wheelchairs but, judging from their patents, except in a few instances most new designs create more problems than they solve. The wheelchair industry is doing even less. Led by Everest & Jennings, they have been only gradually debugging the basic designs introduced in the Thirties, Forties, and Fifties by the founding partners. The only competition that exists in the industry is based primarily on marketing--not on basic function of the wheelchairs or even seriously on price.

The smaller companies, apparently, are happy not to compete on price because they can make more money selling a few wheelchairs at current American prices than they could selling more at a price more closely tied to manufacturing costs.

Ralf Hotchkiss

The manufacture of a wheelchair is somewhat comparable to that of a Schwinn bicycle, but on a smaller scale. What wheelchair manufacturers save in gears, chain, and steering mechanism, they lose in casters, greater number of brazed joints, and chrome plating. If the \$80 price of a 3-speed Schwinn is doubled to allow for smaller production, one approaches the \$180 price of an Everest & Jennings sports-type wheelchair available in England today. This English Everest & Jennings model is a fairly good machine in comparison with present-day wheelchairs. Unfortunately, E. & J. does not allow this model to be shipped to American customers. The nearly identical model Americans are allowed to buy has been given the inexcusably high price of \$566.

It might appear that E. & J., with its comfortable market position, would not be likely to carry out the kind of NASA-type project which is necessary to study the spectrum of disabilities and generate whole families of liberating devices. But E. & J.'s market position has been slipping considerably; perhaps now there is the economic incentive.

ASSETS

The most important and most overlooked step in generating a new mobility device is to understand thoroughly the characteristics of the present devices. As they are now, wheelchairs allow most users the barest chance to be self-sufficient; to lose any of their peculiar set of attributes, even if another is gained, is generally disastrous.

Keep All

<u>Weight:</u>	30-60 pounds
<u>Width:</u>	19-26 inches
<u>Length:</u>	42 inches
<u>Folds</u>	to fit behind car seat
<u>Rolls</u>	over minor obstacles
<u>Turns</u>	on a dime

Left to your Own Devices

Of particular importance are the width and the folding feature. The new machine should fold in such a way as to fit behind the seat of a two-door car, because most independent wheelchair users travel this way. The width of most present wheelchairs is too great, so any new device that is still wider will be useless in most places.

DEFICITS

The deficits of present wheelchairs can be divided into two categories: *easy*, for deficits that could be eliminated from the present designs; and *difficult*, those that require significant changes or which require completely new machines.

[Electric wheelchairs are not discussed here. To cover the explosion and fire hazards, thermal hazards, incomprehensible control-box-width problem, electrical problems, drive-train problems, foreign-trade problems, and power-waste problem of the current electrical wheelchairs requires another paper.]

Remove Any

<u>Easy</u>	<u>Difficult</u>
Reduce width	Curb climbing
Strengthen and lighten frame	Shorten chair
Lessen rolling resistance	Kneeling, bending, standing
-downhill steering	One-hand operation
-caster inefficiency	Rough ground and snow mobility
-caster shimmy	Stair climbing
Strengthen wheels	
Snow mobility	

WIDTH

The most important change, easy or difficult, is reduction of the width. Excess width is the single most debilitating aspect of modern wheelchairs. The average wheelchair forbids its owner full access to critical parts of most private homes and public facilities. Indeed, there are not many other places to

Ralf Hotchkiss

go. In a recent survey by Project Volunteer Power of the President's Committee on Employment of the Handicapped, the manufacturers who chose to respond unanimously said there was no serious problem. Several stated that the average door width is 30 inches. That may be true, but the average building has critical doors which are only 22 inches wide--and if you can't use those doors, you can't enter the building. The most common wheelchair for "independent" living--the E. & J. standard size, removable arm, Premier--is 26 $\frac{1}{4}$ inches wide. It can be narrowed momentarily by a crank-type "narrower," but not to 22 inches. In addition, the mechanism for adjusting the width is slow and cumbersome, and it can't be used by many otherwise independent quadriplegics.

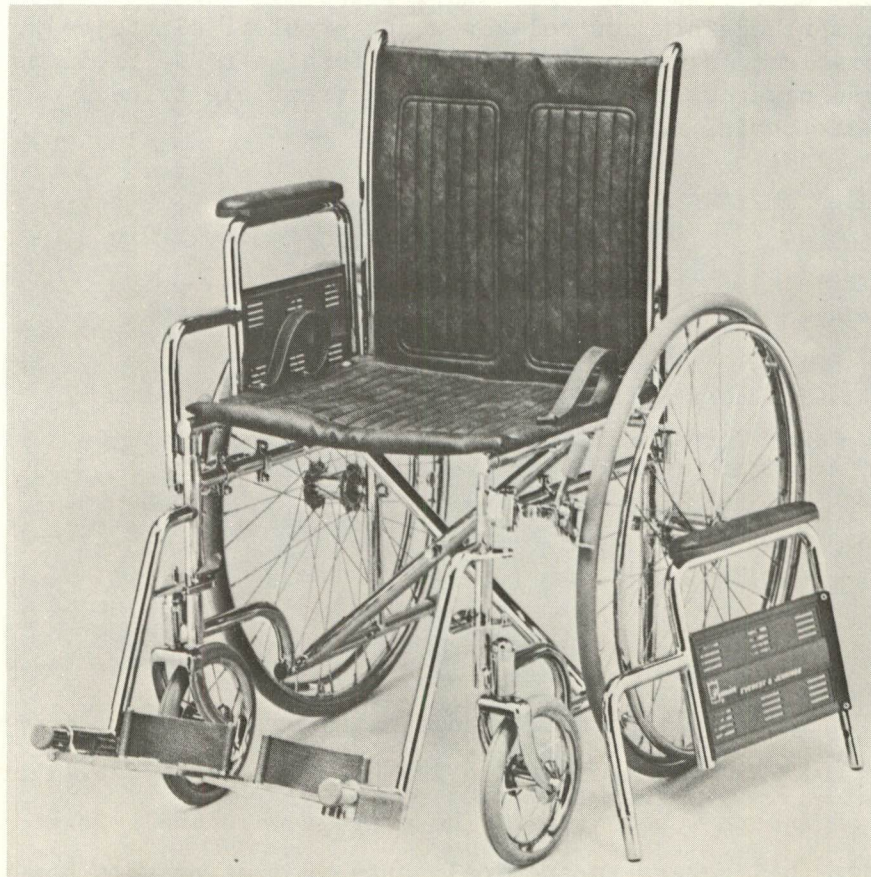
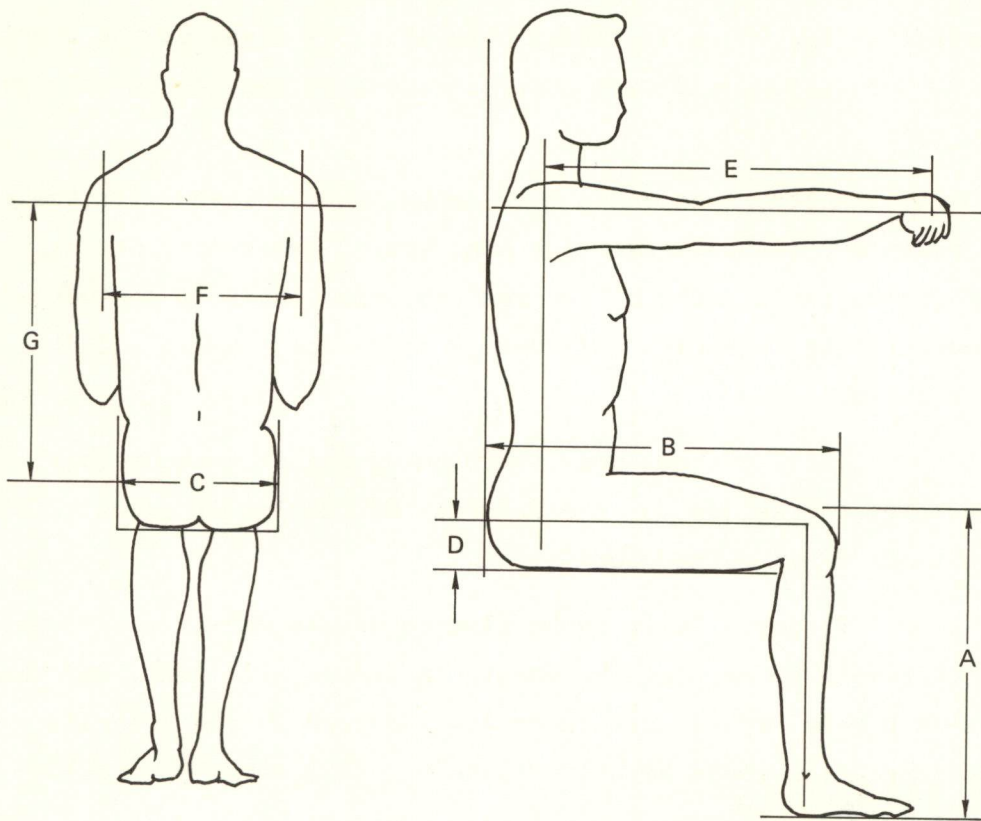


Fig. 1. The E. & J. standard size, removable arm, Premier.

Left to your Own Devices

For the vast majority of wheelchair users, then, most buildings are inaccessible. But the width problem is not a technical one. It can be seen from the anthropomorphic data that a 50th percentile person could fit into a seat 13-3/4 in. wide (with 14 in. upholstery to account for the seat sag). Such



	<u>5 %ile</u>	<u>50 %ile</u>	<u>95 %ile</u>
A. Knee height	19.40	21.37	23.29
B. Buttock-knee length	21.46	23.33	25.35
C. Seat breadth	12.10	13.74	15.78
D. Back adjustment	2.30	2.95	3.57
E. Arm reach (to knuckle) (joint-to-joint)*	26.70	29.03	31.40
F. Shoulder breadth (joint-to-joint)*	12.82	13.84	14.68
G. Back height (joint-to-joint)*	17.14	18.90	20.70

* Joint-to-joint measurement derived from standard anthropometric measurements. All dimensions are in inches.

Fig. 2. Anthropometric measurements.

widths are available, but their use has so far been effectively discouraged by providing only two widths for immediate delivery and mislabeling the 16 in. which fits 95 percent of the population as "narrow," and the one 2 in. wider as "standard." A similar move for the convenience of the clothing industry would provide only extra-large and XX-large clothing. Proper wheelchair fitting, which is likely only if it is urged by the wheelchair industry, could save most users one to two inches of overall width.

Another one and a half inches can be saved with the wraparound removable arm. The many years' delay in reducing the unacceptable width of the removable-arm chair is poor testimony to the ingenuity and concern of at least Rolls and E. & J. personnel.

These two measures, both using existing technology, can make it possible for the majority of wheelchair users to negotiate 22 in.-wide doors.

Properly built spoke flanges on the wheels would save another inch by keeping the wheels in proper alignment, and the one-inch wheel-wobble clearance now required by the Veterans Administration could be halved safely. This step would bring over 95 percent of wheelchair users within the 22-in. overall width, giving them access to most places now inaccessible. None of the good features of present models needs to be sacrificed to permit reduction in the width.

SPOKES

One of the greatest nuisances of wheelchair maintenance is spoke breakage. This came as quite a surprise to me, after years of highly competitive bicycle racing where I experienced no broken spokes except as a result of direct impact. Wheel spokes, even the heavy ones, on many wheelchairs often

Left to your Own Devices

become loose soon after tightening, and break in large numbers for no apparent reason. As any good bicycle mechanic can tell you, the trouble is not weakness of the spokes but rather in the hub design. The holes for mounting the spokes are too big and the metal is so thin that the bent shaft near the head of the spoke is allowed to straighten out, the spoke loosens, and eventually breaks. This problem is present on all American E. & J. wheelchairs I have seen, but not on the German E. & J. models or some of the other American brands.

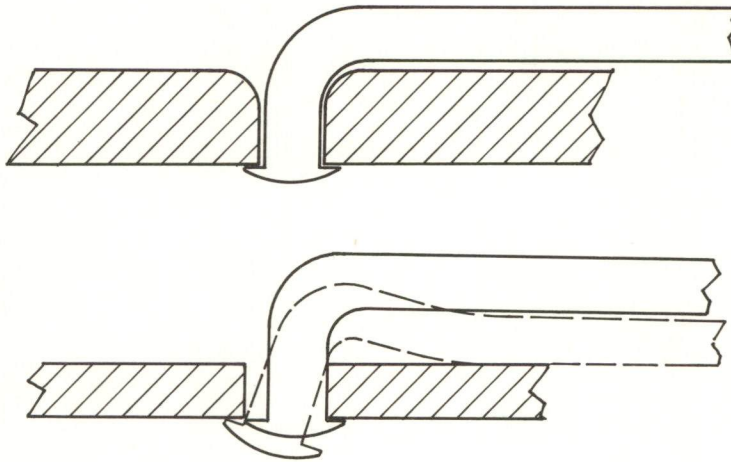


Fig. 3

Use of a proper bicycle hub would strengthen the wheel enough to keep the rims in alignment much better, would permit the use of lighter spokes, and decrease the need for stocking spokes of many diameters. Thus, any bicycle shop could handle spoke repairs with their normal stock.

WEIGHT AND STRENGTH

The need for lighter wheelchairs has long been recognized; light weight and the X-frame were the bases for E. & J.'s first patent in 1937. The wheelchair industry has responded well to this need by thinning out the steel to an optimum point. There is some possibility, though, that both lower weight and higher strength may be achieved through more basic changes.

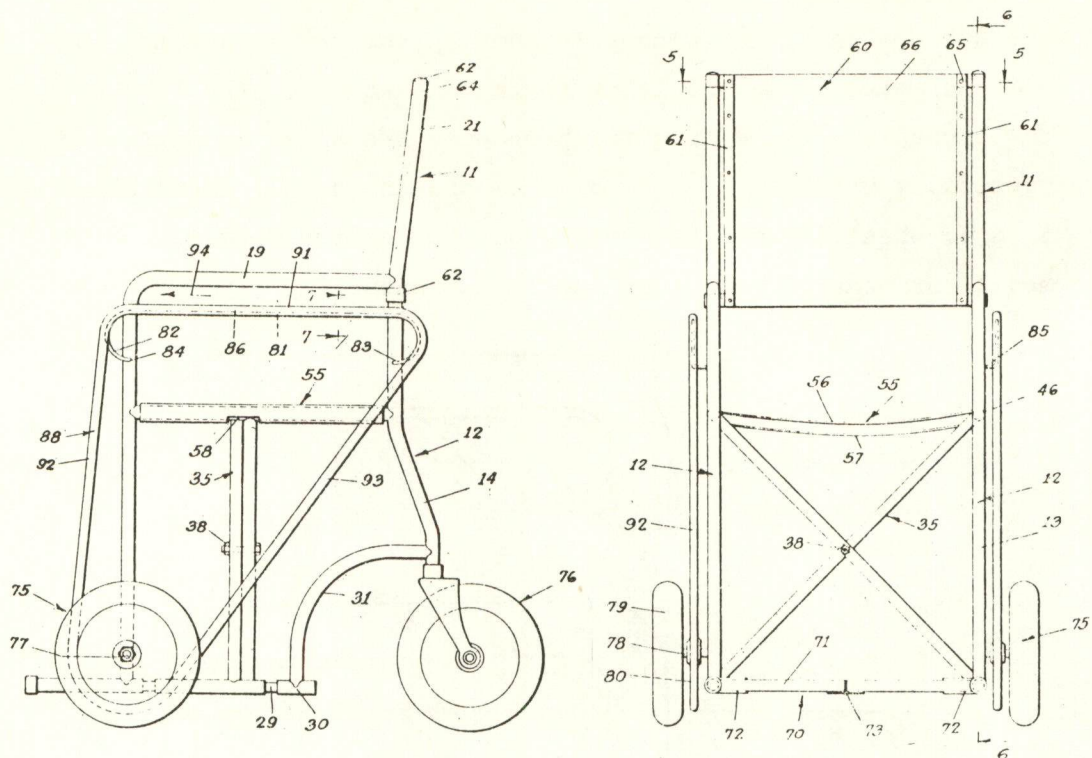


Fig. 4. E. & J.'s first patent (No. 2,095,411--Oct. 12, 1937).

Around the turn of the century, bicycle manufacturers recognized that bicycle frames could be made much lighter and stronger if the frames were connected with lugs which withstood the concentration of shear stresses near the tubing junctions. These lugs did the job better than the brazed joints used on older-style bicycles and newer wheelchairs. Perhaps this framing technique has been tried. If it has been tried but made no difference, I would suspect that it is because the wheelchair is not designed to take advantage of the strength of its tubing, regardless of the stability of the joints. A bicycle, for comparison, is a simple double triangle with most of its forces

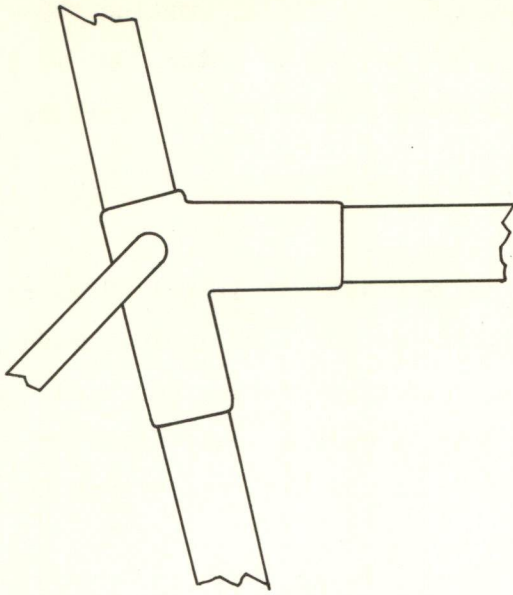


Fig. 5

applied to stretching and compressing the tubing. A wheelchair is a mess of miscellaneous plumbing with footrests, casters, and main wheels applying forces in many directions.

A classic case of failure occurs in the X-frame, in which the X-frame bends or breaks in half while the chair is coming down from a curb. The force of the rider pushing

down on the seat (and the ground pushing up on the wheels) is concentrated in the X-frames, causing them to bow. Because of this circumstance, X-frames must be made heavier than the other tubing in many chairs. A tensile connection near the bottom of

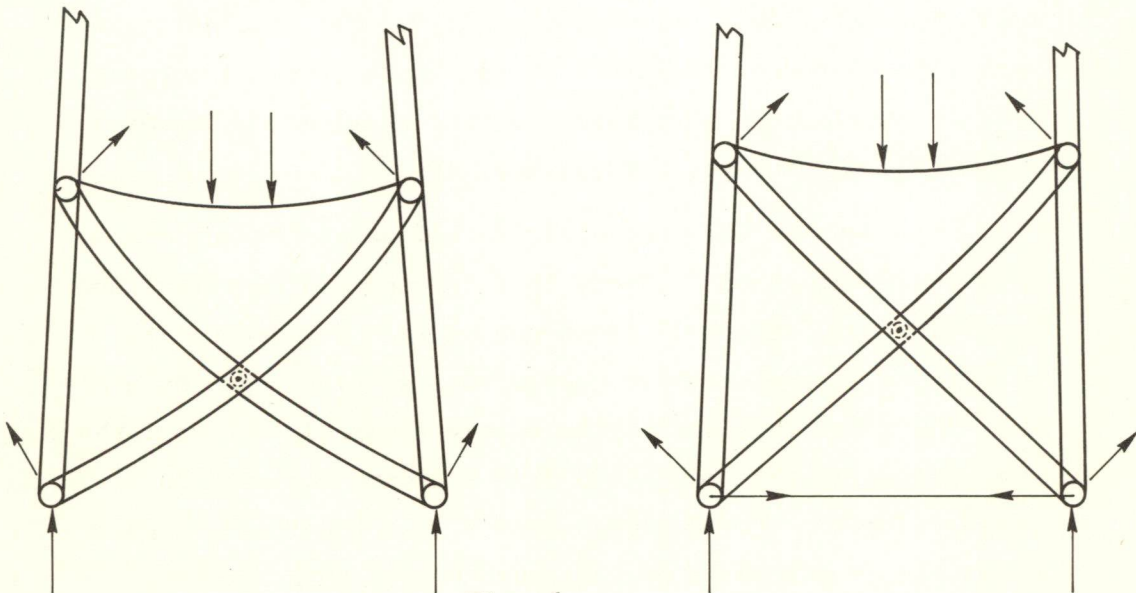


Fig. 6

the X-frame would make the bottom triangle rigid, cutting the flexing force at least in half. This may be of value, but more to the point it would be studying whole new frames and framing technologies.

ROLLING RESISTANCE

A wheelchair, for all the mobility it is called on to offer, is the least efficient, human-powered land vehicle made. It not only rolls quite poorly on coarse pavements, but even under normal conditions it makes use of only a small fraction of the energy supplied to it because of the high resistance to rolling.

The reason for this is that the weight on the front casters turns them downhill. Thus, on an ordinarily tilting sidewalk or street, in order to travel in a straight line, the user must drag one hand and push ridiculously hard with the other. Pushing a well-tuned wheelchair at a jogging pace is easy for most users on a perfectly flat surface, but even a sustained walking pace is difficult on sloping pavement.

Some solutions to this problem have been tried, but most impede the indoor maneuverability of the wheelchair in some way. A concerted effort to eliminate downhill turning must be made if the wheelchair is ever expected to become a worthwhile machine for outdoor mobility.

Most of the wheelchair's rolling resistance comes from the front wheels. Their inefficiency can be visualized by imagining pulling a full-grown person in a toy wagon (its wheels are like wheelchair caster wheels) over a grainy sidewalk and comparing that to the energy required to propel the same person at the same speed down the same sidewalk on a racing bicycle. The European E. & J. wheelchairs have pneumatic caster wheels which roll much better than anything

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offered here. They should be made available everywhere. Increasing the diameter of the front wheels would help too--if anyone could figure out how to do it without increasing the wheelchair length.

A centered wheelie-bar can help with the rolling resistance, downhill steering, and curb-climbing problems--but only with riders who are courageous enough to use it.

Caster shimmy seriously decreases speed, and sometimes causes instability and upsets when it happens on a steep hills. Bronze caster pivot bearings have been used to absorb the oscillation, but often they don't work unless the fork nut is carefully, and frequently, tightened. This in turn causes rapid wear of the upper pivot bearing.

I would suggest washers of automotive brake lining placed below the normal ball bearings. After a day's oiling and breaking in, their friction is hardly noticeable, yet shimmy is no longer possible. Their damping force can be varied if necessary by changing the diameter of the brake-lining washer.

CHAINS

It may not seem critical to residents of the Los Angeles area, but for a good part of the year thousands of wheelchair users are totally immobile outdoors. A good snow-traction device, if available, would make a great difference in the

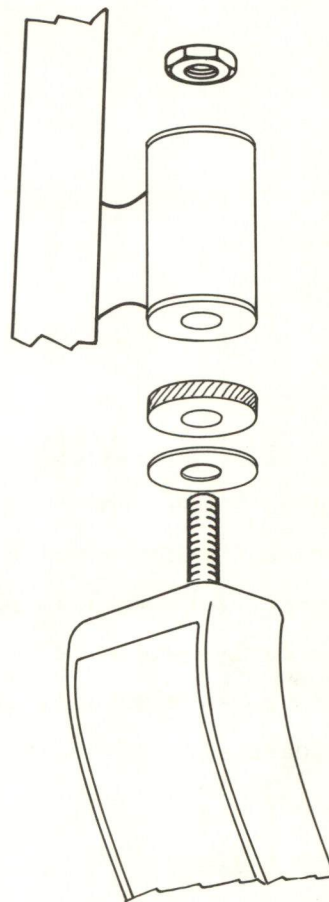


Fig. 7

Ralf Hotchkiss

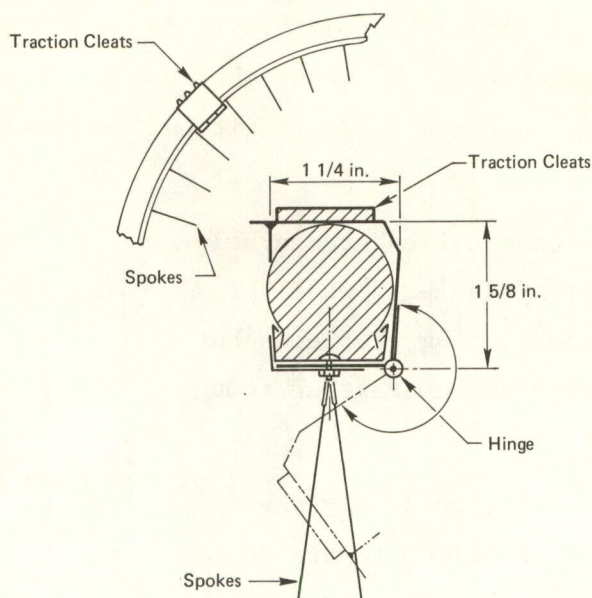


Fig. 8

traveling speeds of many of these people, even if they still couldn't move very fast. Clamps swinging out from between the spokes, or hooks going over the tires, are possible traction devices. Both methods should be investigated. A traction-producing device would be of great value even if the going was slow, because snow usually comes in small patches; i.e., shoveled streets and sidewalks but poorly cleared driveways and parking areas.

CURB CLIMBING

Many curb-climbing devices have been tried; the best one that I have tried or seen is the Coffee device. I understand that Aztec Company is no longer in business. If Coffee has no further plans, I recommend that his device be taken over, refined, and marketed.

LENGTH

After width, length is the primary impediment to maneuvering effectively in indoor situations. A wheelchair ideally should not stick out ahead of the user any more than a

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kitchen chair does but, because of the area needed for the casters to pivot, the footrests must extend about 12 in. forward of the seat, thus preventing close access to closets and corners and requiring wheelchair users to do all work in normal kitchens and workshops from the side.

One solution to this problem is the use of smaller casters and placement of the footrests between them. However, smaller casters roll less freely and get stuck in cracks and holes more easily. Small double-wheels, as are used in Umleroller strollers, tend to roll well on rough surfaces despite their small size. They might work as wheelchair casters, allowing the footrests to be placed between them. The all-directional wheels invented by NASA can move in any direction while pointed straight ahead. Although both of these ideas have possible problems, their drawbacks can only be weighed after the devices have been thoroughly de-bugged and use-tested.

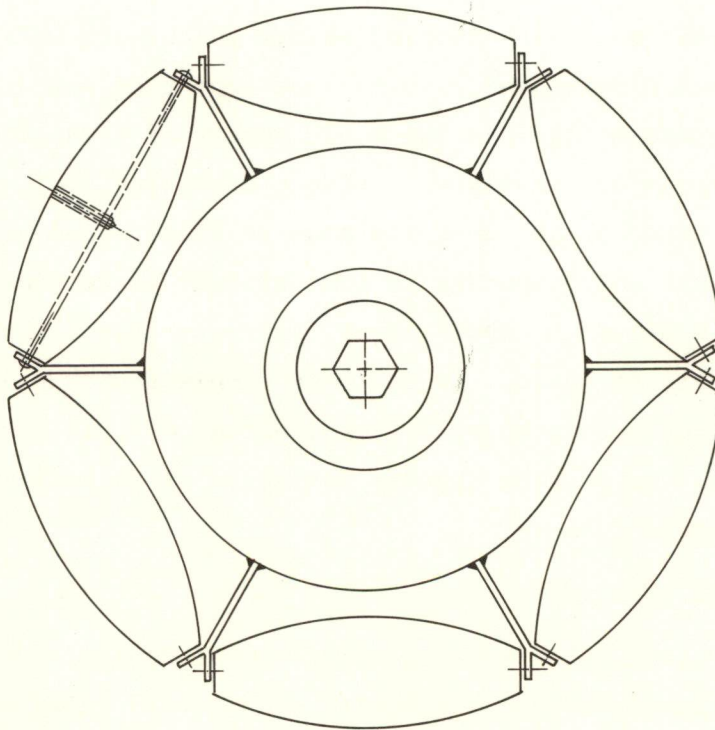


Fig. 9

Ralf Hotchkiss

STAIR CLIMBERS

The need for stair-climbing wheelchairs is a serious one which has drawn much attention from inventors. The technical problems are among the most difficult to solve, especially if the vehicle is to remain usable off the stairs. And of the scores of inventions which have been built, or patented, only a few will even climb stairs satisfactorily. Some, according to their own diagrams, will fall down the stairs--as they leave a step on the way up, their center of gravity is out beyond their point of support. Others are only marginally stable.

Some stair-climbing devices have been driven by multiple stepping wheels and some by legs, but most have been driven by tracks. I learned about one of the drawbacks of tracked vehicles when I drove mine up the front steps of a lovely lady's house in Ohio. She still refuses to acknowledge the gaping hole in her carpet.

The few stair-climbing chairs which work well still have a common problem which so far has kept them out of general use--they do not retain the basic assets of a wheelchair. I rode a German one easily up a flight of stairs, but, after it was unplugged at the top, its massive frame would hardly move. The one which appears to come closest to keeping the wheelchair's assets is the Alamont Staircat--itself a wheelchair with tracks added. It may have problems with width, weight, and cornering on stairs or landings but, if these are not serious, the machine appears workable. I am anxious to see it in operation.

STANDING AND KNEELING

Standing has been one of the most needed and least available exercises for people with spinal-cord injuries. The risk and hassle of ambulation with orthoses convince virtually all trainees not to practice it. The Kwik-Brace is an

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improvement, and the parapodium has many possibilities. None of these devices will be useful for doing everyday work, though, until standing and sitting are so quick and easy that the user can pick up everything he has just dropped. The Bressler chair comes closest to this, though it still has some problems. Peter Bressler's perseverance is at least as remarkable as his ingenuity in that he has overcome the disinterest of the industry and found a manufacturer.

NONLICENSED VEHICLES WITH AN EMPHASIS ON ROUGH TERRAIN

Martin T. Prast

To begin with, we must define rough terrain. To many people, the words "rough terrain" are synonymous with hilly terrain. Unfortunately, for the wheelchair-bound, this is not necessarily the case. Rough terrain for the wheelchair user runs a full gambit of obstacles. Carpeting, doorsills, curbs, stairs, grassy areas, gravel, sand, inclines of various degrees, and even snow and mud, are just a few of these obstacles. Thus, it is obvious that the category of mobility aids which is directed to rough terrain includes everything over and above smooth terrain. This category encompasses curb-climbing devices, stair-climbing vehicles, all-terrain vehicles, and any other type of mobility device.

Now that we have defined rough terrain, we must ask ourselves if there is a need for research to be done in this area. For the disabled individual the answer is obvious, but for the layman it may not be so apparent. I believe there are three very good reasons to be concerned with this problem: education; vocation; and recreation.

In order to get an education one must be able to go to school. Unfortunately, mankind has laid a number of architectural barriers in the way of the handicapped. Therefore, I feel one must devise a way of getting around these barriers.

Having been educated one can get back into the mainstream of society by becoming a functioning member of that society. Unfortunately, the handicapped person is confronted again with the problem of getting to and from their place of work.

Nonlicensed Vehicles

Finally, I believe there is a psychological need for recreation and even a demand for the handicapped to advance beyond just the activities of daily living with a sort of "getting off the pavement and into the woods" attitude.

This brings us to consideration of what is available to the handicapped today. There are approximately eight vehicles which are commercially available and which I consider applicable to the problems of rough terrain. Each of these has certain advantages and disadvantages.

THE "ADVANCED" WHEELCHAIR (Fig. 1)

This chair is very similar to conventional wheelchairs in patient utility. It is a high-performance vehicle specifically adapted for use outdoors. It may be used indoors since



Fig. 1. Advanced Wheelchair.

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its size is not unlike conventional wheelchairs, but it is very noisy. It has a 24-volt system with a proportional control unit. It is dangerous in that it has so much power that it will do "wheelies," but it can be made safe by adding a small set of tip wheels in the rear. The chair can also be breath-controlled or chin-controlled.

THE ZIP CART (Fig. 2)

According to some newspaper articles, this vehicle is used by Governor Wallace. It offers little use to most quadriplegics. The controls are difficult to operate. The cart-like construction offers no wheelchair-type advantages and it is much

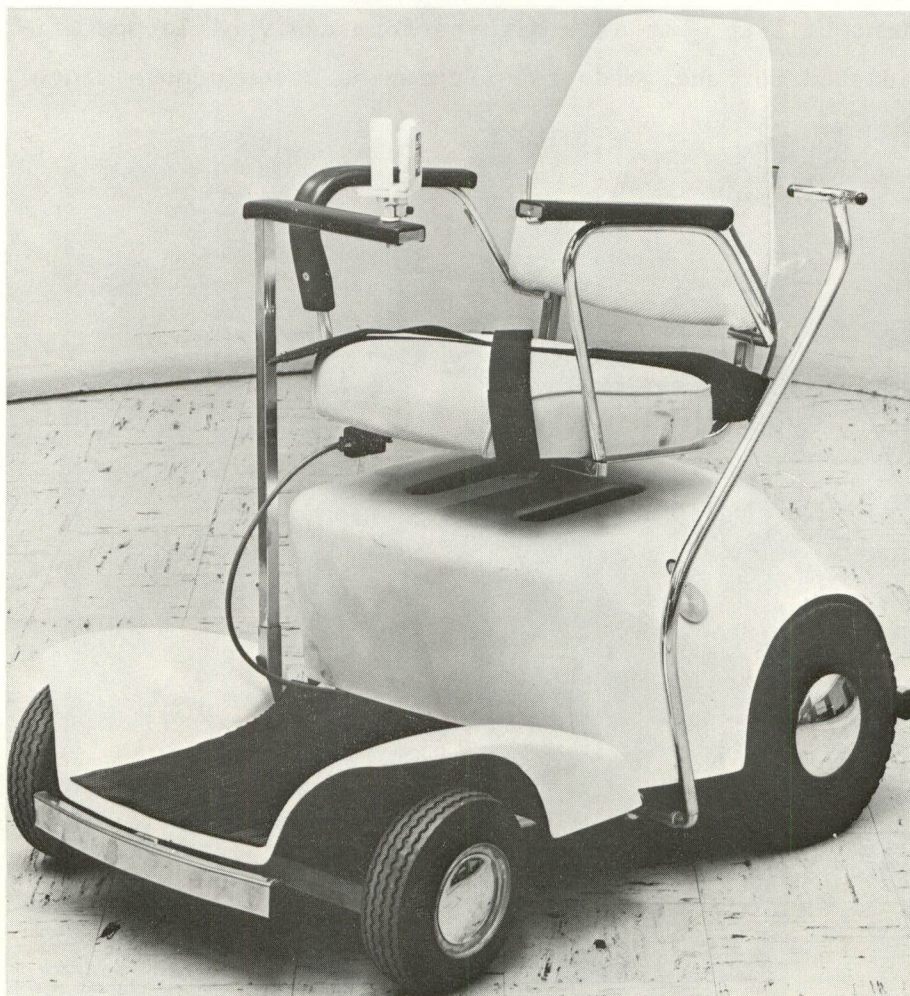


Fig. 2. Zip Cart.

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too fast and sudden. It is good for outdoor use only. It has a 12-volt drive system. The steering is by tiller which presupposes good arm function. It has a mechanical braking system which is elbow-operated and presupposes good trunk stability. It has a variable speed control but its poor construction leads to jamming. Also, the seat is not mounted properly to the cart. The armrests swing away for transferring in and out of the vehicle.

THE STEVEN MOTOR CHAIR (Fig. 3)

Another outdoor vehicle it is very awkward to steer via a swinging armrest. It is not a wheelchair and is very fast and jerky. The three-point stance makes this vehicle inherently



Fig. 3. Steven Motor Chair.

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unstable. It offers very little to most quadriplegics. The armrests and footrests are not movable, thus transferring is a difficulty. It has a 24-volt drive system with a battery charger incorporated into the vehicle. There is a shock hazard present.

E & J MARK 20 POWER CART (Fig. 4)

This vehicle is similar in performance to the Zip Cart and Steven Motor Chair but much smoother and easier to operate. However, it is not directed to the seriously physically disabled and falls far short of the advantages exhibited by the Advanced

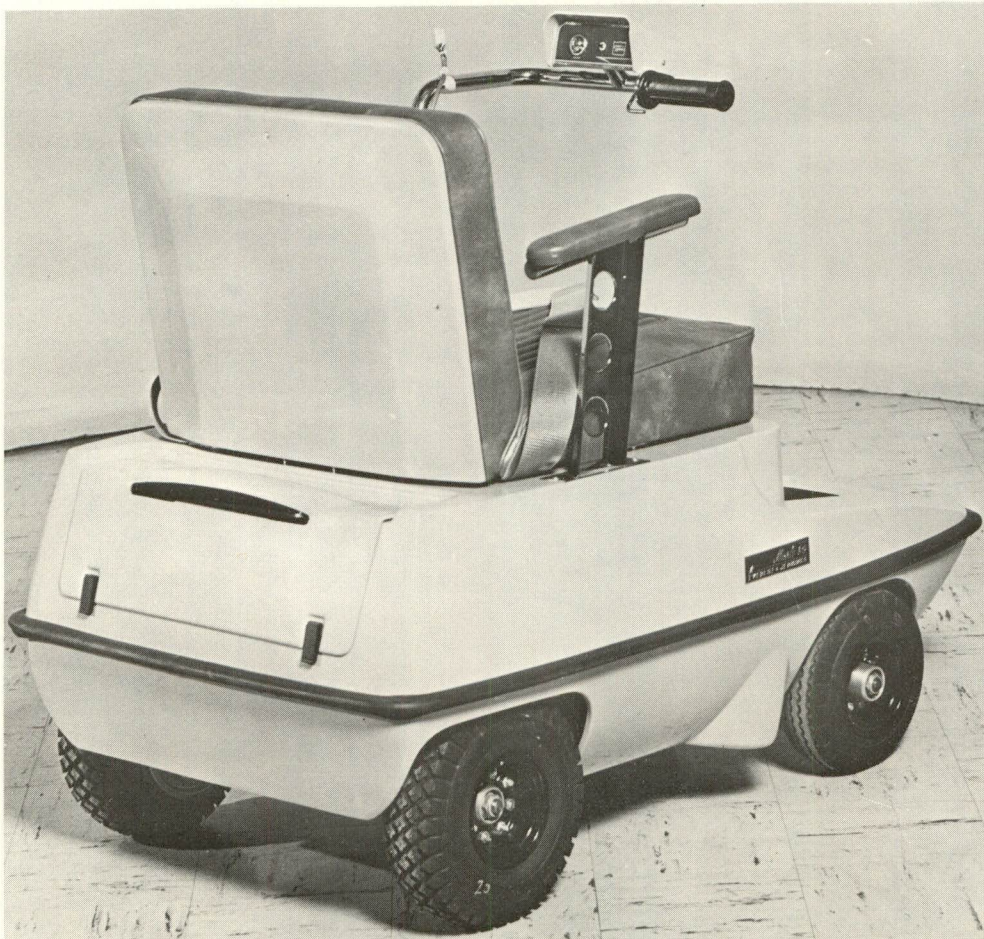


Fig. 4. E & J MARK 20 Power Cart.

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Wheelchair. It has tiller-type steering which offers little use to most quadriplegics. It has a 24-volt drive system and removable armrests.

All of the vehicles mentioned above cost between \$800 and \$1,200.

PERMOBIL EXTERIOR

A very-high-performance vehicle, the Permobil Exterior requires excellent hand, arm, and shoulder strength and range of motion. Trunk stability is necessary as well as good upper limbs on both sides. Possibly it can be used on a farm or difficult terrain. It has a 36-volt drive unit. It is also rather costly--\$2,000-\$3,000.

PERMOBIL SUPERIOR

The Superior is a very comfortable wheelchair and has a substantial power capability. Its cost, unfortunately, approaches that of a luxury automobile--\$8,000-\$10,000. It is usable by a quadriplegic with a breath control. The leg rest and back rest are powered giving it a multiposition chair feature. It has a 36-volt system with the battery charger incorporated into the chassis. Superficially, it may seem that the Permobil from Sweden may be a solution to the rough-terrain problem. Unfortunately, this is not so since the devices are difficult to operate by severely physically disabled as well as being extremely expensive. All the Permobil's have one thing in common--they are difficult to repair. The difficulty exists due in part to the high level of technical competence required, but even more so to the necessity of having spare subassemblies on hand.

. The next two vehicles, I believe, have application to paraplegics alone.

THE COMMERCIAL GOLF CART

These vehicles give the paraplegic a greater range of mobility. They can be readily adapted to fully hand-controlled vehicles. They have three major disadvantages at present. They cannot be licensed for use on roadways, one cannot take his wheelchair along, and the vehicle must be trailered from one area to another due to its size.

COMMERCIAL ATVs

These vehicles give an even greater range of mobility because they can go in water and nearly everywhere. They are fully hand-controlled vehicles as produced and therefore require no modification. These, too, have the same major disadvantages as golf carts.

There are also several experimental or laboratory-curiosity items which must be mentioned. In the article *Five Years of Wheelchair Evaluation*,* multipurpose chairs are described as wheelchairs which offer several auxiliary functions. They are multipurpose devices which theoretically increase patient mobility. For example, stair-climbing wheelchairs would fall into this category. As a class, multipurpose chairs exhibit common problems. Specifically, none of the functions they provide are performed as efficiently as those of the individual devices that they intend to replace. The danger exists that the auxiliary functions may preclude maximum efficiency of the primary function. It is apparent that it is illogical for an individual to use throughout the day a vehicle weighing over 200 lb. as a conventional wheelchair in order to provide a secondary function which is used only three or four times a day.

Stair-climbing wheelchairs have been a subject of many designers for a number of years. The functional requirements

* Peizer, Edward, and D. W. Wright, *Bull. Pros. Res.* BPR 10-11, 9-37, Spring 1969.

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for conventional wheelchairs may, however, be incompatible with the hardware and weight requirements of stair-climbing wheelchairs. At the present state of the art, all proposed stair-climbing wheelchairs seem to become such vehicles while losing some or all of the desirable features of a conventional wheelchair. While this is true for nonpowered models, it is probably also true for powered stair-climbing wheelchairs when compared to the typical powered wheelchair available today. It is apparent that the wheelchair occupant is severely penalized on level ground as he is required to start and stop a device with the added weight of the stair-climbing gear. A powered vehicle, because of its additional weight, requires a larger battery package, and is therefore extremely large and is awkward to use in small spaces.

All of the stair-climbing vehicles which have been reviewed to date exhibit two characteristics. They cannot be folded and most designs use a tread-like tractor belt or similar arrangement which depends upon friction for negotiating stairs. This system is very dangerous because both tracks are required to work perfectly while climbing stairs to avoid an accident.

If we consider a less challenging goal and approach the problem of climbing curbs, the chances of success are much greater. It seems that the curb-climbing mechanism should be incorporated as a supplementary attachment which may be added easily to any conventional wheelchair. The device, of course, should be available for use with nonpowered as well as powered wheelchairs. It is interesting to note that in spite of this reduced design goal, no curb-climbing attachment is in general use today.

In conclusion, we see that in general there are no working practical models available today which would fit into this category of vehicle for the physically handicapped. It may

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be that perhaps we should lower our sights to more reasonable goals, or it may be that our current state of technology precludes us from solving these problems.

Several questions must be answered before pursuing a proposed solution. The first--is there a genuine need for the physically disabled to have these vehicles on an everyday basis? Thus, is there a market? If the answer is yes, then we must ask whether a manufacturer is available to produce these vehicles at a reasonable price and profit so that he will be willing and able to meet these needs. Therefore, is it economically feasible? I think it is necessary to ensure that someone would be willing to produce these items on a regular basis. Otherwise, the finest working device may indeed be fabricated in some laboratory but unfortunately will not be available to the general public. Nevertheless, one must keep in mind that "imagination will continue to be the mother of invention."

I would like to thank the VA Prosthetics Center, and Ronald Lipskin in particular, for all the help they have given in the preparation of this paper.

LICENSED MOTOR VEHICLES FOR HANDICAPPED DRIVERS

Anton J. Reichenberger

Congressional action resulting in PL 91-666 revealed the need for standards and specifications applicable to a wide variety of commercially available, adaptive automotive-control equipment for handicapped drivers. The development of a workable document for the procurement of adaptive automotive driving aids to assure maximum safety to disabled drivers and the general public was given high priority. Correspondence with all state authorities for licensing drivers revealed a complete lack of standards and specifications for the assortment of adaptive automotive-control systems designed, manufactured, and distributed by a number of business establishments in the United States. Surely we all agree that an industry providing useful products and services to many handicapped drivers must have a common interest in protecting the consumer. Therefore, the development of a document to define minimally acceptable levels of safety, quality, and performance to guide manufacturers and installers of driving aids is absolutely necessary.

The first phase in our development program called for an evaluation of all commercially available items, and we consequently purchased driving aids from 16 known manufacturers. An engineering analysis resulted in the recommendation that five adaptive hand-control systems be road tested, working with volunteer drivers from the New York Chapter of the Eastern Paralyzed Veterans Association.

To understand fully the mechanics of currently available hand controls used by handicapped drivers to operate automobiles, we classify these systems into four types, i.e., the push-pull, push right-angle-pull, push-twist, and the crank type. For uniformity in description, we assume that each control is operated with the left hand.

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PUSH-PULL CONTROL SYSTEM (Fig. 1)

To apply the brakes, the driver pushes the operating lever away from him or her in a direction parallel to the steering column, and actuation of the accelerator is achieved by pulling the same lever in exactly the opposite direction, toward the driver.

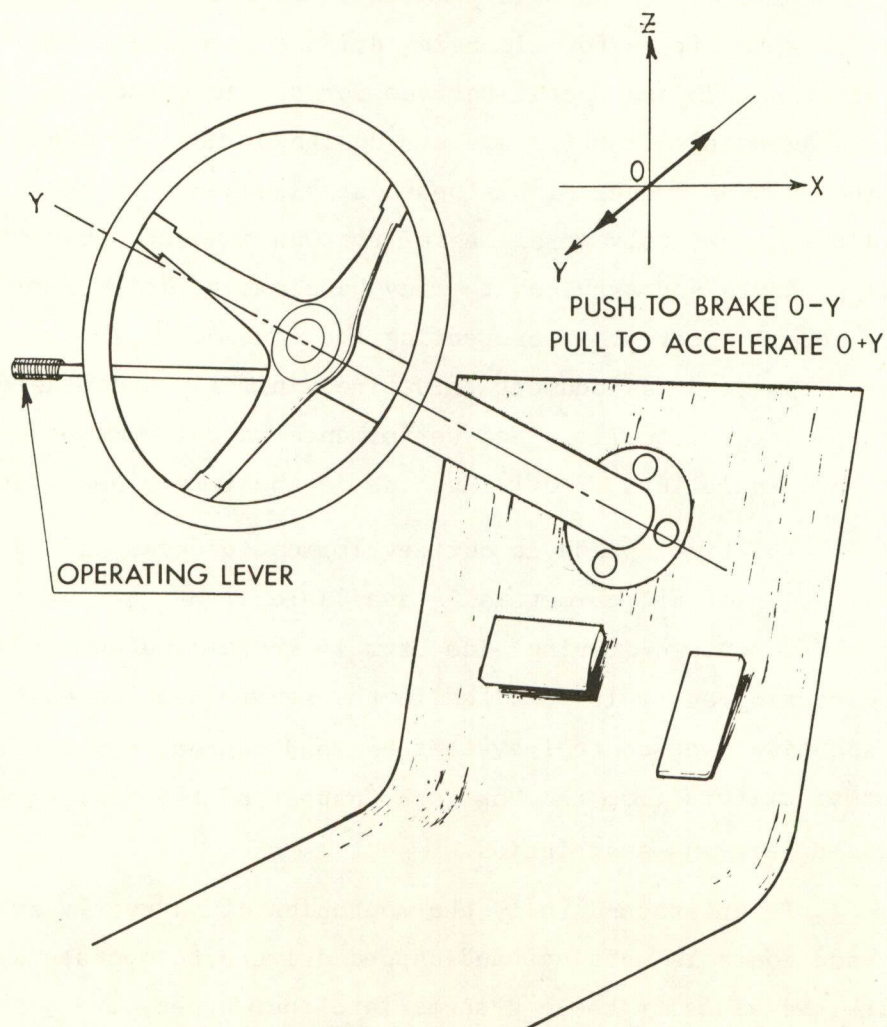


Fig. 1. Push-pull Control System.

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Figure 2 shows a typical push-pull hand-control system installed in a laboratory test device used during the engineering analysis.

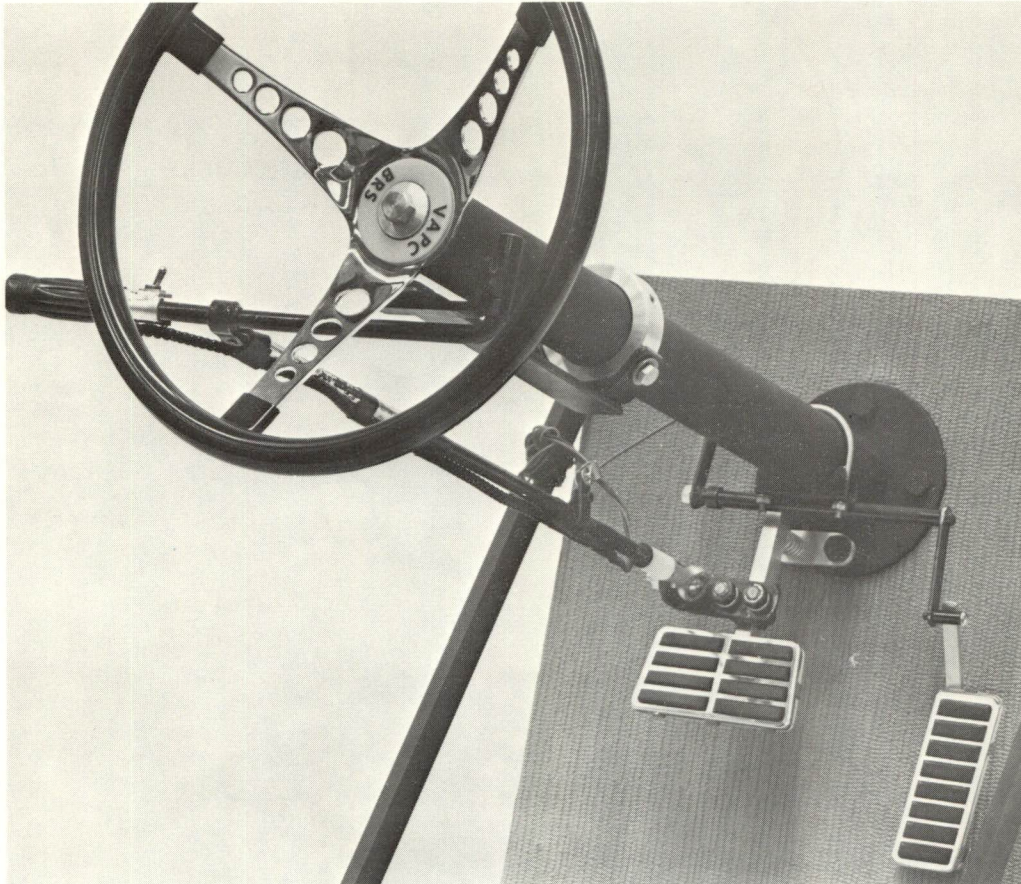


Fig. 2. Push-pull Hand-control System.

PUSH RIGHT-ANGLE-PULL CONTROL SYSTEM (Fig. 3)

To apply the brakes, the driver pushes the operating lever away from him or her in a direction parallel to the steering column, and actuation of the accelerator is achieved by pulling the same lever in a direction perpendicular to the steering column and toward the driver.

Figure 4 shows a typical push right-angle-pull hand-control system installed in the laboratory test device.

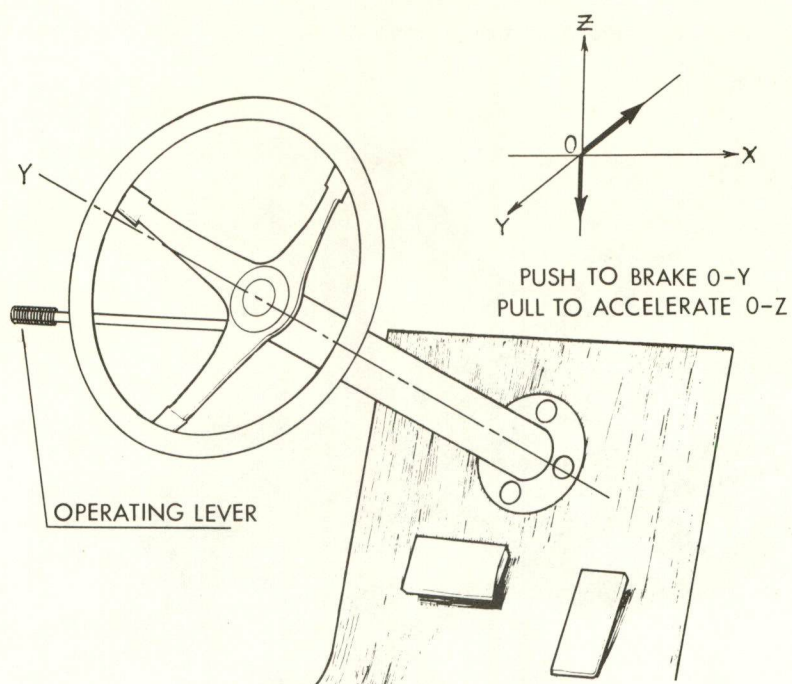


Fig. 3. Push Right-angle-pull Control System.

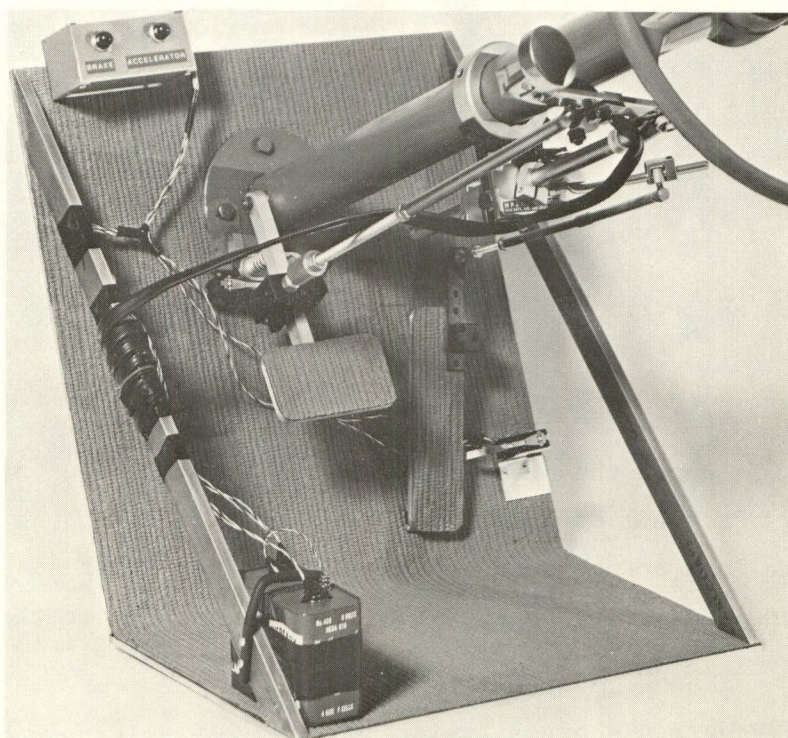


Fig. 4. Push Right-angle-pull Hand-Control System.

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PUSH-TWIST CONTROL SYSTEM (Fig. 5)

To apply the brakes, the driver pushes the operating lever away from him or her in a direction parallel to the steering column, and actuation of the accelerator is achieved by counterclockwise rotation of the handgrip.

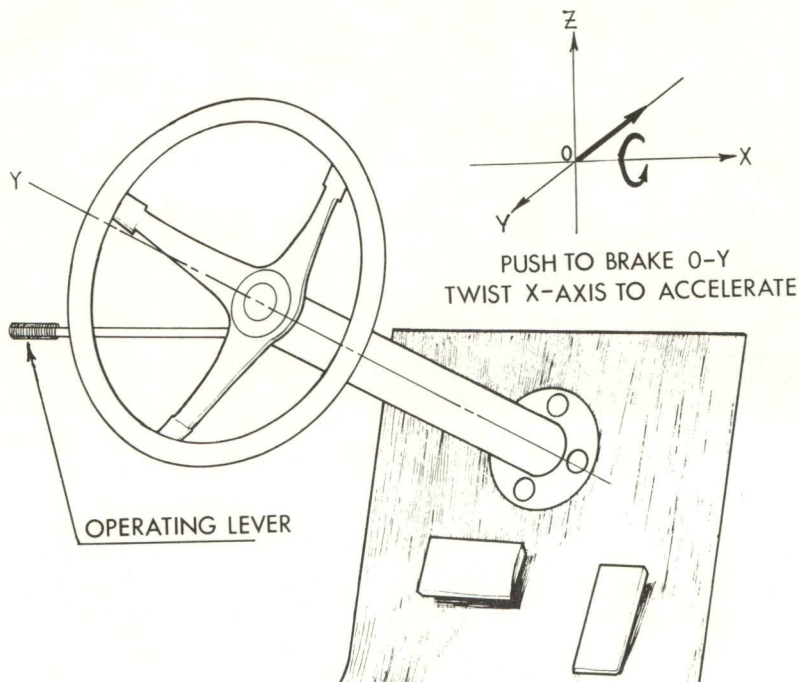


Fig. 5. Push-twist Control System.

Figure 6 shows a typical push-twist hand-control system installed in the laboratory test device.

CRANK-TYPE CONTROL SYSTEM (Fig. 7)

To apply the brakes, the driver cranks the handle in a clockwise direction away from him or her, and actuation of the accelerator is achieved by cranking the handle in the opposite direction and toward the driver.

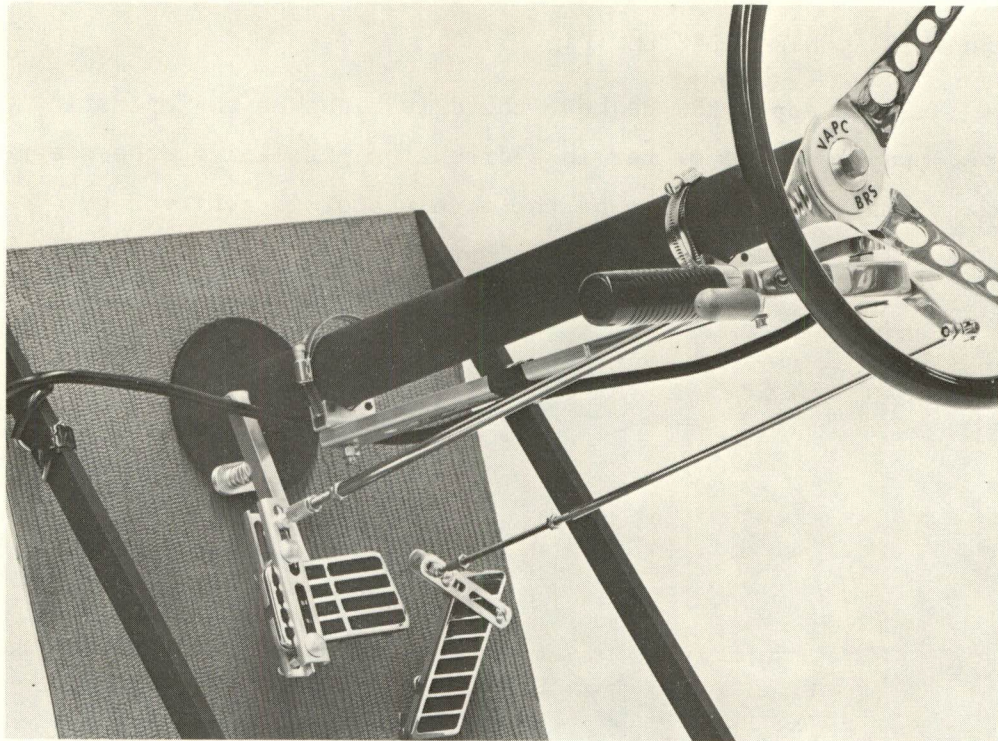


Fig. 6. Push-twist Hand-control System.

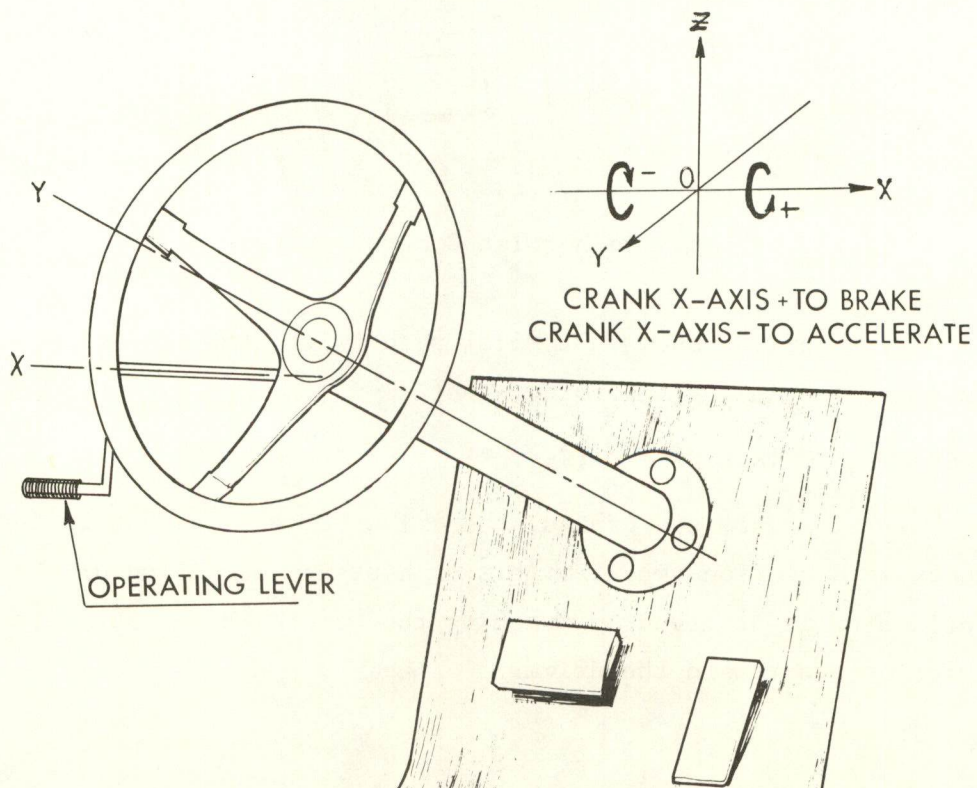


Fig. 7. Crank-type Control System.

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Figure 8 shows a typical crank-type hand-control system installed in the laboratory test device.

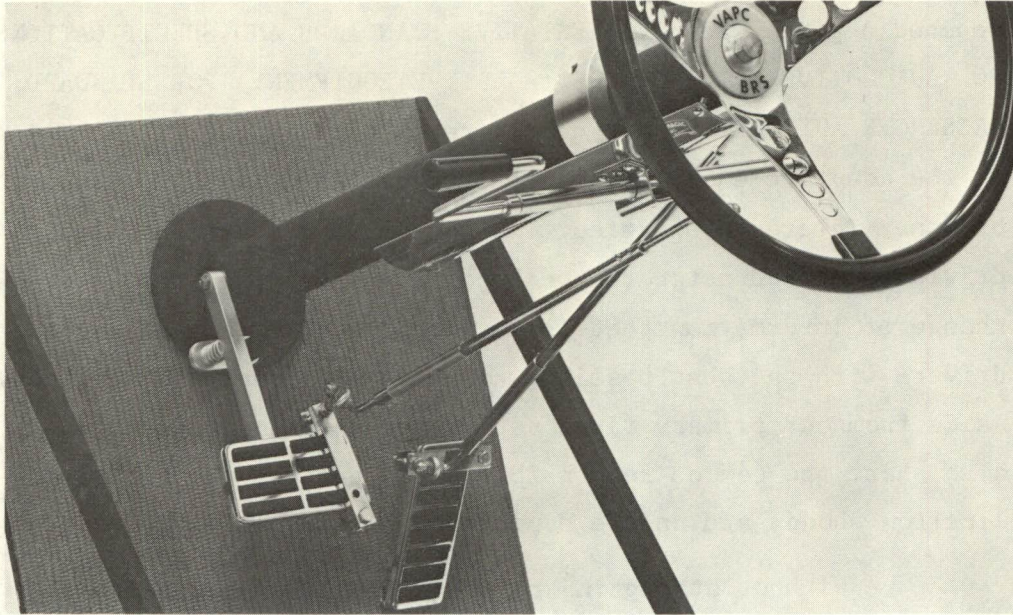


Fig. 8. Crank-type Hand-control System.

Most hand-control systems are manufactured and sold supposedly to fit the entire spectrum of commercially available motor vehicles on the market, i.e., compacts, standard-size sedans, luxury-type automobiles, vans, trucks, etc., as long as the vehicle is equipped with an automatic transmission. Experience gained from working with adaptive, automotive, hand-control systems has taught us that this is an assumption that can often lead to substantial problems. Frankly, the variety of automotive styles combined with frequent design detail changes of the passenger compartments require individual considerations to complete a satisfactory installation of a particular hand-control system. It would be unrealistic to imply that one specific set of hardware can be used universally, and we can readily sympathize with driving-aid manufacturers trying to market hand-control systems for all available automobiles. Our proposed standards and specifications address the

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installation of driving aids specifically as one of many pertinent points to assure safety, quality, and performance.

The development of standards and specifications has reached a point where VA TENTATIVE STANDARDS AND SPECIFICATIONS FOR AUTOMOTIVE DRIVING AIDS (ADAPTIVE EQUIPMENT) FOR STANDARD PASSENGER AUTOMOBILES are nearly ready for limited distribution to the adaptive-equipment manufacturers, as well as to a number of other interested parties. In scheduled discussions with driving-aid manufacturers, we hope to inspire the free interchange of information that is required to provide handicapped drivers with the best possible adaptive equipment and services. Aside from our primary mission to serve the handicapped, we also share the common responsibility to protect the entire public from shoddy and unsafe equipment.

Without attempting to present the actual version of the tentative VA standard here, some of the specific questions we raise are listed below. As one can easily see, a negative answer to any one of these questions leads almost always to rejection of the automotive aid, since components not in compliance with our proposed standards are assumingly unacceptable.

1. Are driving aids within reach of handicapped driver when lap and shoulder belts are securely fastened?
2. Are there reflective surfaces on the installed equipment that tend to reflect sunlight into the driver's eyes?
3. Are there sharp edges or projections on the equipment that might cause undue injury in the event of impact?
4. Does any part of the equipment deform permanently when it is used in simulating normal driving conditions?
5. Is rust or corrosion found on any part of the assembled and installed equipment?
6. Are all fasteners used in assembly and installation of the driving aid securely tightened?

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7. Are all electrical components safe from accidental shock, short circuits, sparks, etc.?
8. Does the installation permit conventional use of the vehicle by normal drivers?
9. If the installed driving aid is a brake-and-accelerator hand-control system, does it remain in the neutral position in the hands-off mode?
10. Are the motions required to actuate brake and accelerator controls distinctly different?
11. Can the accelerator be actuated by applying a force in the forward direction away from the driver?
12. Has the driving-aid manufacturer provided adequate instructions to permit proper installation of the equipment to the motor vehicle?
13. Does the installed equipment interfere with the collapsible feature of the automotive steering column?
14. Did the source of the driving aid provide instructions on its proper use in the motor vehicle?
15. Did the installation of the driving aid result in unnecessary modifications of the vehicle?
16. Was the driving aid inspected by the manufacturer for quality and proper functioning?
17. Is a statement of warranty included in the purchase of the driving aid?

To complete our discussion of licensed motor vehicles for handicapped drivers, we must include the van-type automobile intended to give maximum mobility to many handicapped drivers who either cannot transfer from their wheelchairs into standard passenger automobiles, or have selected a light truck-type vehicle for a specific reason, e.g., business, travel, camping, etc. There are a number of business establishments throughout the United States that modify standard van-type vehicles for operation by handicapped drivers. The interior of these motor

vehicles can be supplied to resemble a panel truck, or can be elegantly finished for maximum utility and personal comfort, depending on the individual's preference. Naturally, each van must be equipped with a wheelchair-access system, and again there are a number of devices on the market.

There are rear-loading and side-loading wheelchair lifts available. Most are fully automatic and can be controlled completely by the handicapped driver. Manual types usually require some assistance by an attendant. Several wheelchair lift designs incorporate the lifting platform in the automotive structure, lowering reinforced and hinged side doors of the motor vehicle for wheelchair entry and exit. The VA Prosthetics Center is currently involved in the evaluation of several van-type motor vehicles equipped with wheelchair-access systems, and, although satisfactory progress has been made, it would be premature to predict the final results. We have learned a number of important details in working with vans--information necessary in the preparation of future standards and specifications.

To introduce a variety of equipment, we present three specially modified van-type motor vehicles for handicapped drivers. Specifically,

CHEVROLET SPORTSVAN (Figs. 9 and 10)

The Chevrolet Sportsvan is equipped with a side-loading wheelchair lift provided by Helper Industries, Inc. The driver remains in his personal wheelchair.

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Fig. 9. The Chevrolet Sportsvan.



Fig. 10. The Chevrolet Sportsvan.

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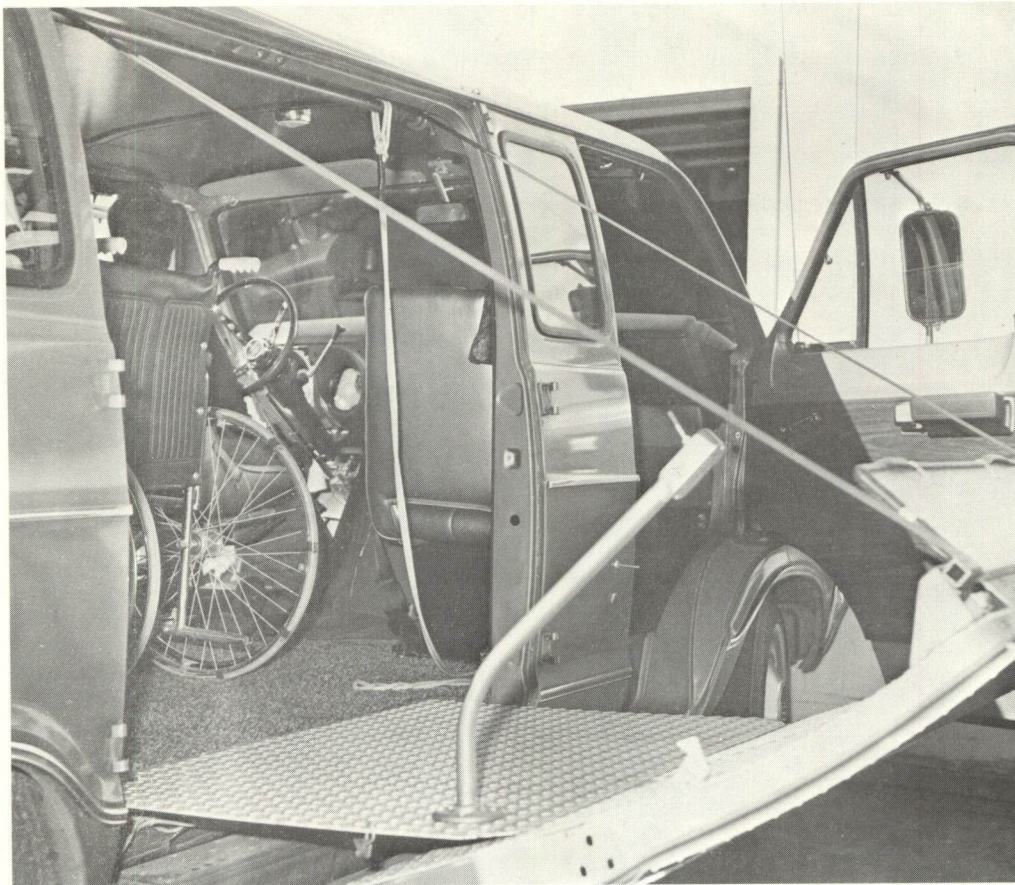
DODGE SPORTSMAN VAN (Figs. 11 through 14)

The Dodge Sportsman Van is modified to hinge the reinforced right side door for wheelchair entry and exit. Once the driver has entered the vehicle, transfer is made to a specially designed driver-chair that permits adjustments for maximum comfort and is fastened to the vehicle to withstand normal changes of inertial forces.



Figs. 11 and 12.

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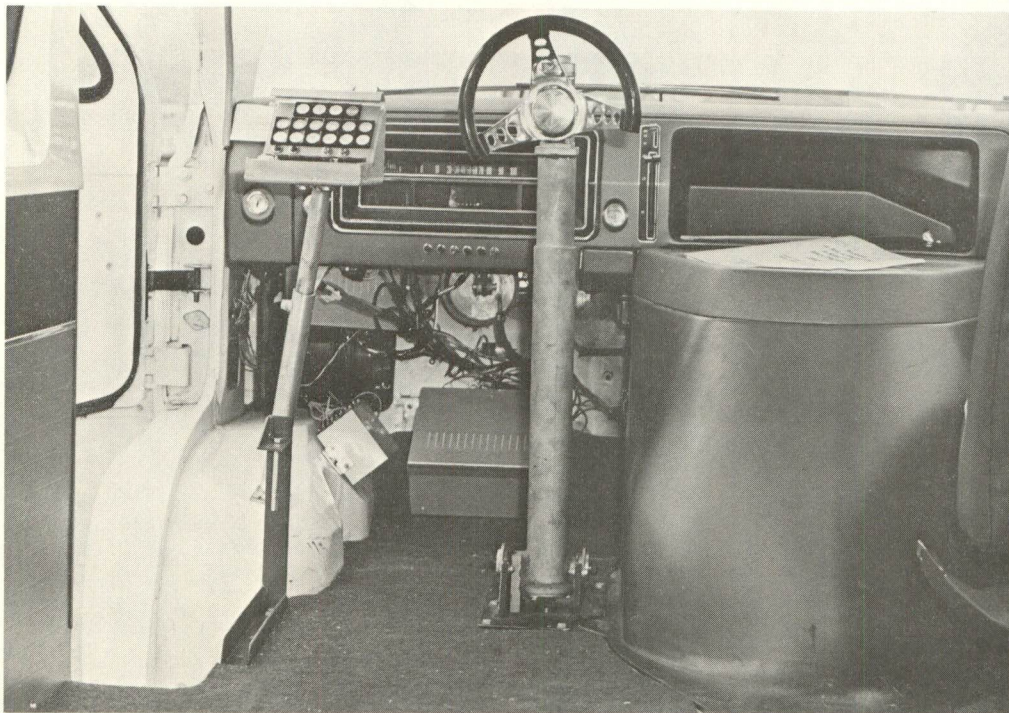


Figs. 13 and 14.

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FORD ECONOLINE 100 SUPER VAN (Figs. 15 through 18)

A Ford Econoline 100 Super Van was used to provide this special vehicle for severely handicapped drivers. The standard steering mechanism and brake-accelerator control systems were removed from this vehicle, and replaced with a hydraulic servo system that requires very small forces for



Figs. 15 and 16.

Licensed Motor Vehicles

application of brakes or accelerator. Steering requires very limited motion of the wrist and can be achieved with either the right or left hand. The complexity of this design indicates that more development is needed to assure maximum safety to drivers as well as to the general public. We are continuing efforts along this line.

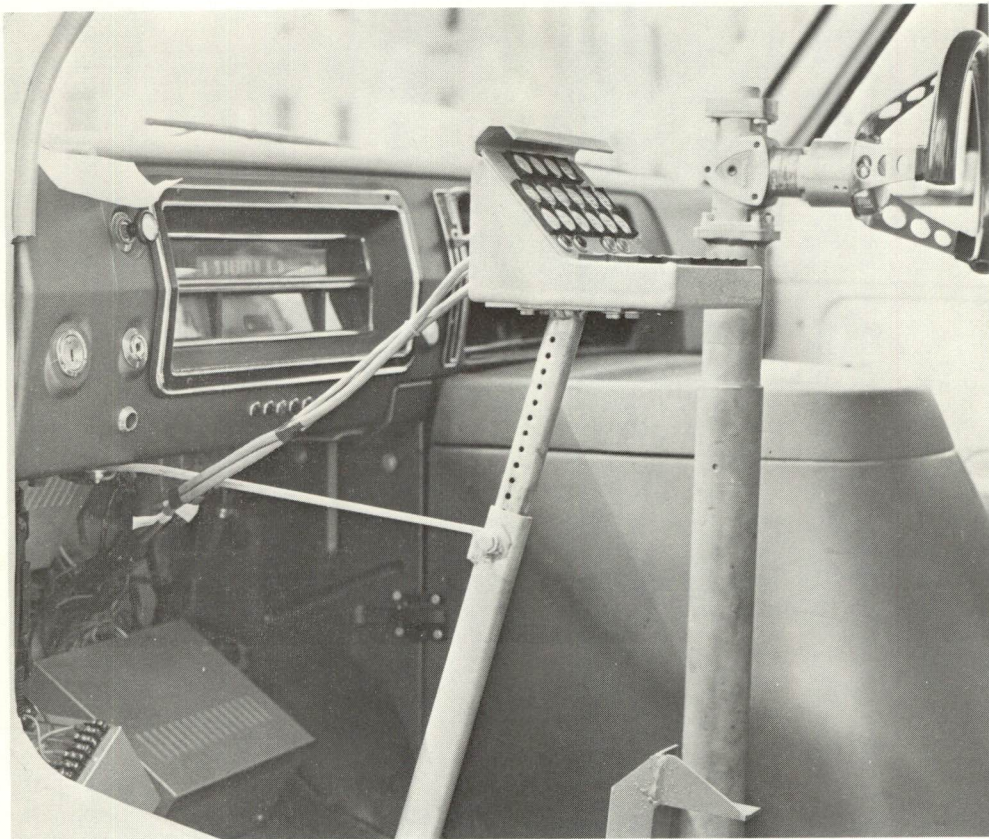


Fig. 17.

Figure 18 shows an experimental model of the SCAT electric wheelchair as used with the SCOTT Van. The chair features a bucket seat, lap and shoulder belts, and height adjustment, and is constructed for automotive use when locked to the motor vehicle. When not in use with the SCOTT Van, this item takes the place of a standard electric wheelchair.

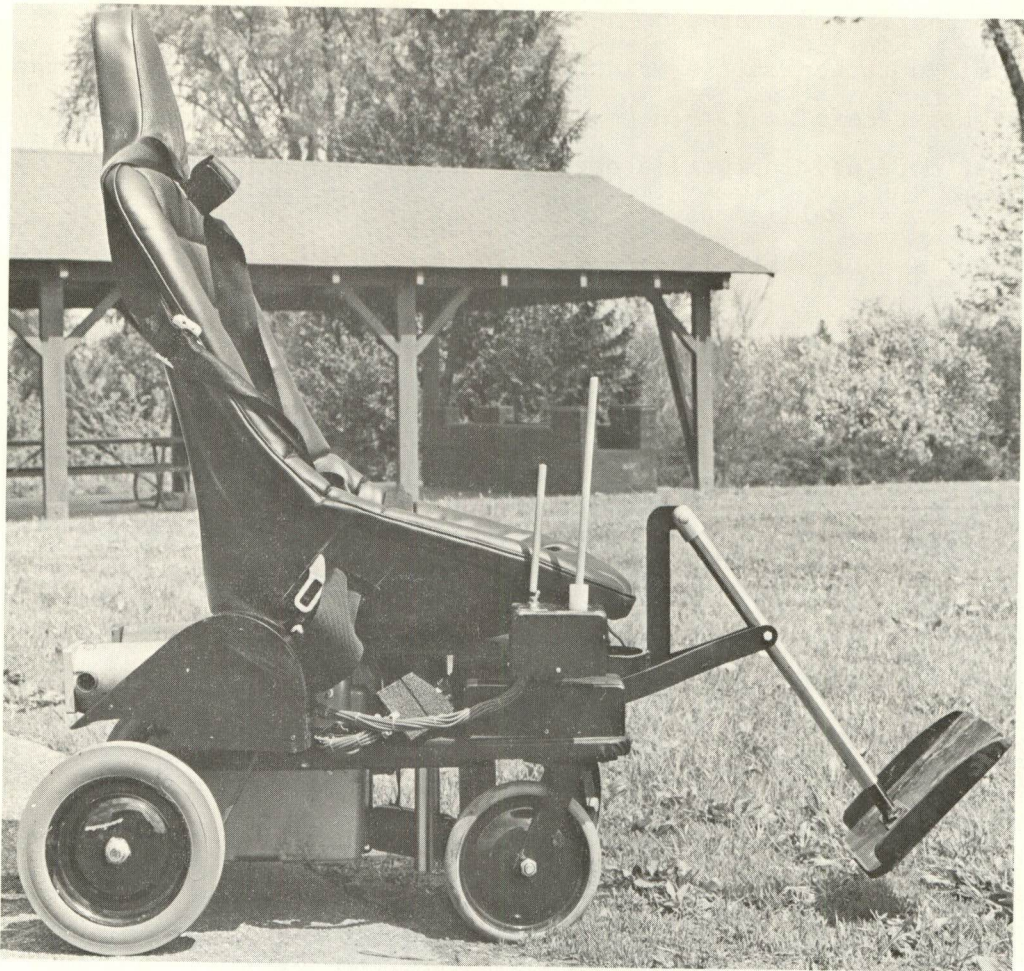


Fig. 18

Obviously, there is no need to transfer from chair to chair for the seriously handicapped driver.

Before concluding this discussion of Licensed Motor Vehicles for Handicapped Drivers, special mention should be made of the new 1974 VOLVO Disabled Driver's Car, 140 Series, equipped with a factory-installed pneumatic servo system. This design is the most promising hand-control system for handicapped drivers that we have seen so far, being guaranteed and serviced by VOLVO as one of their products. At this time VOLVO is the only major automobile manufacturer in the world that markets a

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hand-control system for handicapped drivers, and deserves recognition for this achievement.

One should wonder how long it will be before our automotive industry realizes that handicapped drivers are part of the real world--a consumer group in need of better and safer equipment as the automobile becomes better and safer.

PUBLIC TRANSPORTATION

Patricia Cass

Let me first express my pleasure at being here today. For the past two years I have been talking with some of you on the telephone from Washington. I have also talked with a few members of our "consumer" group. Most of my discussion has been with our Urban Mass Transportation Administration (UMTA) constituency--the Public Mass Transportation Authorities--about how they should be handling the disabled. This is my first opportunity to meet face to face with you who are working daily to help disabled individuals become more productive members of our society, hence my pleasure.

It probably will be useful to describe briefly the programs of UMTA and how we are attempting to provide mobility for the handicapped.

I use the words "mobility" and "handicapped" deliberately. DOT, and most particularly UMTA, are looking for solutions to the mobility problems of the handicapped person from the minute he (or she) leaves home to his arrival at his destination. We are concerned with accessibility to urban mass-transit facilities, but recognize it is only a small part of total mobility.

The word "handicapped" is embodied in our legislation, put there by the Congress and approved by the President. It may not be a word you are comfortable with, but it is the law. Our governing Act defines a handicapped person as "any individual who by reason of illness, age, congenital malfunction or other permanent or temporary incapacity or disability is unable without special facilities or special planning or design to utilize mass transportation facilities and services as effectively as persons who are not so affected."

Public Transportation

UMTA's mission is, and I quote again from our Act, "to provide assistance for the development of comprehensive and coordinated mass transportation systems in metropolitan and other urban areas...." This means we exist to revitalize urban mass transit. We started small in 1965, and got a big assist in 1970 when President Nixon signed legislation providing almost one billion dollars a year for our programs, and another assist in 1973 when the Highway Trust Fund was opened up to transit.

UMTA has four major programs. The first of these-- Research and Development--is directed toward the development and testing of new and improved hardware (and software) for mass-transit systems. In Morgantown, West Virginia, UMTA has built, and is testing prior to operation, a personal rapid-transit system. Many components of the BART system in San Francisco, such as cars, tracks, etc., were tested with UMTA R&D funds. More significant to us here today, though, is the UMTA TRANSBUS program. Three contractors are each building three prototypes of 50-passenger city-transit buses. One each of these buses has features to allow the bus to accommodate wheelchairs. One will have a lift, one will have a ramp, and the third provides for platforms at the curb. Later this year the buses will be evaluated at test centers and in passenger service in four cities. At the completion of this phase of the program, the best vehicles, or the best parts of all the vehicles, will be available for purchase under our capital assistance program.

Another project of special interest is the small bus development program that is just getting under way. There is heavy emphasis on accommodations for the elderly and handicapped. Tasks to be performed by a contractor consist of (1) investigation of services already being provided by small buses; (2) investigation of elderly and handicapped travel demands and mobility limitations; and (3) development of vehicle specifications based upon the travel requirements, difficulties and

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hazards identified in tasks 1 and 2. This effort will be completed in approximately a year.

The second program I should like to describe is UMTA's operational demonstration program. In this program we develop and test new services and concepts which are planned to make urban mass-transit more attractive. Those here from Washington will recognize the Shirley Highway express-bus service as an example. In Los Angeles, the San Bernardino express busway is an UMTA demonstration.

More pertinent to us is that component of the program of operational demonstrations directed toward improving mobility of the elderly, the handicapped, the poor, the unemployed, and youth.

Two examples of these demonstrations are under way now in Connecticut and Rhode Island. In Connecticut, a demonstration was planned with a combination of fixed-route scheduled service between four towns in the Naugatuck Valley to serve the general public, and a demand responsive service for the elderly and handicapped to take them to social services, medical services and recreational opportunities. (For those not familiar with the term "demand responsive," this means you call ahead and request a ride to a particular place at a certain time.) The system also has a credit-card fare-collection device whereby either the rider or the client of the rider can be billed for the trip. The demand responsive portion of the system became so popular that the fixed-route service never happened. Six small buses are operating, one with a lift and all with low steps and grab rails in order to make it easier to get on and off the bus.

In Cranston, Rhode Island, three small buses are providing a dial-a-ride service to the elderly and handicapped. (Dial-a-ride is another term on the list of trade jargon meaning that you call a central dispatcher and request a specific ride

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at a certain time.) One bus with a lift is used daily to take 18 children and adults to a sheltered workshop and training center for the mentally retarded. Primarily, the service is used by the elderly, but in at least one case a man in a wheelchair is using the lift bus for recreational purposes. He says he had not been out of the house for four years before the service had been installed. Now he rides around town in the bus at least once a week.

The point of these demonstrations is to test innovative services so that the agency and the transit industry can apply the services in other cities when they are successful. We also hope that they will be so successful that the cities we are trying them in will continue the systems after federal money runs out. Two years is about the length of our involvement.

Our third and largest program is Capital Assistance. This fiscal year we have \$872,000,000 to assist public agencies (on an 80/20 matching ratio) in the construction of new systems and to purchase equipment and facilities for urban mass-transit service. As I said before, these funds can be used only for capital purposes; they cannot be used to underwrite the cost of operations.

However, rising operating costs are the crucial immediate problem facing transit systems. Since World War II, transit riding has taken a terrific plunge, while operating costs have risen astronomically. In 1973, the estimated total annual deficit of all mass-transit systems was over \$400,000,000. This is why you see few private companies anymore. Transit no longer is able to pay its expenses out of fare-box revenues at an acceptably low rate of fare. It needs public monies in order to continue operating. It must be recognized that transit is a public service just like fire and police protection or

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maintenance of streets, and any other public service supported from tax revenues.

Recognizing this fact, President Nixon, on Feb. 13, proposed new legislation to Congress to be called the "Unified Transportation Assistance Act of 1974." UTAP, as it has already been christened, provides for \$700,000,000 in Fiscal Year 1975 for block grants to states from which it will then flow to urbanized areas. These funds can be used either for capital equipment or for operating subsidy. I urge you to support this bill, as it can be very important in improving mobility for the handicapped, because it gives the local officials the capability of exercising the option of how to spend their transportation monies. In short, UTAP puts the decision-making where it belongs--at the local level.

And now I come to the program which I believe can yield the greatest benefits for the money toward providing mobility for the handicapped. This is our planning assistance program. This program provides 80 percent matching money for the development of short- and long-range urban transportation plans. In each of these we require that solutions to the transportation problems of the elderly and handicapped be included. The first step is identification of the transport problems of our target groups. The planner then determines travel demands of the handicapped, both recognized and latent. He also finds out what services are already being provided in the area by agencies such as the Red Cross, Easter Seal, Cerebral Palsy, Model Cities, and the like. From reports we have read, conferences we have attended, and people we have talked with, we believe that a great deal of money is being spent for transportation for the elderly and handicapped by public and private agencies (not transportation authorities). There are also private profit-making companies which provide transportation for the handicapped. We believe that a significant amount of these

Public Transportation

monies could be and should be channeled to the local transit authority in order to (1) encourage the operator to provide the service, and (2) provide a continuum of reliable service for the rider--which he does not necessarily get from an *ad hoc* system.

Upon documentation of all of the above, the planning agency then develops solutions to the mobility problems of the handicapped. This may be dial-a-ride feeder systems to the fixed-route service; it may be simply some rescheduling of the current service; it could be a complete door-to-door service; or it could be gathering together under one umbrella the transportation services already being carried out in the area--trains, buses, taxis; all of them, public and private--and supplementing these as necessary to provide mobility.

Development of solutions will depend somewhat on the economics of the situation, but more on the needs of the riders.

You will note that this process starts and is carried out at the local level. You, therefore, have a job to do in your various cities and towns. Because you are involved in programs for improvement of mobility for the handicapped, you should get involved in the transportation planning process when it is being conducted at the local level. You are the experts and should lend this skill to the urban or transportation planner who does not have knowledge of the problems of the handicapped. It is up to you to make sure the right things happen. We, of course, are doing all we can in Washington, but the development of the plans and their implementation must be done locally. We can help with funding and advice, but the local people must make the decisions.

I should like to return briefly to my point of mobility versus accessibility. Let me give you an example. Elevators in subway stations make that portion of the transit system accessible

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but do not necessarily provide mobility for an individual; he must still get to the station from his home and from the station to his ultimate destination. There is also a fairly pragmatic argument against elevators. In all subways in Manhattan, for instance, UMTA could insist that, before giving New York any more funds, they would have to put elevators in all their above- and below-grade stations. In 1972, we estimated this cost to be approximately \$1 million per station; therefore, 487 stations would cost about half a billion dollars. This is over half the monies we have to spend this year. And, of course, we would have to say the same to Boston, Chicago, Philadelphia, and Cleveland, not to mention all the cities which are planning or building new rapid rail systems. As you can easily see, that would eat up our program in a hurry and still would not provide the kind of mobility the handicapped need.

So what we are looking for are solutions to mobility problems--reasonable rational solutions--where everyone benefits and where everyone has the same opportunities for employment and fun.

ARCHITECTURAL CONSIDERATIONS IN HOME AND PUBLIC

Pamela Cluff

I have been asked to discuss mobility for handicapped persons in both the home and public environments, but believe that there is a natural interaction between the two for the greater part of the handicapped person's life. I, therefore, intend to explore them in a continuous format as they would be experienced by a person growing from childhood to adulthood and eventually old age.

There is no simple way of looking at mobility for the handicapped without considering them as individuals coping with a total social and physical world through which they must make their way. We must, therefore, look at the potential of the whole person, not simply a sum of the parts.



GROWTH

THE CHILD

The baby and the young child are concerned only with those activities of daily living which occur in the home--sleeping, eating, toileting, dressing, playing, learning, and participating.

Mobility is part of the learning process, through exploration, biofeedback provides responses to the sensorially perceived environment. The handicapped child's environment must be supplemented and modified to allow him to experience and thereby learn from his environment in order to develop normal mental and social skills.

The young child's HOME RANGE is extended through social integration with his family, friends, and neighbors--his experience should not be that of an observer but of a participator. The learning process cannot be curtailed by lack of mobility skills or suitable aids, and fear should not be the rationale for limiting his experience and contact with the world.

The school-aged child needs integration into normal school systems accessible to him, in order that he enjoys and develops normal relationships and values along with his peer group. By optimizing his limited resources and the process of normalization, he will learn to cope with his handicap; this in turn will increase his personal expectations and goals. Frustration and apathy or adverse social reactions and fear will be minimized.

The goal, therefore, for our profession, is to provide supportive, accessible and therapeutic environments in which the handicapped may achieve their highest potential--HOME RANGE IS EXTENDED INTO THE LOCAL COMMUNITY.

Architectural Considerations

THE YOUNG ADULT

The young adult will seek senior and possibly graduate education or training in line with his capabilities. The decision-making role will follow that of his peer group, and his expectations of normal interaction in society will increase his need to be mobile. Activities which must, therefore, be made accessible will include social settings, leisure opportunities, sports facilities, etc. The HOME RANGE has broadened to the total PUBLIC ENVIRONMENT, which at this stage should be unlimited.

THE MATURE ADULT

The mature adult has expectations of marriage and participation in family life. Characteristic patterns should parallel the norms of his society and the concurrent development of social skills.

Toffler's *Future Shock* has made us all aware of the sharp rise predicted in technological and social change. The mature adult will, therefore, expect and explore all the interfaces with society, individuals in the community, and the total physical environment which the non-handicapped utilize.

Our efforts, therefore, should not rest with a ratio of 1:1 solutions to satisfy a limited number of goals or extended capabilities. Ideally, we should combine the expertise of all professionals--surgeons, physiotherapists, occupational therapists, prosthetics engineers, sociologists, and psychologists. The architect's role should be to provide and advocate through all levels of government a totally accessible environment, designed with the handicapped in mind. All forms of handicap must be considered since many criteria overlap, and no group should be excluded because of a limited view by the design professions.

Architectural services currently extend beyond mere buildings to total environments, which include landscaping, city

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planning solutions, interior design, and detailed furniture and equipment design. Architects, then, are in a position to synthesize the work of specialized designers of physical components making up the total environment.

A totally accessible city would include accessibility to and use of all public buildings, roadways, sidewalks, parks, recreational facilities, educational facilities, etc.

We have moved a long way from the simple solutions such as the ramp up to the front entrance of a house, or a specially equipped and accessible bathroom. However, mandatory legislation has not yet had sufficient impact on the public environment, although there is Federal legislation now, as a result of the White House Conference on Aging, 1970. This will not rectify existing situations unless it becomes a matter of public awareness, consciousness, and policy.

Logical extensions will be made to existing solutions and new solutions will be designed after further research by interdisciplinary groups. The capability exists within the professions assembled at this workshop to solve immediately the problems of public transportation for the handicapped. Devices are needed that will increase the utilization of otherwise under-used sensory capability and thus extend the functions and experience of the individual handicapped person.

Participation in a totally accessible physical environment will result in a diminution of trauma in the individual and a greater acceptance by the non-handicapped.

The flow between HOME and the PUBLIC ENVIRONMENT will be continuous, not intermittent, as it now is for many.

Demand-responsive transit systems for the maximally handicapped, at a reasonable cost, will allow these persons to participate in work, social and leisure-time activities, currently

Architectural Considerations

unavailable to them. The accessible environment will not contain the current endless frustrations and inconveniences that are the normal situation today.

The greatest achievement for the handicapped person, resulting from all of these efforts, will be that he has a choice in housing, job activity, and location, leisure and recreational activity, vacations, and companionship. His limitations will only be those that plague many of us--lack of courage, a poor personality, or a choice not to participate, and, of course, this choice too should be available!

HOUSING AND HOUSING CHOICE

INDEPENDENT LIVING FOR THE HANDICAPPED INVOLVES MAXIMIZATION OF THE INDIVIDUAL'S CAPACITY TO COPE WITH HIS ENVIRONMENT. This requires that he be mobile, both inside and outside his home.

In order for the individual to function at all, his primary needs, apart from suitable housing or other forms of shelter, are support services and functional aids.

In both public and private housing, there has always been limited CHOICE. Where new accommodation has been provided, it has frequently been in the form of one-bedroom or bachelor-apartment units, and only rarely has there been an attempt to provide support systems which would enable the handicapped to live their lives in their original environments as long as possible. In addition, very little attempt has been made to adjust existing environments to meet specific needs or changes in the individual's capabilities.

On the subject of HOUSING DESIGN for the handicapped, the primary concern has been for the satisfactory design of physical elements involving safety, economics, and maintenance.

Although there has been excellent research done on barrier-free architecture by central government agencies, these standards have not been universally applied or referred to.

To date the single greatest lack has been consideration of the handicapped person as an individual, with personal needs and preferences which involve not only safety but also privacy and personal space, plus their social complements, participation, and social interaction.

Too frequently the economic criteria of management and easy maintenance have produced a managerial "overburden" which directly affects the life-style of residents.

The greatest difference in the thinking that is required, however, concerns the planning for the future. The handicapped, due to both a greater life expectancy and the better health services, will fall into distinct groupings:

- Those who can manage independently
- Those who need some supportive care
- Those who need some nursing care
- Those who need full supportive care.

In designing for these groups, we must recognize that, in the case of at least the first three groups who have not suffered the whole series of described losses, every attempt must be made to maintain and optimize their capability to cope with their environment, thereby retaining their own self-determination for as long as possible.

Designing for those suffering from physical or sensory losses presents, in many cases, a reasonably simple problem. Studies in anthropometrics have broadened to a point where we should no longer be making the simple mistakes of designing buildings with physical barriers and inadequate provision for safety; however, greater understanding of the psychological needs and stresses affecting the handicapped is essential.

Architectural Considerations

Leon Pastalan in Michigan has researched "life space," which can be related to the handicapped, in which he suggests a method of "redundant cueing."

To explain these terms simply, "life space" involves the changing area or region with which the individual can cope if he undergoes a series of physical and psychological losses. For the handicapped, this range may be approximately 1/4 mile radius from his living unit. This, therefore, provides us with locational criteria for building new housing within easy access of needed social and public services such as shopping, churches, doctors' offices, community centers, parks, etc.--1/4 mile representing easy travel-distance capability. Pastalan has also demonstrated that with increased disability individuals can cope less and less with complex environments. We must, therefore, consider the scale and number of units built in one location, as well as the complexity of the interior design itself.

On the subject of redundant cueing, Pastalan and his colleagues suggest supplementing normal cues, such as alarm bells, switches, etc., with a second set of cues to offset sensory losses. These can take many forms utilizing tactile, visual, olfactory, and audio senses. Color coding and color psychology have not yet been adequately studied as means of supporting independent living or representing necessary sensory stimulants.

The provision of housing itself still poses unanswered questions in relation to mobility and other factors.

1. Siting must be determined by such questions as access, transportation, travel distances, location of essential social services, etc.
2. Low rise or high rise--these criteria, I believe, are related to the neighborhood development. In downtown urban settings high rise could be a very satisfactory answer, although definite provision should be made for easy access to garden areas at grade.

3. Segregation or integration--the most satisfactory settings we have observed were integrated into the neighborhood with unperceivable boundaries.

Finally, we consider the design of the unit itself.

In current solutions for the handicapped, frequently the following rooms are too small:

1. The bedroom. - This room should permit a minimum of two single beds and space for accessory furniture or equipment necessary for the handicapped individual.
2. The kitchen. - Galley kitchens with limited or high counter space at the side of the stove do not work well; frequently no provision is made for eating in the kitchen space, nor is there adequate room for maneuvering by a handicapped user. The Fokus Society in Sweden has done some excellent research and implementation in this field (Fig. 1).

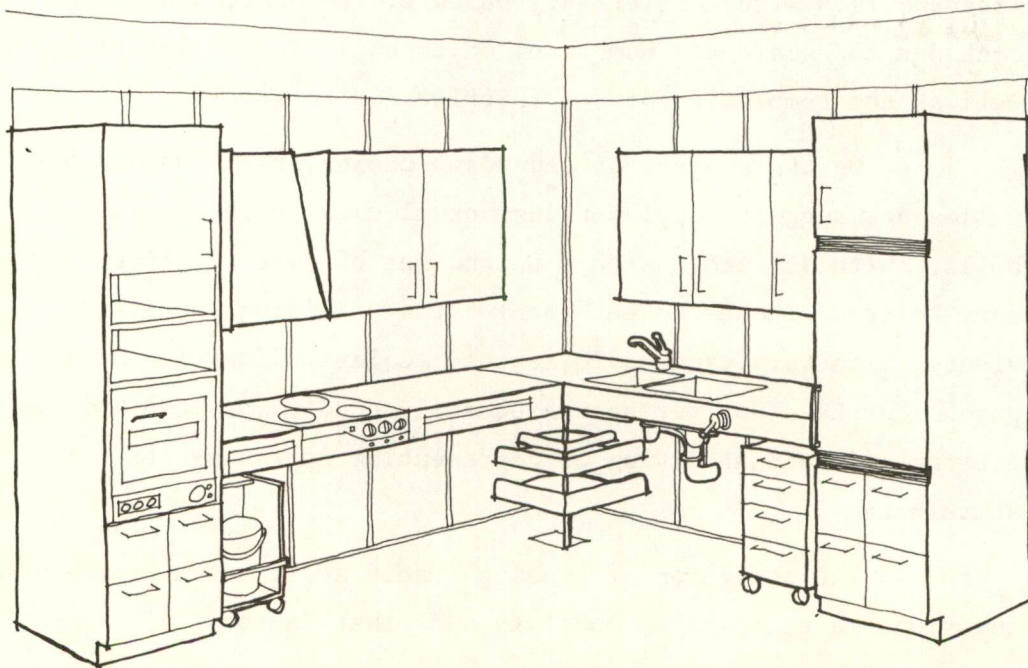


Fig. 1. FOKUS kitchen--adjustable units.

While we do not wish to exaggerate the needs of the handicapped, it should be mandatory that units have doors of sufficient width to permit the passage of a wheelchair, and that grab rails should be provided at bath side and adjacent to the toilet.

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The list of items could obviously be extended indefinitely but I think the primary purpose should be to focus on the "quality of life."

PUBLIC ENVIRONMENTS

We have discussed housing in some detail; however, the design criteria for handicapped users in the public environment are very similar and, therefore, are capable of being extended into the total environment.

Access is a question of public policy; the details and legislation will automatically follow. In discussing the progression through life, from childhood to adulthood, it is obvious that all the facilities which the ambulant persons utilize throughout their lifetime should be designed by a person confined to a wheelchair. Total accessibility assists the whole community, including children, the elderly, mothers with baby carriages, etc.

Mobility as a goal can be achieved and supported by special transportation systems which have been mentioned briefly and will be discussed by others. Independent, custom-designed vehicles, in addition to mass public transportation which is accessible, will release most of the physically handicapped from the current confines of location, work opportunity, status, and income.

In conclusion, it is apparent that, from whatever discipline we derive, it is time that we cooperated in serving the handicapped in terms of their whole environment and optimize their capabilities throughout their life-span (Attachment 1).

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DESIGNING FACILITIES FOR THE HANDICAPPED.

In exploring the potential life styles available, or that should be made available to the handicapped, special interest should be taken of all the possible transitional stages between total dependence and independence. The basic need for "shelter" and personal care cannot be isolated from other factors that contribute to a successful solution.

PSYCHOLOGICAL, SOCIAL AND PHYSICAL CONSIDERATIONS FOR SUCCESSFUL PROGRAMS PROVIDING "LIVING SOLUTIONS"

ACCESSIBILITY	INFORMATION
ACTIVITIES	INVOLVEMENT
ACUITY LEVELS	MEDICAL ASSISTANCE
ADMINISTRATION	NUTRITION
BEHAVIOURAL PATTERNS	PERSONALITY
CHOICE	PRIVACY
COMPANIONSHIP	PUBLIC ATTITUDE
CONTINUITY	RECREATION
COMMUNITY CONCERN	SAFETY
DISCOURAGEMENT	SELF-WORTH
ENVIRONMENTAL IMPACT	SENSE OF PLACE
FAMILY CONCERN	SENSE OF PURPOSE
FINANCIAL SECURITY	SENSORY DEPRIVATIONS
FUNCTIONAL CAPABILITY	SHELTER
HANDICAPS	SOCIO-PSYCHOLOGICAL SETTING
HAPPINESS	SPIRITUAL NEEDS
HEALTH PATTERNS	STIMULUS
HOME-RANGE	TERRITORY
HOPE	THERAPY
HUMAN DIGNITY	TRANSPORTATION
INCOME	WELL BEING
INDIVIDUALITY	WORK

SOCIAL BENEFITS OF MOBILITY ENHANCEMENT OF THE PHYSICALLY HANDICAPPED CITIZEN

The Economics of a Proposed Delivery System

Thomas R. Shworles

REHABILITATION, MOBILITY, AND THE ERA OF ECONOMIC ACCOUNTABILITY

As a philosophy, rehabilitation can be found generally whenever mankind has concerned itself with the welfare of its citizens.¹ Democratic concepts such as individual rights and freedoms have contributed to the gradual development of rehabilitation now as a specific objective--a vital concern for the effects of disease and injury on the lives of disabled persons. In the latter half of the 19th and first half of the 20th centuries, rehabilitation emerged as a methodology--a wide range of forces involving many disciplines and factors aimed at preventing and ameliorating the disabling complications of illness and physical trauma.² Economic pressures, in part, have forced rehabilitation suddenly to become an even more important subject and activity of our modern existence. The costs and the benefits of removing or markedly lessening the effects of disability are now a regular and public concern. So much so that some rehabilitation professionals have typified these times as "the era of accountability."³ It is the purpose of this paper to discuss,

¹ Expressions of rehabilitation as a philosophy are diverse. "Men who are occupied in the restoration of health to other men, by the joint exertion of skill and humanity, are above all the great of the earth. They even partake of divinity, since to preserve and renew is almost as noble as to create." From *A Philosophical Dictionary* (Voltaire).

"That everyone shall exert himself, in that state of life in which he is placed, to practice true humanity towards his fellow-men; on that depends the future of mankind." From *Out of My Life and Thought* (Albert Schweitzer).

² Allan, W. Scott. "The Concept of Rehabilitation," in *Rehabilitation: A Community Challenge*, John Wiley & Sons, Inc., New York, 1958, pp. 1-5.

³ Earlier texts have acknowledged this view as a general rehabilitation value. Cf. Allan, *op.cit.*, "Economic Values of Rehabilitation," chapter 18, pp. 161-171, and "The Cost of Rehabilitation," chapter 21, pp. 187-197. But it was not until 1965 that the Federal Government announced new planning, programming, and budgeting systems with the expressed purpose to improve the efficiency and effectiveness, as one result, of the state-federal vocational rehabilitation programs. The following probably marks the formal entrance of the vocational rehabilitation movement into public and studied assessments of the "dividends" derived from vocational rehabilitation costs.

Mars, Lawrence I. *An Exploratory Cost-Benefits Analysis of Vocational Rehabilitation*. U.S. Department of Health, Education, and Welfare, Vocational Rehabilitation Administration Division of Statistics and Studies, Washington, D.C., 1967. The admonition for the rehabilitation network to be more accountable for its production is reflected in, West, Jude. "Motivation of Professionals." Paper presented at the meeting of the Minnesota Rehabilitation Association, Minneapolis, Minnesota, May 5, 1971.

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from an economic viewpoint, one aftereffect of physical disability and its remedies--the decrease of mobility capacity.

If economics was the study of bookkeeping or accounting, then the author would be least equipped to lead a discussion on the economics of mobility for the physically handicapped. Also by this definition, it is probably true that most engineers or other citizens initially concerned with mobility of the physically handicapped person would not find the subject matter compelling enough to remain meaningfully interested or involved. But if we understand economics to be a concern for the application and use of scarce public and private resources for competing ends, then a broader based societal interest is justifiably expected.

Thus, economic resources in this discussion refers to not only dollars and cents but also to the many pieces and parts involved in delivering mobility to the physically disabled person. For example, we must consider as economic resources the engineer, the manufacturer who--after design, development, and evaluation--builds and distributes a mobility device or system, the private and public dollar used in purchasing the device or system, the networks which back up, run, or maintain the transportation or mobility device or system. Another pervasive and sometimes overlooked economic term involved in the mobility system is the environment of the user insofar as that environment affects the maintenance, the comfortableness, the desirability, the efficiency or inefficiency of the mobility device or system. And in a discussion concerned with the allocation of these resources, we must consider the status of the users themselves. It is the users who, by their circumstances, capabilities, and needs, determine ultimately, of course, the benefits or non-benefits to be derived by committing some or all of these resources towards increasing their mobility status.

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Modern industrial and post-industrial western society has been credited with mastering the secret of productivity, whereby a given expenditure of capital or exertion of labor gains more output proportionately. This "achievement" is reportedly the product of the engineer and the economist both united by the concept of efficiency. Words such as maximization, optimization, least cost, or economizing refer to the science of the best allocation of scarce resources among competing ends. The originators of these so-called concepts of rationality are referring to means, a way of best satisfying a given end. But the ends of life itself are not given and remain to be determined freely by the members of society who choose daily among a plurality of ends.⁴ Those of us in the rehabilitation network are concerned with developing as ends the full social, psychological, vocational, and recreational potential of the physically handicapped citizen. And basic to these ends, in most cases, is the need for increased mobility. At first glance, it may seem that in order to achieve these ends the cost of utilizing monetary resources, physical effort resources, and time and material resources will far outweigh the benefits to be derived. Tests, of course, should be made to determine if, where, and under what circumstances this is or is not so. The rehabilitation network must alert itself at least in elementary ways to some of the costs and benefits involved in delivering increased mobility to the physically handicapped citizen. By this process, the rehabilitation-oriented citizen will lay the social foundation for the political consensus necessary to allocate scarce resources to the end of eliminating mobility handicaps.

Terms and concepts are presented here in their broadest and most general format. This is so because the user

⁴ Bell, Daniel. "The Sub-Ordination of the Corporation," in *The Coming of the Post-Industrial Society*. Basic Books, Inc., New York, 1973, pp. 267-299.

population being defined herein is a broad cross-section of the physically handicapped and because various mobility devices and mobility systems in mind are also very different in their applications. In essence, this paper recommends that problems involved in increasing mobility for the physically handicapped person should be viewed economically and macroscopically as problems of putting together an efficient and maximized delivery system. Ideas contained herein are in support of the thesis that, unless one can see more clearly the total process involved in moving a mobility device or mobility idea from the state of conception to the endpoint of handicapped-user utilization, the national impact of public and private resources will be far less than maximal.

PUBLIC TRANSPORTATION, THE PHYSICALLY HANDICAPPED USER, AND SOCIAL BENEFITS

Let us look at one of the more socially visible modes of mobility--public transportation--and consider what is currently estimated to be the benefits accruing from making this mobility mode accessible to physically handicapped persons. Abt's study is uniquely significant in that it anticipates the future needs of the handicapped population, and provides a set of forecasts for 1985. These forecasts are useful to the many cities contemplating and planning for the improvement in existing transportation systems as well as for new systems. Almost 34,000,000 persons are expected to be functionally disabled with regard to public transportation in 1985. National priorities to eliminate these mobilities limitations can be justified alone by looking at the economic cost of these limitations due to reduced employment.⁵ From the Abt handicapped sample of persons limited in mobility, results have shown that by improving

⁵ Allan, *op.cit.*, p. 161, distinguishes humanitarian and social values of rehabilitation from economic values. Four valid methods are presented for measuring economic factors in rehabilitation: (1) efficient manpower utilization resulting from habilitation or rehabilitation; (2) economic gains in restoring workers to earning power; (3) tax savings made by removal from (continued)

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accessibility to public transport systems at least 13 percent of persons aged 17--64 would be able to return to work. Assuming only persons located in the Standard Metropolitan Statistical Areas (1,456,000 handicapped residents), this means that 189,015 would return to work and bring the total yearly economic benefits to \$824,040,000. Incidentally, the authors of this study roughly calculated that the benefits derived from a thorough redesign and replacement of 50,000 buses would exceed the costs involved even if the project resulted in employment of only 10 percent of the 189,000 handicapped.

Approaching the definition of mobility limitation from a viewpoint different from the above study, a second study concludes that the number of employable transportation handicapped persons was demonstrated to be 1,493,000.⁶ Seven percent, or 103,000, were estimated to be "transportation sensitive unemployed" either because of the cost or the unavailability of transportation to work. Incomes of over \$453,000,000 each year would be generated if this group was able to overcome their transportation limitations. In addition, public welfare payments to these persons would decline by almost \$50,000,000 and income taxes would increase by almost \$40,000,000 per year.

(ref. ⁵continued)

public assistance rolls; and (4) reduction in the cost of rehabilitation. Ronald Conley's works are probably the most comprehensive in rationale and methodology in measuring both the tangible and nontangible costs and benefits of rehabilitation. "Benefit-Cost Analysis of Vocational Rehabilitation," in *Research Utilization in Rehabilitation Facilities*, ed., Ralph N. Pacinelli, October 1971. "A Benefit-Cost Analysis of the Vocational Rehabilitation Program," *The Journal of Human Resources*, IV, 2, 1969. The following also compare some unique tangible and non-tangible benefits of a current homebound vocational rehabilitation project.

Shworles, Thomas R. and Tamagna, Irene G. "A Benefits-Cost Analysis and Discussion," in *Development of Modern Vocational Objectives for Severely Disabled Homebound Persons: Remote Computer Programming, Microfilm Equipment Operations, & Data Entry Processes*, Final Report 12-P-55077/3-04 (RD-2943 G) Grant Period August 15, 1968--April 30, 1973, Chapt. 7, pp. 7.1-7.23. Although the following does not utilize statistical methodologies, it does refer to economic benefits that would flow to half of the physically handicapped persons interviewed in a New Jersey study, who, although not working after rehabilitation, said they could work if they could solve their transportation problems. Bean, William. "Transportation Overview," *Rehabilitation Record*, July-August, 1972, p. 8.

⁶ Abt. Associates, Inc. *Travel Barriers - Transportation Needs of the Handicapped*. Cambridge, Mass., 1969. Arthur D. Little, Inc. *Employment, Transportation, and the Handicapped*. Division of Research & Demonstration Grants, Office of Research, Demonstrations, and Training, Social and Rehabilitation Service, HEW, Washington, D.C., July 1968. The authors of the former outlined the mobility-limited population in terms of functional disability, i.e., the lessened ability or total inability to perform a function required by public transportation. In their words, "since any given medical condition may result in a variety of functional disabilities, it is not possible to assess the functional disabilities of the population from medical information alone." p. 16. In the latter study, it was assumed that a mobility handicap (transportation handicap) always coincided with one of nine medical conditions (cerebral palsy, muscular dystrophy, etc.).

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A third study yielded a 1970 estimate of 13,390,000 handicapped Americans who would experience difficulties in utilizing existing mass transit systems⁷. The authors of this report feel that a significant group of handicapped would be capable of work if transportation were no longer a problem. The report states that the handicapped are statistically disadvantaged in employment, i.e., only 47.8 percent of the handicapped aged 16-64 are in the labor force, which compares with 65.1 percent for the general population. It is acknowledged even further that this group, disadvantaged in employment, also is required to use its limited resources for more expensive means of transportation. They take 14 percent of their trips by taxis compared with two percent of the non-handicapped. This report uniquely provides alternative solutions for making mass transit available to the handicapped and elderly citizen, and the costs of alternative improvements are delineated in relationship to the extra markets served and benefits to be derived. The alternative systems described are various low-cost improvements on existing facilities, dial-a-ride feeder-distributor systems, new ubiquitous fixed routes, transit stamps, and taxi coupons.

The significance of these studies is not in the discrepancies or problems found in defining transit-relevant handicaps, in determining and forecasting the numbers of physically disabled persons with such mobility limitations, or in validating the analytical methodologies for weighing the social returns against the social investments. The meaningfulness of these studies resides in their significant attempt to relate increased mobility for the physically handicapped to decided benefits for society as a whole if and where these benefits do occur. In the mobility arena this approach has generally been overlooked,

⁷ U.S. Dept. of Transportation, and Urban Transportation Advisory Council. *The Handicapped & Elderly Market for Urban Mass Transit*, Washington, D.C. 1973.

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and an expansion on this approach will enhance the future of consensus-making in regards to the allocating of scarce resources.⁸

OTHER MOBILITY AIDS AND DEVICES

This workshop has been commissioned with the task of reviewing all relevant mobility devices and systems as they might (or presently do) aid the physically handicapped person in moving about the home, neighborhood, city, and between cities. As well as public transportation systems, this workshop therefore will intensely study such devices as orthotics, and modular bracing systems which make ambulation possible. Included, in addition, will be various positioning and seating aids which allow the severely disabled person to use other transportation and mobility systems. Also, transfer equipments which lift or move the disabled person from one position to another will be discussed. Licensed and non-licensed vehicles for the physically handicapped person are part of the agenda. Among these are especially equipped vans, and, of course, the wheelchair.

The remainder of this paper will deal almost solely with considerations of these mobility aids, and will not refer to issues regarding public transportation. The author finds it logical to separate the discussion of public transit systems from other mobility aids on three issues. Problems surrounding the design, prototype production, field testing, limited or mass marketing, and the eventual use of these aids by the severely disabled person, are of a different order and magnitude than those described and associated with mass transit mobility systems accessible to physically handicapped persons. Secondly, the fate of the handicapped person's use of public transportation

⁸ One example of a significant study which does not provide the balanced view of weighing total costs against total returns is the following: U.S. Dept. of Transportation, *Additional Costs of Providing Mobility for the Elderly and Handicapped in the Washington Metropolitan Transit System*. Washington, D.C., 1973.

(and related economic issues) is tied into an existing complicated institutional web that plans and operates public transportation systems and from which flow key urban transportation decisions.⁹ As difficult and as frustrating as it may be, the advocate of public transportation use by the physically handicapped at least has broad-based, visible institutions with which to relate. For the present, other areas must confront a vast number of formal and informal institutions which for the most part are not interconnected into a socially useful whole (research institutions, manufacturers, rehabilitation facilities, insurance companies, local, state, and federal agencies). From a third perspective, problems of handicapped use of public transportation are essentially different from problems inherent in enhancing other mobility capabilities. In the former the physically handicapped person is buying a service. In the latter, he or she is buying an item, a device, a unit. In this instance, the handicapped person aspiring to greater mobility may be most susceptible to frustration. In a society based on a private-enterprise market system, and broad consumer need, as we shall notice below, what is needed may not be marketably feasible.

THE SIZE OF THE MARKET: MET OR UNMET NEEDS?

The studies by Abt Associates, Inc., Arthur D. Little, Inc., and U.M.T.A., previously quoted, are useful initial sources for estimating the number of physically handicapped persons with mobility handicaps, and, therefore, also the number of persons in need of or using various mobility aids and devices. They are also useful in that they summarize numerous other sources for such information, and present replicable methodologies for future projections. The work by LeBlanc should also be included.¹⁰

⁹ Colcord, Frank C. "Institutions for Urban Transportation," *Technology Review*, Vol. 76, No. 1, Oct.--Nov., 1973, pp. 53-57.

¹⁰ LeBlanc, Maurice A. "Patient Population and Other Estimates of Prosthetics and Orthotics in the U.S.A." *Orthotics & Prosthetics*. 27:3:38-44, September 1973.

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A brief enumeration is suggestive. The total afflicted with multiple sclerosis is estimated at 250,000, muscular dystrophy total is 200,000 (135,000 are children), 600,000 with cerebral palsy, and 450,000 persons estimated as legally blind in the United States (Abt). Limited in mobility due to arthritis and rheumatism and not institutionalized (ages 18-64) are 2,201,000 persons, 300,000 amputees are in the United States (70% are lower limb), 1,135,000 persons have spinal deformities, 27,500 have spina bifida, 340,000 have hemiplegia or hemiparesis, and it is estimated that there are 125,000 to 200,000 paraplegics in the United States and 38,000 quadriplegics (LeBlanc). Each estimate probably involves one or a combination of the mobility devices mentioned above. The question which follows upon these statistics is how comprehensively are the mobility needs of these persons being met.

During this workshop answers to the above question should be forthcoming. In the meantime, and for the sake of this presentation, some few answers will be implied from the literature and from comments so far made at the workshop. Literature which deals with development of other aids for the physically handicapped, such as sensory and environmental control aids, fails to describe how much testing has been accomplished and how far along in the delivery system or general use is each device reported. Also, they are characteristic in forgetting to include cost factors and other basic economic discussions.¹¹ It seems that engineering design considerations

¹¹ Some of the following articles are illustrative of the reference material which portrays on-going technology as applicable to problems of the physically handicapped, but which fail to specify such information as how far beyond prototypes and field testing are the devices, how many are in practical use, what are the unit costs, are they obtainable to the majority of needy physically disabled public, or how well do they perform under daily practical use. In view of no public address to these basic issues, we must conclude that there is a sparsity of delivery of technology to needy physically handicapped persons. Allen, James R. "Technology Advances the Frontiers of Rehabilitation," *Journal of Rehabilitation*. Vol. 40, No. 1, January-February 1974. pp. 15-21. Culasure, David F. "Medical Benefits from Space Research," *Journal of Nursing*. Vol. 74, No. 2, February 1974. Metcalf, B. L. "Space-Age Technology Brings New Devices to the Handicapped," *Accent on Living*. Summer 1973, 18:1:48-51. NASA. *Technology Utilization Program Report*. Introduction, pp. 1-4, and Rehabilitation, pp. 51-58. December 1973. NASA SP-5119. Washington, D.C.

represent far lesser problems than do considerations of coordination, evaluation, and deployment of these aids, and systems, to the severely disabled persons. The author is of the same opinion as that of Hobson: on close examination, engineering to date has had a comparatively small effect on the daily lives of the general population of rehabilitation patients.¹² Insofar as this is the only first significant conference on the mobility needs of the physically handicapped, we might fairly conclude that the preceding comments are equally applicable to mobility systems and aids.

Let us look cursorily at the wheelchair for support of the previous observation. It has been stated that there is only little serious work going on to develop hardware for the wheelchair. The wheelchair industry is characterized as only gradually debugging basic designs worked out in the 1930s, 1940s, and 1950s by the major manufacturer and seller of wheelchairs. What competition there is in the industry is primarily based on marketing and not on basic functions of wheelchairs.¹³ Also, it has been stated that manufacturers have delayed in developing a sports-activity model wheelchair, although sports basketball from wheelchairs began in approximately 1946 (it was only in the late 60s that the manufacturers came out with wheelchairs for sports).¹⁴ There has been a persistent cry for proportional controls on electrically driven wheelchairs and only now is the concept being incorporated into wheelchair design. It has been estimated that the United States purchases each year about one wheelchair for every 2,000 persons whereas in Sweden one wheelchair is purchased per year for every 800 people.¹⁵ These

¹² Hobson, D. A., and D. A. Winter, "Engineering in Rehabilitation of the Physically Handicapped," unpublished manuscript. Director, Rehabilitation Engineering, Shriners Hospital for Crippled Children, 633 Wellington Crescent, Winnipeg, Manitoba R3M 0A8, Canada.

¹³ Hotchkiss, Ralf. "Left to Your Own Devices: The State of the Art of Wheelchair Design." Presented at National Conference on Mobility & Physically Handicapped, sponsored by National Academy of Sciences, at the Rancho Los Amigos Hospital, Downey, Calif., Feb. 22-24, 1974.

¹⁴ Aballo, Peter. Paralyzed Veterans of America, Inc. Comments during "Open Discussion on Needs and Solutions," Feb. 24, 1974.

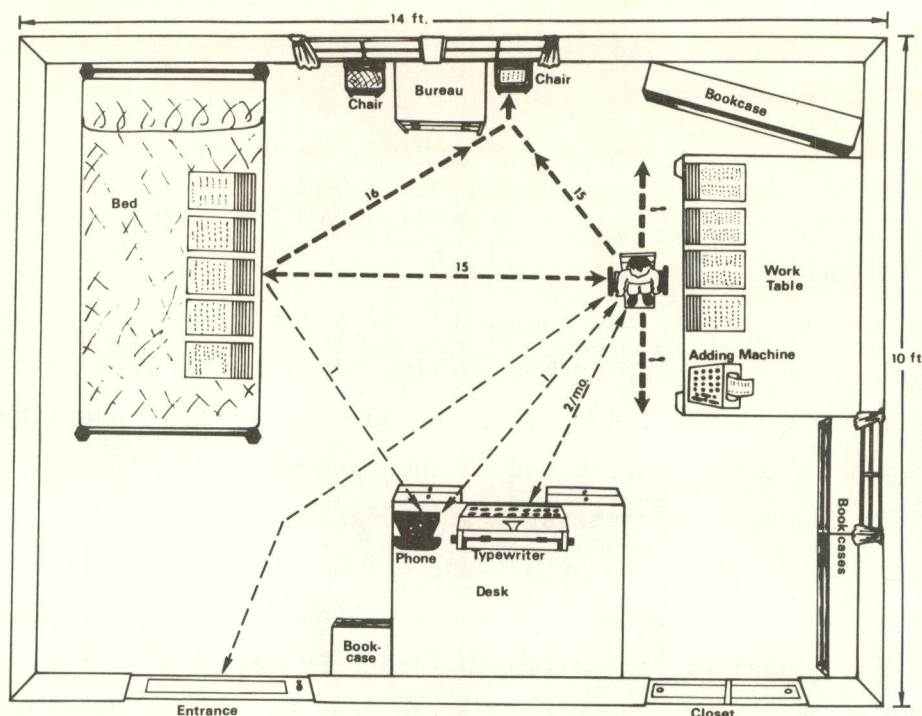
¹⁵ Hansson, Åke. Private correspondence. Director, Transportation Aids, Swedish Institute for the Handicapped, Fack 161 03 Bromma, Sweden.

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observations suggest that there are inherent problems in delivering the appropriate mobility device to many needful physically handicapped users.

THE SOCIAL BENEFITS OF ENHANCED MOBILITY

Before we proceed to a discussion of perceived and conjectured causes of decreased mobility among the physically handicapped, let us personalize an example of a quadriplegic (c-5-6) who aspired to work, and is now working productively as a result of an increase in mobility. This 44-year-old, single, wheelchair-bound male is totally homebound in the conventional sense that he is unable to use public transportation facilities mainly because of architectural barriers or because of the inability to be lifted in and out of a car. From a functional viewpoint he has only press capacity, fair strength, and fair dexterity, fair coordination, and has a reach of only 1½ feet from the body center line. He was trained on the job to function in a decentralized location, his home, and employed as a supply clerk for the General Services Administration (Inquiry and Adjustment Section), U.S. Government. His job involves essentially correcting discrepancies in purchase orders by crediting, debiting, and authorizing return of incorrect merchandise. This requires filling out different sets of forms, and sorting and forwarding them. It is necessitated that the various job subtasks be designed in a configuration which compensates for his inability to reach above or below heights and because of strength inability to work through piles of papers. It can be seen from the diagram how his work is laid out functionally and organized. In order to gain access to the work materials and equipments he makes on the average of approximately 50 movements--wheelchair movements--per day. There was no way this person could hand-propel himself in a conventional wheelchair continuously and daily around his work environment. Therefore, a private service organization purchased an electrically powered wheelchair at the cost of approximately



MOBILITY REQUIREMENTS WITHIN THE HOME ENVIRONMENT OF A FULL-TIME EMPLOYED SPINAL CORD INJURED (C-5, QUADRIPELEGIC) SUPPLY CLERK

George Washington University Rehabilitation Research and Training Center--Laboratory for Job Development for Severely Disabled Persons

\$1100. This wheelchair has saved him an enormous amount of energy and allows him to work at above-average competitive outputs according to ratings by his supervisors. If we calculate total gross salary for 5 years it is \$37,000, and for 20 years it is \$148,000.¹⁶ The total return to the general public

¹⁶ These benefits reflect the general return on costs in the federal-state vocational rehabilitation program. In fiscal year 1972, over 326,000 individuals were rehabilitated. Annual earnings at time of placement approximate \$1,200,000,000. It is estimated that \$60,000,000 will be paid in taxes to state, federal, and local governments, and public assistance payments in fiscal year 1973 were reduced by \$25,000,000 based on the removal or the reduction of payments to the 51,000 public assistance recipients rehabilitated. Division of State Program Financial Operations, "Seminar and Workshop Materials for Fiscal Year 1973." Department of Health, Education, and Welfare, Rehabilitation Services Administration, December 1970. As earlier discussion indicated, the benefits to be derived from "rehabilitated" paraplegics, quadriplegics, or other severely disabled persons can be even greater (as in the case of the wheelchair bound "rehabilitated" quadriplegic described above). Efforts to enhance mobility status of severely disabled persons coincide fortuitously with three other movements, all of which by interactive support can bring substantial private and social benefits: changing work patterns advantageous to the work aspirations of severely physically handicapped persons¹⁹; the growing effort to better evaluate case outcomes and reward rehabilitation counselors for working with severely disabled clients by weighting case closures; and the new emphasis on the vocational rehabilitation of the severely disabled in the Vocational Rehabilitation Act of 1973. Conley, Ronald. "Weighting Case Closures: Concepts, Problems." *Rehabilitation Record*, 14:5:29-33, September-October 1973. Noble, John H., Jr. "Actuarial System for Weighting Case Closures," *Rehabilitation Record*, 14:5:34-37, September-October 1973. *Vocational Rehabilitation Act of 1973*. Public Law 93-112, 93rd Congress, H.R. 8070, Sept. 26, 1973. Secs. 7(12), 130.

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revenue in terms of taxes for 5 years is \$3,000 and for 20 years is \$12,000. The total savings to the U.S. Treasurer on social security benefits which he previously received and are now ceased for 5 years is \$7200 and for 20 years is \$28,000.¹⁷ In the first five years of employment, his gross salary generates \$37,000 to the GNP, and taxes combined with relinquished social security benefits total in the same period \$10,200.¹⁸

A more exact analysis would take into account cost of living increases in salary and other changing values such as depreciation of the dollar or inflation. Also, an equation should be used which more precisely estimates the ratio between rehabilitation dollar spent and dollar return to the individual and society. It is recommended that the following formula be used for obtaining such benefits-ratios.

$$\left\{ \begin{array}{l} \text{Increased} \\ \text{Earnings} \\ \text{for 5 Yr.} \end{array} \right\} = X + \frac{X(1+g)}{(1+d)} + \frac{X(1+g)^2}{(1+d)^2} + \frac{X(1+g)^3}{(1+d)^3} + \frac{X(1+g)^4}{(1+d)^4}$$

Where: g = growth rate = 2.5%
 d = discount rate = 6%
 X = present annual income

But as indicated previously, a true B-C formula should take into account not only the costs, but also the non-tangible individual and social benefits. Real benefits must not be ignored just because they are difficult to measure. A true B-C formula should look like the following:

$$\left\{ \begin{array}{l} \text{True} \\ \text{Benefit-Cost} \\ \text{Ratio} \end{array} \right\} = \left\{ \begin{array}{l} \text{Increased} \\ \text{Earnings} \end{array} + K \left(\begin{array}{l} \text{Social} \\ \text{Improve-} \\ \text{ments} \end{array} + \begin{array}{l} \text{Long-Term} \\ \text{+ Vocational} \\ \text{Growth} \end{array} + \begin{array}{l} \text{Psychologi-} \\ \text{cal Satis-} \\ \text{factions} \end{array} + \dots \right) \right\} \frac{1}{\text{Cost}}$$

K = Conversion factor which transfers
the abstract events in one scale.

¹⁷ The average value of future benefits that would have been payable to a disabled beneficiary who had not been rehabilitated and had benefits terminated is estimated at more than \$16,800. Through Fiscal year 1970 (beginning from 1966), the present value of savings is about 112.9 million dollars for the more than 7,100 disabled beneficiaries who received rehabilitation services under the Trust Fund Reimbursement Provision and who were terminated from the social security benefit rolls. Social Security Administration. "Study of Experience in Financing the Vocational Rehabilitation of Disability Beneficiaries from the Social Security Trust Funds." Department of Health, Education, and Welfare, Social and Rehabilitation Service, April 1972.

¹⁸ Mallik, Kalisankar. "Cost Benefit Analysis in the Vocational Rehabilitation of Physically Disabled Homebound Persons," *Proceedings of 25th Annual Conference on Engineering in Medicine and Biology*, Oct. 1-5, 1972, Florida.

A one-time mobility enhancement investment of \$1,100 has allowed this person to capitalize on a unique job opportunity, to become substantially independent, and to return benefits to society. This analysis does not reflect other non-tangible benefits derived, i.e., increased self-esteem, independence from family's time and physical resources, and improved morale. This increased mobility also allows this person to expand his social existence by visiting neighbors, to participate in personal responsibilities, and to assume some family chores. The electrically driven chair allows him to relieve his elderly father of the strain once associated with being the only source of energy for getting up the automobile ramp.

The uniqueness of the case described may properly be questioned. Is it possible that the provision of this mobility in other environments can achieve the same or nearly the same private and social benefits? The answer to this question is yes. Other homebound and/or severely disabled persons have demonstrated that new training programs which present opportunities for information-handling jobs plus increased mobility result in similar favorable personal and societal benefits. It has been demonstrated unequivocally that these types of persons can work as remote-computer programmers, microfilm operators, and data-entry operators. Providing increased mobility as one ingredient in modern rehabilitation programs is coming at a time when emphasis on manual dexterity is not the main prerequisite for job behavior. This "post-industrial society" is fast becoming information-oriented, telecommunications-dependent, and decentralizing those job functions oriented around information handling and information processing.¹⁹ Changing

¹⁹ Bell, *op. cit.*, "From Goods to Services: The Changing Shape of the Economy," Chapt. 2, pp. 121-164. Drucker, Peter F. "Work and Worker in the Knowledge Society," in *The Age of Discontinuity: Guidelines to Our Changing Society*, Chapt. 13, pp. 287-311, Harper & Row, N.Y., 1968. Noble, John H., Jr. "Exploiting Information Technology for the Severely Handicapped and Homebound," *Rehabilitation Record*, 14:4:7-10, July-August 1973. Overby, Charles M. "Will Technology Change Work-living Patterns?" *Journal of Rehabilitation*, November-December 1973. Shworles, Thomas R. "Technical Innovations in the Information Industry and New Vocational Experiences for the Severely Handicapped and Homebound Persons: International Possibilities" in *Proceedings of Twelfth World Congress of Rehabilitation International*, 1:194-199, Rehabilitation International, New York, N.Y., 1972.

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work patterns and resultant new jobs now can be accessed more readily by physically handicapped persons at higher probabilities. An increase in mobility capability will certainly enhance these possibilities whether or not we are talking about modular orthotic devices for ambulation, or positioning or transfer aids, or use of licensed and nonlicensed vehicles, or the diminution of architectural barriers.

The social costs in not rehabilitating and remedying related mobility handicaps of the severely disabled must be staggering. In the state of California there are an estimated 200,000 homebound persons and, roughly, 25,000 are added to this list each year. Limited studies indicate that many of these persons (physically disabled restricted by architectural barriers, cardiac patients, the blind who lack mobility skills) can be rehabilitated and have sufficient potential to justify vocational rehabilitation programs.²⁰ There are an approximate 8,000 new spinal-cord-injured persons each year of whom 50 percent are quadriplegics. In a study by the Liberty Mutual Insurance Company of the economic cost of traumatic paraplegic of a group of mail spinal-cord-injured persons with a median age of 29.5 years, a life expectancy was predicted of 41.4 years. In that life span the estimated medical costs come to \$65,000 (multiply this by 3 for quadriplegic patients), the wage loss \$228,000 and the tax loss (calculated at 10% of gross) is \$22,800 per person. In total, \$315,800 is the loss if no remedial and effective rehabilitation program is available. The chief examiner of Liberty Mutual claims that proper treatment, management, and rehabilitation of the spinal-cord injured is a profitable undertaking for financial sponsors and society in general (their experience indicates that for each \$1.00 expended on rehabilitation

²⁰ Walker, James A. "What About the Homebound? Technology - the Key for Disabled Persons," *Journal of Rehabilitation*, 39:2:21-22, 41, March-April 1973.

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and management, they have saved about \$2.90 in combined indemnity and medical costs).²¹ We might conclude that mobility enhancement is an integral component of the rehabilitation programs recommended.

ECONOMIC ROADBLOCKS TO ENHANCED MOBILITY:
LACK OF A SYSTEMS VIEWPOINT

A review of some of the discussions from this workshop reflect a consensus of possible useful answers as to why we are not reaping more substantially the economic social benefits of increasing enhanced mobility of physically handicapped citizens. At first glance the answer seems simple, i.e., there appears to be a major dichotomy between what is actually needed by the physically handicapped consumer and what is marketably feasible. In other words, there is a vast variety of different devices needed in small numbers but which are characterized by high unit costs. But then other discussions suggest that the issue is not only one of cost but rather one of detailing extensively the various disability groups in mind. Some manufacturers in the audience suggested that a central information agency (a joint study between government and manufacturers) distribute to all manufacturers such disability information and knowledge and allow the manufacturer to interpret those statistics in terms of their staff disciplines and in terms of their market capabilities. Thus, money would be saved by avoiding duplicated studies and all interested parties would have planning information available to them. Fear of the government controlling design, fabrication, and other criteria was expressed on one hand, and on the other hand, consumers from the audience expressed considerable skepticism with the desire or ability of the manufacturer to respond in kindly and useful ways to the perceived needs of the users.

²¹ Barrie, Dave. "The Economics and Management of Spinal Cord Injury," in *Input Conference*. Institute of Rehabilitation Medicine, Spinal Injury Service, Good Samaritan Hospital, Phoenix, Arizona, April 1969.

Social Benefits of Mobility Enhancement

In workshops the question "Who is going to pay for it?" is usually presented as the fundamental question. But this question detracts from the issue "Why does it cost so much?" which reflects on the broader, more complex, and perhaps the real fundamental issue--what are the characteristics of the delivery system? What are the technological, political, economic, medical, and cultural components in moving a concept from idea to use? If we settle on the first question as the fundamental issue, then we infer that we are accepting the current existing delivery system as it is, we infer an acceptance of the status quo. The question really is "in this immediate time who pays for the device which is being produced by a present system that encourages high cost?" In these words, the question is highly relevant. We are dealing with limited resources and may and perhaps should change certain terms in the delivery system. If we are to utilize our resources more expeditiously, then you as the engineers and we as consumers, in harmony with manufacturers and other citizens, must develop a conscious awareness and knowledge of the delivery system and a capacity to manipulate it to the finest ends. If this society is to realize some of the benefits inherent in the discussions described above, then we must accept change as a normal process and go about the job of changing those components of the delivery system requiring such change.

AN ECONOMIC RECOMMENDATION: THE INVENTION OF A MOBILITY AIDS DELIVERY CENTER

Why not support on a national basis a procedure, an organization that would concern itself with inventing new procedural methods for the delivery of mobility aids and services to the physically handicapped user? This organization and its procedures, unlike the traditional agency, would not consume its valuable resources with developing methods of self-maintenance and perpetuation as is characteristic of most institutions, and

which may be characteristic of some of the agencies and organizations now purportedly working on behalf of the severely disabled person.²² The first major activity of this center could be to declare an intensive discussion and dialogue regarding the pieces and parts that make up the delivery system. The weaknesses and strengths of various steps involved in moving a mobility concept from innovation to actual use would be explicitly specified.

The author wonders what learning value, what impact could be provided if this workshop recommended an immediate study and publication of two case histories regarding what happened to a mobility idea that at first glance seemed eminently feasible. Why should this information be the exclusive (although unintended) property of the well-informed when so many have a costly stake in the delivery system? These case histories, publicly documented with frankness and fairness, would help emphasize and make more sensitive the engineer to the concept of the delivery system, and thus perhaps he would be stimulated to reach out beyond the status quo and utilize his resources more judiciously by seeking innovative approaches.

An example of this delivery-system invention in broad action is the compromise between free enterprise and government control suggested by Hotchkiss at this workshop. He proposes demonstration centers with every conceivable transportation aid or device representing both small and large manufacturers. These aids and devices would be tested by visitors (prototypes would be made by government funding and demonstrated at these centers). If no one manufacturer is able to produce some of them because of the high unit cost, and low consumer demand, then the device in mind would be contracted out to local jobbers. The jobber in turn could be paid in part by the State DVR.

²² Conger, D. Stuart. "Social Inventions," *The Futurist*, 7:4:149-158, August 1973.

Social Benefits of Mobility Enhancement

The establishment of such centers would become a basic commitment to the transfer of technology. The center's prime responsibility becomes a program of moving discoveries from the engineering laboratory into prototypes and into production, and goes beyond the mere publication of technological findings to an active encouragement of such findings by industry and ultimately by the user.²³ In essence, the persons involved in such a center will become immersed in the emerging disciplines of the social sciences which focus on processes of change, innovation, and knowledge utilization. Basic conceptual and empirical ingredients of this new discipline are now present.²⁴ The managers of these centers and others along the delivery system will become experts in the communication factors which influence the success of applied research.²⁵ The managers and workers in the delivery systems must be willing to recognize and accept the management risks involved in the technical, scientific, engineering, production, and marketing areas. Risks involved in timing, obsolescence, and in just being an individual also will have to be acknowledged and accepted. The engineer in this delivery system

²³ There are already facsimiles of this proposed "center" in the public sector. The Veterans Administration conducts development and research of aids. They report that they develop standards and specifications and that they support cooperation with other VA facilities as well as with non-VA agencies and organizations. The Committee on Prosthetics Research and Development of the National Academy of Sciences also accepts sponsored research and development and reports having significant success in the field of prosthetics and orthotics and with some sensory aids. The Social and Rehabilitation Service (HEW) now is in the process of establishing rehabilitation engineering centers around the country. The National Science Foundation through its Office of Experimental Research and Development Incentives sponsors projects which identify institutional barriers to innovations and experiments with appropriate actions that might reduce such barriers. Another but more specific example is the work at the Library of Congress (Division of the Blind and the Physically Handicapped) which is field testing different tabletop automated microfilm viewers eventually to be available to hundreds of severely disabled users of the public library systems. In spite of these significant programs, there is no ombudsman to represent all parties in the delivery system, and in particular physically handicapped consumers themselves to determine and assess the real impact of these efforts. There are no procedures to assess the efficacy, relevancy, timeliness, and even needless duplication of the above efforts to enhance the overall functioning of the severely disabled person.

Incidentally, the managers of the proposed delivery system center should consider allaying themselves with developments which purportedly are basic to the economic structure, i.e., emerging humanistic capitalism and corporate social responsibility. Harman, Willis W. "Humanistic Capitalism: Another Alternate," *Fields*, 4:10:1-15, Winter 1973. Bowman, Edward H. "Corporate Social Responsibility and the Investor," *Technology Review*, 76:1:45-51, October-November 1973.

²⁴ Havelock, Ronald G. *A Comparative Study of the Literature on the Dissemination and Utilization of Scientific Knowledge*. Institute for Social Research, University of Michigan, July 1969.

²⁵ Glaser, Edward M., and Samuel H. Taylor, "Factors Influencing the Success of Applied Research," Human Interaction Research Institute, Los Angeles, Calif., 1969.

will become aware that present value theory heavily discounts the long time future. However, the ability to conceive of benefits and applications of these technologies for removing mobility limitations relies heavily on the capacity to conceive of future events; social, technological, cultural, economic, and political.²⁶

The engineer in harmony with others in the rehabilitation network and with the physically handicapped consumer will become involved intimately in the process of assessing knowledge: knowledge regarding the benefits that can be derived from increased mobility, knowledge regarding how delivery systems can be strengthened, and knowledge regarding how decisions are made that affect our lives. And ultimately the delivery system will become individuals who have learned that to advance their interests they must organize and campaign, they must inform other people, and they must bring pressure to bear on those in power by direct action or the use of their political strength. This is in the last respect the pinnacle of good economics--not only knowing how to allocate effeciently scarce resources among competing ends, but, more importantly, having the social consensus to determine the ends themselves.

²⁶ Benn, Tony. "Technology Assessment and Political Power," *New Scientist*, 58:847, May 24, 1973. Bright, James R., ed. *Research, Development, and Technological Innovation*. Richard D. Irwin, Inc., Homewood, Ill., 1964.

SWEDISH ATTITUDES AND SOLUTIONS OF MOBILITY PROBLEMS

Åke Hansson

GENERAL

When the possible types of solutions of mobility problems are divided into four categories it is easier to explain the present attitudes and solutions in Sweden:

1. Improvements in the environment
2. Improvements in mass-transit systems
3. Individual technical aids
4. Individual or group service

Each of these four categories is all important and none can be left out if we are to provide disabled people with a level of mobility freedom similar to that which other members of society have.

Of a total population of eight million, approximately 70 percent live in urban areas: 45 percent of the population live in the three biggest cities. In these cities mass transportation is fairly well developed. In Stockholm 50 percent use mass transportation going to and from work and only 25 percent use their cars.

IMPROVEMENTS IN THE ENVIRONMENT

All newly constructed buildings that are to be used by the public must be designed so that they are also available to people with mobility handicaps. The same applies to work places even if they are not public buildings. Old buildings that are subject to major repair also must be rebuilt to suit people with mobility problems. As this legislation has only been in force for a few years, the total situation is not improved very much. There are also some cost limits more or less established that leave a possibility for dispensations.

IMPROVEMENTS IN MASS-TRANSIT SYSTEMS

There is still no obligation to make mass-transit systems available to people with mobility problems. There is not even any expressed policy from state or local administration. However, a year ago a working group associated with the Department of Transportation started an investigation to find out the obligations different authorities had towards disabled people, and also to find out what has been done so far. This working group is also expected to give suggestions to the Department on further action to be taken to improve the situation.

Some conclusions can be drawn already.

BUS SYSTEMS

Thirty-seven Swedish bus companies with a total of 5,000 busses are organized in an association. They have agreed on some standards for busses. Most of these busses have some simple arrangements for disabled passengers such as elevated seats near the entrance door, grip bars at entrances and at the



seat. Little or nothing has been done to improve entrance and exit step heights.

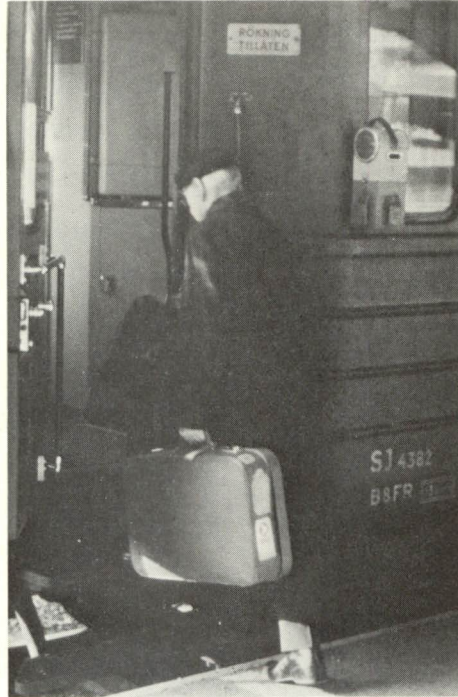
Wheelchairs have no access to busses.

Any major improvement in bus design will probably not be in general use until the year 2000 even if the decision were made today. The attitude to possible solutions is that they must not be disadvantageous to other passengers.

Swedish Attitudes and Solutions

TRAINS

So far entrances have been equipped with grip bars. Apart from that nothing has been done. It is probably not possible to solve the problem of high entrance steps. There is a European agreement on load profiles which fixes the maximum height of platforms to approximately 1100 mm. At the same time buffer heights are also standardized, which in its turn decides the minimum floor height. Minor improvements can be achieved with motor coaches. This type of train has a motor in each coach which reduces the dimensions of the chassis.



Trains in Sweden belong to a State-owned company with too narrow for wheelchairs, and no existing coach model will let a standard-size wheelchair pass.

Trains in Sweden belong to a state-owned company with a few exceptions. Within this company an investigation has been made as to what demands different groups of disabled people have on the rolling stock and on station buildings. They have not, however, committed themselves to any improvements that are not profitable to the company.

URBAN-TRANSIT TRAINS

This type of train uses the same tracks as the long-distance trains and for this reason the problem of high steps at the entrances is the same. As each coach is individually motorized, the floor height is slightly lower than in ordinary trains.

Åke Hansson

Two seats in each coach are elevated and equipped with grip bars. Urban-transit trains cover only the Stockholm area. Of a total of 52 stations, 28 have or will soon have platforms that can be reached in a wheelchair from the street.

SUBWAYS

Only Stockholm has a subway system. Floors and platforms are on the same level at all stations. Platforms can be reached by wheelchair from the street level in 29 out of a total of 74 stations. Another 13 stations will be rebuilt by 1975. In newly built parts of the subway all stations will be accessible to wheelchairs.

Twenty new stations are under construction. Each coach contains four elevated seats with grip bars. In new coaches all seats will be slightly elevated and eight will be extra high. All seats will have grip bars.



TRAMS

Only two cities still have trams, and no adaptations have been made to meet the demands of handicapped passengers.

INDIVIDUAL TECHNICAL AIDS

WALKING AIDS AND WHEELCHAIRS

This type of aid is prescribed free of charge if the need is demonstrated. There is no expected lifetime for these aids and a new one may be prescribed as soon as the old one is worn out.

Swedish Attitudes and Solutions

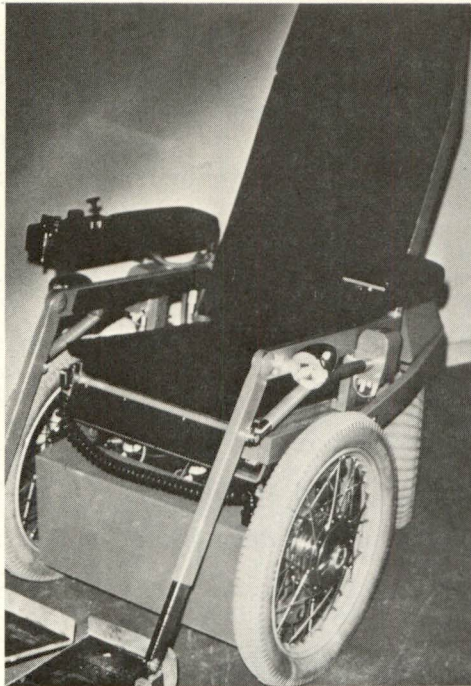
Approximately 25,000 people are confined to wheelchairs and most of them have one or two wheelchairs. Some 10,000 are sold every year and, of these, 6,000 are prescribed to individuals and the rest are sold to institutions and hospitals. Ten percent of the 6,000 are powered wheelchairs. According to the legislation, it is possible to prescribe up to three wheelchairs to one individual without cost limits.

As with most of the individual technical aids, wheelchairs have to be tested by the Swedish Institute for the Handicapped before they are listed amongst authorized products. Only those products passing the tests are allowed to be prescribed by the doctor. Approved products must meet the demands of the disabled for functional design and safety as well as the demands of society for good value for the money.

Wheelchairs in Sweden are much the same as in other countries. Roughly, 70 percent are imported Everest & Jennings products. Of the remainder two thirds are powered vehicles imported from Germany or England. The only commercially available powered wheelchair of domestic origin is the Permobil in its various models. Among hand-propelled wheelchairs, most Swedish-made models have the large wheels in front and are equipped with seats and backrests of cushioned, solid wood. Some of the special types are shown on page 132.

In the field of research and development we try to aim at modular systems where the final wheelchair is built up of standardized components. A very small number of basic chassis will be used.

Most of the Research work is carried out by Professor Brattgård in Gothenburg. The manufacturers themselves still do most of the development work based on either their own experience or the test results of the Institute for the Handicapped. Some of the more interesting projects follow.



Left, Permobil SA.

Above, Hd-122 Relax.

Electrically Powered Wheelchairs for Car Drivers

This wheelchair is meant to be used as a driver's seat. The aim of the project is similar to that of the Anderson wheelchair and lift device project at the University of California in Berkeley.

The design of the wheelchair is different, though, and involves four small, independently powered and steered wheels. The wheelchair will have the feature of being able to move sideways.

The lift will be built into the door of the car, and the whole lifting procedure will be carried out according to a preset program.



Swedish Attitudes and Solutions

The Spira Wheelchair

This electrically powered wheelchair has extreme maneuverability achieved by special constructed wheels similar to the NASA all-directional wheel. The chair can turn, rotate, and go sideways without turning any of the wheels.

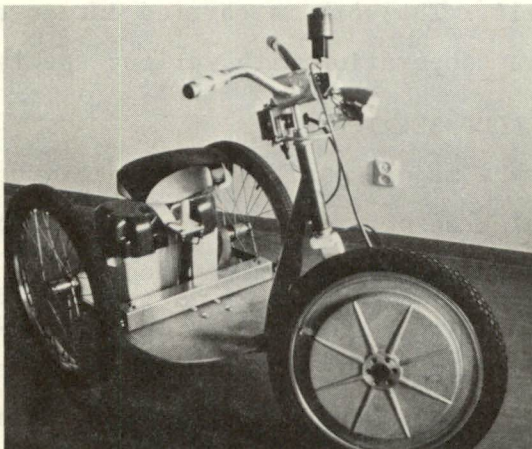
The Flexo System

This is a modular wheelchair system which, at the moment, involves two basic chassis. In the standard chassis the front and back wheels can be interchanged. All four wheels can be of small size in another version, and two of the wheels can be replaced by power units.

The second chassis involves a hydraulic system to raise the seat and lower the backrest in order to achieve a horizontal position of the same height as a bed. Different means of propulsion can be obtained also in this chair.

The Pia Bike

This three-wheeled vehicle reminds one of a bicycle and has as a special feature a new type of wheel with a built-in electric motor and a worm gear. The bike can be equipped with either one or two of these wheels. The first 25 units are soon to go into production.



AUTOMOBILES

Disabled students and employees who need an automobile can receive financial support to buy a standard car and special equipment for it. The amount of money is dependent on the income, and there is a maximum limit for the grant. Approximately 2,100 automobiles are given out annually, and of these some 500 are equipped with special controls. In 90 percent of the cases the controls consist of hand-operated accelerator and brake. Normally the cars are equipped with automatic transmission. In 10 percent of the cases there is a more advanced need for equipment such as foot- or knee-operated steering, servo-assisted brakes, special seats, or special lifting devices.

A disabled driver can receive a budget price from the manufacturer up to 20 percent of the normal price. He can also get exemption from tax for the car and a certain amount of fuel.

Some of the more interesting development projects are:
The Volvo Accelerator and Brake System

Accelerator and brake controls are built into the steering wheel and they follow the turning movement of the wheel. The system involves a pneumatic servo based on standard Volvo components.

The Sigvard Holgersson Project

This project aims at solving the car-driving problem for a severely disabled, post-polio student. So far steering, braking, and acceleration have been built into a Valiant and the boy is able to operate these controls himself. The work is carried out at the Institute for the Handicapped in cooperation with various specialists.

INDIVIDUAL OR GROUP SERVICE

Throughout the country a majority of the regional authorities have established a special transport service for the disabled. A majority of the vehicles used are standard taxis which can be used at the cost of a bus ticket. There is no limitation in number of trips to work and to hospital for treatments. For private transportation, different systems are used, but in Stockholm, for instance, there is no limitation in the number of trips.

Swedish Attitudes and Solutions

This type of transport is purely local, and only in exceptional cases can it be used for long-distance traveling. Approximately one percent of the total population is entitled to this transportation service, and out of these 14 percent need special vehicles; that is, minibusses which can take, for instance, wheelchairs. Sixty percent of the users are more than 67 years of age.

It is expected that the Parliament this year will give financial support to the regional authorities in order to obtain an equal level of service all over the country.

Different activities are being started in order to improve the standards of this service system. Among technical improvements higher level of safety can be mentioned.

CONCLUSIONS FOR THE FUTURE

A major task for the future development work in the field of mobility for the disabled is to create integrated solutions to the four mobility problems described in the introduction. It is obvious that the environment and the public transportation cannot be 100 percent available for the disabled but on the other hand, large improvements can and have to be made. The problem is to get an agreement on realistic demands that can be expected to be met in a not-too-distant future. Knowing these demands it will be easier to design suitable individual aids such as wheelchairs. It will then be possible to say that if the wheelchair has specific dimensions and step-climbing ability in so many inches, it is possible to go anywhere in the environment and to use public transport.

Signs of this future situation can be traced in ongoing investigations on the bus of the future in Sweden and also in the design of future taxis.

PSYCHOSOCIAL AND LEARNING CONSIDERATIONS IN USING MOBILITY SYSTEMS

Carolyn L. Vash

AROUND THE HOME AND NEIGHBORHOOD

MOTORIZED TRANSPORT IS NEEDED

The relationship between the amount of work performed and the reward gained from that work has been amply demonstrated in the psychological laboratory. Rancho Los Amigos Hospital can look to its own history to document this relationship when it comes to a quadriplegic's willingness to perform the work necessary to propel a manual wheelchair compared to the gratifications derived. The exercise of wheeling the chair was considered good for them and it probably was on the rare occasions when they did it. But for many years patients sat and did nothing in the hallways and in their homes because it was too much effort to get from one place to another and the satisfactions weren't worth the price. When they were provided with motorized wheelchairs, they began to go all over the place, got involved in all kinds of avocational and even vocational activities, and probably got a lot more exercise doing whatever physical work was required to carry out these more gratifying activities. It was dramatically obvious that the mobility provided by a motorized wheelchair increased rather than decreased their own activity level and greatly expanded their consciousness with respect to what it is possible to do and enjoy in this life.

BUT FIRST YOU HAVE TO BE ABLE TO BUY ONE

Psychologically speaking, the major problem of poverty is that the poor person simply does not get his basic human needs met; needs for adequate food, adequate shelter, etc. Surely the need for mobility is almost as basic as these. When you are paralyzed and too poor to buy a \$1200 electric wheelchair, it is oppressive. I wonder why electric wheelchairs have to

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cost so much. The "limited-market" answer doesn't help me understand one situation where a vehicle was built and touted as a woman's grocery-shopping cart. After it was discovered as a longer range wheelchair for paralyzed people, the cost immediately rose from \$395 to \$895, with no elevation in the cost of manufacture and with a suddenly expanded market. I think we need to worry about such issues.

WHAT DO YOU WANT IT TO DO AND HOW DO YOU WANT IT TO LOOK?

Versatility and cosmetic aspects must be considered together. Very simply, the more it does the weirder it's going to look; the weirder it looks the more it's going to put people off; and the more it puts people off the harder it's going to be to get the non-disabled majority to see you as having enough in common with them for them to want to know you, hire you, fall in love with you, or whatever it is you want them to want. As for cosmesis, I believe it is important to minimize the hardware, but don't try to make a wheelchair look like a non-wheelchair. Part of the adjustment is acknowledging your differences and getting desensitized to them, not trying to hide them. To relate this to my previous statements, please note that a rolling overstuffed chair looks weirder than an ordinary wheelchair. As for versatility, I believe that a chair compact enough to maneuver around the house and still sturdy and fast enough to traverse the neighborhood is desirable as it can avoid frequent unnecessary transfers. By sturdy I mean sturdy enough to do a little cross-country, through parks and backyards; and by fast I mean speed of 6 maybe 8 or even 10 miles per hour. It also needs to be powerful enough to take a 20-percent grade comfortably. On the issue of versatility, I have seen several designs for a wheelchair which also becomes a standing board, and/or climbs stairs. I am extremely dubious about both. As for stair climbers, I would rather see the time, energy, and money put into removing stairs than into building chairs that will climb them.

Carolyn L. Vash

On the standing-board issue, I can only say that I certainly wouldn't want one for two reasons: there is a lot more to break down, and it will surely be heavier and a lot weirder looking.

SAFETY--REAL AND APPARENT

Chairs designed for both home and neighborhood use may present problems of safety in cross-country or on steep hills. It is important that a chair not appear to be tippy as this is alarming to the user. Obviously, it is even more important that they are not actually tippy. This gets us into the effect of negative transfer of training. Customers need to have very specific training on the limits of newly purchased chairs, and on the differences between chairs they have had experience with in the past and new ones so that there will be no negative transfer of training calamities. I personally, after years of experience with "brand A" which would take the ramp into the shed in my backyard, tried "brand B" which tipped over backward and I got a good hit on the head. I was told by the manufacturer of "brand B" that it would do everything and more compared to "brand A." This was not true. After the incident, thinking through the mechanical differences in chair design, I could see why it would not do what the former chair had, but it didn't come to me intuitively. I should have been given accurate information on the limits that applied to the new chair--limits which had not applied to my old one.

AROUND THE CITY AND FARTHER

LEARNING ASPECTS OF CONTROL SYSTEMS

I cannot and will not try to give you any specific guidelines here; the main message I want to get across is that we need human-factors research in each and every case. Logic doesn't always provide good answers. For example, when it comes to braking systems on a joy-stick-type control, logic will tell

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us that braking backwards to match the direction of movement is the way to go. Unfortunately, logic also tells us that braking forward to match our bracing inclination is the way to go. Obviously, what appears to be logic turns out to be intuition and we need human-factors research on a case-by-case basis to tell us which intuition is correct. It may even be that such decisions have to be tailored to individuals' inclinations if there are strong individual differences.

NEED AGAIN

I expect that we may find the same consciousness-raising phenomenon which I described with regard to the use of motorized wheelchairs where the freedom of mobility leads to higher aspirations and expectations of what can be done and gotten out of life. The effect may be even more pronounced than it was with motorized wheelchairs since the degrees of freedom are increased so much more.

COST AGAIN

As with the case of motorized wheelchairs, this topic too could be subtitled "there must be a cheaper way." We in the State Department of Rehabilitation receive from many quadriplegic clients requests for vans. I know of one case that was just turned down because it would have cost \$15,000. Two such cases would bankrupt a Department of Rehabilitation Counselor for an entire year; he or she would have no money left to spend on behalf of any other clients. We, in the Department, strongly believe that the kind of mobility that these vans allow quadriplegic clients is good for them psychologically and, therefore, ultimately vocationally. But if they are going to be purchased in any volume, there has got to be a cheaper way.

VANS VS. CARS--WHICH DO THE HANDICAPPED PREFER?

I know of one very expensive project which sought to develop a prototype using an automobile rather than a van which

was premised on the insight of the designers (both non-disabled engineers) that "the handicapped" would prefer to ride in "normal vehicles." There is simply no such thing as what "the handicapped" prefer. Most human attributes are found to vary along a normal curve, the old bell-shaped distribution, including preferences. There is no reason to think that the preferences of people with disabilities are going to be univocal. There will be some who want nothing but a van, some who want nothing but an automobile, and most will be willing to negotiate, depending upon how they weigh the advantages and disadvantages relative to their own needs and life-styles. It's a matter of individual taste; there is no unitary preference. If the reasons given for preferring a more expensive/less functional solution appear to reflect self-image hangups or some other motives we choose to define as neurotic (especially if the taxpayers are paying), then maybe some counseling is in order, rather than trying to instrument an automobile when a van would be better, or vice versa.

DRIVER EVALUATION AND TRAINING

I think the most basic issue here is that we have to walk a tightrope between over- and under-caution regarding who is able to drive. The decision may be more clear-cut with spinal-cord-injured persons; it is not clear-cut if we include other quadriplegics. I recall a couple of cases where a cerebral palsied individual with a great deal of athetoid movement and a brain-injured person with considerable incoordination and apparent slowness of reflexes proved that they could drive safely, much to the surprise of myself, a neurologist, and other people at this hospital, including the driving evaluator. We all said no. Both patients found a driving school that trained them, and both are still in the process of proving us wrong by building safe driving records.

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A rather important psychological factor that must be considered is risk-taking willingness. There are inter-individual differences in willingness to take risks generally, and there are intra-individual differences in willingness to take risks in different realms of life. I can use myself as an example to make this concrete for you. I'm very willing to take the risk of being the last person to be evacuated from a survivable aircrash, as I recently indicated to the FAA in their survey, because I see a survivable aircrash as a very low probability event, and I see losing my job if I were unable to fly as a very high probability event. On the other hand, I am not willing to take the risks of getting caught in the boon-docks with a broken-down vehicle, van or auto, because I can fantasize the anxiety I'd go through and I don't need or want to take that chance. Risk-taking willingness will vary with the extent of the risk necessary to support one's chosen lifestyle. As my life is arranged today, I don't need to be able to drive independently to get where I want to go; therefore, the risk has too little payoff. A year from now it might be necessary and the risk would not look so aversive.

As you can see, I am not suggesting that we construct a handy-dandy, risk-taking questionnaire that can be administered to people who are candidates for vehicles because I don't believe we can tap the intra-individual differences across time and across realms of life. What I am saying is that risk-taking willingness is a counseling issue. The staff involved in a decision whether or not to equip a person with a vehicle should counsel with the person and help him get a fix on where he is in terms of risk-taking willingness, to aid him in making his own decisions as to whether or not he wants to try to drive independently.

PUBLIC TRANSPORTATION

There is no question in my mind that it's psychologically bad for people to be deprived of their constitutional and other legal rights. To again use myself as an example, I talked with my tax man the other night and learned that I'll be giving the Federal Government 40 percent of my income this year. Some of that money comes back to help support the RTD, but I can't get on their buses. Who could doubt that this is an unwholesome situation for me and 60,000 other wheelchair users in the greater Los Angeles area? I understand that some years ago General Motors developed a prototype for an accessible bus and surveyed rapid-transit authorities throughout the country as to interest in such a bus. They reported they got back a vote of no interest because the transit authorities were not willing to give up seating for seven passengers which was necessary in an exchange for accessibility to mobility-impaired people. I question whether they have this choice. California, for example, is one of the forerunners among the states in mobility legislation. Some of that legislation spells out explicitly that equipment of rapid-transit authorities has to be accessible to the physically handicapped.

Let me move for a moment to an analogy. All power equipment has safety devices on it. No one says, "Oh, we won't put a safety device on that particular piece of equipment because only about 10 percent of the people who use it are going to cut off a finger, anyway." On the rare chance that an occasional citizen will cut off a pinkie, we insist upon safety devices for the equipment even though they cause the machine to cost more. I believe the same thing applies with respect to accessibility for mobility-impaired people. Once we have noticed the problem, even if it costs more to implement solutions, we are responsible for following through.

Psychosocial and Learning Considerations

On the other hand, I believe the disabled have some responsibilities that haven't always been acknowledged. For example, at the recent FAA hearings where disabled people were asked to voice their comments regarding air transport, a number of people stated that they wanted to be brought onto the airplane in their own wheelchair instead of being transferred to a carry-on chair, stating that the narrow, carry-on chairs made them feel undignified. First of all, airport terminals should have jetways so that no one, able-bodied or disabled, has to climb stairs to get into an airplane. But if that's not possible and if a carry-on chair is the safest, most efficient way to board a person, I don't think airlines should be forced to increase their risks of liability by having to use another method because disabled people haven't gotten their self concepts together. Maybe in this area we need to focus more on helping disabled persons get a better fix on where human dignity really comes from.

ANSWERS TO SOME QUESTIONS

In response to comments made earlier by speakers on the panel, I would like to take this opportunity to give my answers to at least one or two questions that were asked. One was "For what degree of disability do we design?" This related to public transportation. I believe that if we design for wheelchairs, essentially everyone else will be okay. In curb ramping, for example, we have to be very careful that accessibility for wheelchairs doesn't interfere with safety for blind people. Blind people count on the curb to let them know when they are about to get into the street; curb removal could endanger them unless texture differences are introduced to give the cue needed to know the street is right out there. My advisors on issues of the blind assure me that we do not run into such problems in public transportation. Thus, if we design for

access for wheelchair users, we can be relatively certain that people who use crutches, braces, have reduced energy because of cardiac and other conditions, age, and probably the able-bodied will also be benefited. Another question posed earlier by a speaker on the panel was, "Where are the handicapped not going that they should be going?" My answer to this is, "Everywhere the first-class citizens go." Everywhere the regular people go for no better reason than the fact that they want to go there. Efforts to get people with disabilities only to rehabilitation and other medical facilities, and to public and social service agencies, may be a good start in a bad direction--a psychologically unwholesome direction for both the disabled and able-bodied.

PSYCHOSOCIAL ASPECTS OF THE NONDISABLED

This brings us naturally to the last point I would like to discuss. I think we have to face the reality that people with disabilities are, indeed, devalued in society. That is why we have to worry about issues like dignity; that is why we have to worry about getting the world reconstructed so that people with disabilities can move about in it. I suspect that the nucleus for constructive change lies not in hardware and instrumentation, but in modification of attitudes, beliefs, opinions, and feelings about people with disabilities. I can't say with certainty that we have come a long way from the days when disabled people were peremptorily scuttled to the city outskirts or charged with harboring demons. Our verbalizations are less dramatic but the behavioral result is still the same; exclusion from the mainstream of life. Another group that has been excluded from the mainstream of life because of readily visible physical differences, i.e., skin color and hair texture, chose rioting as a preliminary approach to solution and not without at least some success. I doubt that disabled people will be rioting, but there is another hard-nosed approach and

Psychosocial and Learning Considerations

that is court tests. The laws are on the books, but the enforcement provisions are inadequate and missing. Citizens who find themselves physically unable to gain access to or utilize accommodations that were built for public use are using the courts more and more to determine whether they have legal recourse to insist that such facilities be made accessible to and useable by them. This, I believe, is a constructive and psychologically healthy approach.

SECTION III. GROUP REPORTS

- I. NO LOWER-LIMB FUNCTION AND UNIMPAIRED UPPER LIMBS
- II. NO LOWER-LIMB FUNCTION AND NO UPPER-LIMB FUNCTION
- III. NO LOWER-LIMB FUNCTION AND PARTIAL UPPER-LIMB
FUNCTION
- IV. PARTIAL LOWER-LIMB FUNCTION AND PARTIAL UPPER-
LIMB FUNCTION
- V. SPECIAL PROBLEMS

GROUP I
NO LOWER-LIMB FUNCTION AND UNIMPAIRED UPPER LIMBS

Group Leader: Harry Hahn
Group Recorder: Michael Quigley
Members: Ralf Hotchkiss Paul H. Newell
Ira Laster D'Arcy O'Connell
Edward Malmstrom Anton J. Reichenberger
Wallace Motloch Joseph E. Traub

CHARACTERISTICS AND POPULATION

The category considered here is the paraplegic population.

CHARACTERISTICS

There are five variables that directly affect the extent of the disability:

1. The level of the neurological lesion. People with lesions between T₁ and T₂ levels have a greater loss of sensation and less trunk stability than people with lesions between T₆ and L₁.
2. Age. There are essentially four age groups with different functional requirements. They are:
 - a. the first decade of life
 - b. the second decade of life
 - c. adulthood
 - d. the aged
3. Etiology. Four categories of etiology may also influence functional needs. Functional expectations will be different if the cause of spinal-cord impairment is from trauma, if it is a congenital problem, if it is a degenerative condition, or if it is an infectious condition.
4. Complications. These may be due to such conditions as spinal curvatures, excessive or inadequate sensation, osteoporosis, a decreased range of motion in the joints, problems with the autonomic nervous system, and spasticity.
5. Motivation of the person. Motivation depends directly upon the psychological outlook of the patient, as well as the extent of the physical disability.

People who have only lower-limb impairment and normal use of the upper limbs and few other complicating conditions can be expected to attain a high level of physical and psychological independence.

Group I

PATIENT POPULATION

The exact number of paraplegic patients has not been determined. However, figures compiled by the National Center for Health Statistics on persons using wheelchairs and lower-limb orthoses help to provide an estimate of the paraplegic population. A 1969 report by the National Center for Health Statistics, Series 10, No. 78, states that 409,000 people use wheelchairs. Of this number, 204,000 use wheelchairs all of the time; 71,000 people use wheelchairs most of the time; and 149,000 use wheelchairs occasionally. The same publication estimates that there are 233,000 persons with leg or foot "braces" in the United States, or 1.2 people per 1,000 population. Of this number, 42.3/1,000 population that wear braces are unable to walk, keep house, or engage in school or preschool activities, and 30/1,000 population are limited in these activities. That report, however, excluded the institutionalized population, but another report entitled *The Use of Special Aids in Homes for the Aged and Chronically Ill* from the National Center for Health Statistics, Series 12, No. 11, 1964, stated that 117,400 people in these homes use wheelchairs, which is about 1 out of 5 residents, and 5,400 of them use leg "braces."

The population will undoubtedly increase in the near future due to the improved emergency medical care which will save and preserve more people in many age and disease groups, and the general increase in the population.

NEEDS

The needs of the paraplegic are given below and classified by priority.

LOWER PRIORITY NEEDS

Persons with lower-limb disability only do not have many of the problems of other spinal-cord-impaired people. For this reason, mobility priorities will be different for this group of people.

Group I

People with paraplegia generally have enough upper-limb strength to provide easy transfers from one location to another although the patients in this group that have lesions from the T₁ through T₅ level will have a more difficult time transferring due to their lack of trunk stability.

Another low-priority need for this group is outdoor, non-licensed vehicles. Examples of this type of vehicle are golf carts and all-terrain vehicles. The true need for these vehicles has not been determined yet, and the legal limitations have not been stated. For example, it is not known whether they can be driven legally on sidewalks or roads or trails. Speed limitations for these vehicles and the different roads have not been stated. Nor is it known whether handicapped drivers can be made exceptions to the existing laws limiting the use of these outdoor non-licensed vehicles. Some of the main problems that can be foreseen in the use of these vehicles are transporting wheelchairs or other mobility aids on these vehicles while they are being driven so that the person can transfer to his wheelchair upon reaching his destination.

MEDIUM PRIORITY NEEDS

Ambulation, or walking while using assistive devices, is considered in the medium-priority class because it has not been determined whether this is the optimum mode of mobility for people with lower-limb impairments. Standing is also included in the definition of ambulation. The present state of the art is use of exoskeletal orthoses that immobilize joints and thus provide a limited amount of alignment stability. A need for an attendant-free technique of ambulating and for a hand-free technique while standing is apparent. In present systems if a person desires to stand in these orthoses, he must grasp something in order to stabilize himself, thereby preventing the use of his hands for any functional activity.

Mobility can be divided into two areas: Place-to-place mobility which includes mobility around the house, upstairs, around the city,

Group I

and from city to city; and environmental manipulation or maneuvering. Once the patient has reached his destination, he should be able to reach light switches, objects on upper shelves, or under beds. In order to obtain a greater environmental manipulation, greater flexibility in body positioning is necessary. Patients using any device that provides stability or support should be able to stoop down, lean over, or have the ability to place their bodies in any functional position other than standing or sitting. Devices designed to provide body-positioning flexibility or to provide increased place-to-place mobility should require less energy expenditure of the person than is necessary in the present devices. Recommendations in this area are the same as the needs stated above, but additional research and development in the following areas are necessary:

1. Functional electrical stimulation
2. Powered orthoses
3. Sensory feedback
4. Hybrid designs

HIGH PRIORITY NEEDS

A transporter is needed that will provide place-to-place mobility as stated in the previous section. The present state of the art in transporters for paraplegic patients is a chair on wheels. A new design in transport should allow postural changes for comfort and relief and minimize the complications of postural rigidity as well as being compatible with any environment. It is recommended that the transporter have all the advantages of the present wheelchair but with the following changes which fall into both difficult and easy-to-change categories:

Easy to Change or Provide

- Reduce width of the transporter
- Reduce rolling resistance
- Use more efficient casters
- Reduce caster shimmy
- Strengthen the wheels
- Provide better mobility in snow.

Group I

Difficult to Change or Provide

- Provide curb-climbing ability
- Shorten length of chair
- Allow kneeling, bending, standing
- Provide one-handed operation
- Provide rough-ground mobility
- Provide stair-climbing ability

Skin protectors or cushions are also needed to prevent decubitus ulcers which are one of the most common complications of spinal-cord-impaired people. These cushions should be considered an integral part of the transporter. In addition, patients should be better educated as to the techniques and value of pressure relief since many patients who are able to prevent pressure sores (they have strength for push-ups) still get pressure sores. An easy way to provide custom-fitted relief cushions should be developed. More fundamental studies are needed in this area, and results of existing studies should be published widely.

Another high-priority item for lower-limb-impaired people is licensed vehicles. Many people in this category are able to transfer independently into, drive, and maintain an automobile. The present need is for safer, more dependable hand-control devices and for fast and easy wheelchair entrance and exit. Communication systems such as two-way radios should be placed in a vehicle in case of emergencies.

The state of the art in licensed vehicles for these people is hand controls that are not built by automobile manufacturers and are modified to fit the different automobiles. These controls have not changed in 25 years and are modified each year after new auto models are introduced and have many inherent faults (difficult installation, sharp edges, etc.). Sweden presently produces Volvos that offer optional hand controls installed and designed and maintained by the manufacturers, but the United States of America has not had this co-operation from the automobile manufacturers.

Auto manufacturers should design hand-control systems into new models and offer them as optional equipment. This would also

Group I

eliminate installation and repair problems as auto repair shops would be able to repair and maintain this equipment.

Licensed examiners should know how to operate and inspect hand controls for quality and proper installation.

Driving instructors should be able to train people using hand controls.

Insurance standards and rates for hand-control drivers should be based on performance alone and thus would be equal to the rates offered to normal drivers.

Portable, easily interchangeable hand controls for use on different cars while still maintaining safety standards should be made available.

Public transportation should be made available to spinal-cord-impaired people. Present systems of public transportation are not really public, as one out of every seven people in the United States is excluded due to inaccessible buses, trains, taxis, and other vehicles.

The same availability and accessibility should be afforded to wheelchair users as to able-bodied people. Immediate modifications can be made to existing systems at this time and future systems should have a barrier-free design which would allow access to these systems by spinal-cord-impaired people.

The present state of the art in public transportation is buses, subways, and taxis--all of which are inaccessible. Intercity FAA regulations presently mandate that wheelchair people must be accepted and that flight crews be trained in emergency evacuation of these people. In addition, many airline terminals are being modified to allow accessibility of wheelchair users.

Recommendations for short-range attempts at improving the accessibility of public transportation include the installation of

Group I

stairway bus lifts. Units are presently available through the Department of Transportation in Canada at a per-unit cost of about \$2,000. Narrow aisle wheelchairs should be available to be used on intercity buses and on airplanes and should be left on the vehicle during the trip in order to transport wheelchair people from their seats to washrooms. Present use with narrow-aisle wheelchairs is to transport the person to his seat but then remove the wheelchair from the vehicle during the trip. In addition, transit companies should be encouraged to purchase accessible vehicles for future use in order to eliminate the necessity for modifications of vehicles when accessibility laws are enforced.

An additional high-priority need for the paraplegic people is the elimination of architectural barriers. The present status of architecture includes many stairs, inaccessible bathrooms, curbs, and other barriers that prevent access to the majority of existing buildings. Legislation should mandate the removal of existing architectural barriers, and all attempts should be made to prevent future construction of architectural barriers. Mandatory involvement of the disabled, rehabilitation engineers, and others knowledgeable in the field is necessary to draft workable legislation and to design totally accessible buildings.

Educational material and courses are presently extremely limited for the spinal-cord-injured people and for those people wishing to improve the present conditions of the spinal-cord impaired. Grants should be made available to produce educational literature for use by architects, physicians, engineers, designers, and maintenance personnel in order to make them aware of the needs of the mobility-limited. Educational literature should also be made available for parents of the disabled as well as the disabled himself. Third-party payees should have educational material in order to make them more aware of the needs and requirements of these people.

Group I

Aids for the disabled should also be made totally available to the disabled. Presently, many aids for the disabled such as wheelchairs, environmental controls, transfer devices, and other activity-of-daily-living aids are available through many, many sources in the United States and abroad. In order for a disabled person to become aware of what aids are available for him, an enormous amount of time and research is involved. It is recommended that centers for displaying aids for the disabled be established. A showroom or sampling center would allow the consumer (disabled people) to see and try all available models, sizes, and types of wheelchairs and other aids that may apply directly to making him a more functional member of society. Trained professionals should be available in these centers to provide counsel. Purchase of these aids at a location other than the center would prevent any chance of the possibility of pressure sales occurring. The centers could also serve a valuable purpose as evaluation centers and centers for establishing the needs for other equipment to be designed for the disabled.

CONCLUSIONS AND RECOMMENDATIONS

A high level of physical and psychological independence can be expected of paraplegic patients with normal upper-limb function and few additional complications. To help attain this independence, the following conclusions and recommendations were made:

- The need and legal limitations for outdoor non-licensed vehicles should be established.
- Assistive devices to aid in hands-free standing and attendant-free ambulation, while allowing body-positioning flexibility (lean over, stoop down, etc.), should be developed. Present systems may be modified to include powered joints, sensory feedback, or functional electrical stimulation to provide the necessary functions.

Group I

- A transporter is needed that will be compatible with environments other than hard level surfaces, should allow postural changes, and should provide skin-pressure relief. Transporter designs should have all the advantages of the present wheelchair and concentrate on eliminating the disadvantages.
- Hand controls that are more dependable and safer than present models are needed. Automobile manufacturers should design these controls and offer them as optional equipment in new models. Insurance rates for hand-control drivers should be based on driver performance alone.
- Immediate modifications should be made to existing public transportation systems to allow free access by spinal-cord-impaired people. Future systems should be designed to be barrier-free.
- Legislation should mandate the removal of existing architectural barriers and all attempts should be made to prevent future construction of architectural barriers.

A general conclusion by the group was:

When something is good for the disabled, it is also better for the able-bodied.

GROUP II
NO LOWER-LIMB FUNCTION AND NO UPPER-LIMB FUNCTION

Group Leader: J. Thomas Mortimer
Group Recorder: Sheldon Bajema

Members: Reinhard Daher Thomas Shworles
 Geoffrey Dudley E. Shannon Stauffer
 Åke Hansson A. B. Wilson, Jr.
 Charles Scott

DEFINITION AND PATIENT POPULATION

The number of very-high-level quadriplegics that survive is increasing in the United States. The reason is the quality of acute care at shock-trauma units which provide heroic measures to support life. Another reason is the growing number of spinal-cord centers around the country that have extended the life-span of high-level quadriplegics. The Veterans Administration now has 22 spinal-cord centers. The Maryland Institute for Emergency Medicine has been so successful at life-saving that respirators sometimes have to be turned off on very-high-level quadriplegics with functioning brains, simply because there are more people surviving than there are respirators to support life.

Estimates of the rate of occurrence and the total number of patients in the U.S., along with the variations in function remaining, are shown in Figure 1.

PROBLEMS

A. Ambulation is not possible by any known means, not even with personal assistance or appliances.

B. The quadriplegic is totally dependent on attendants for transfer, for equipment maintenance, and help in feeding, elimination, and dressing. Mobility of high-level quadriplegics adds to the burden on the attendant, compared with confinement

Group II

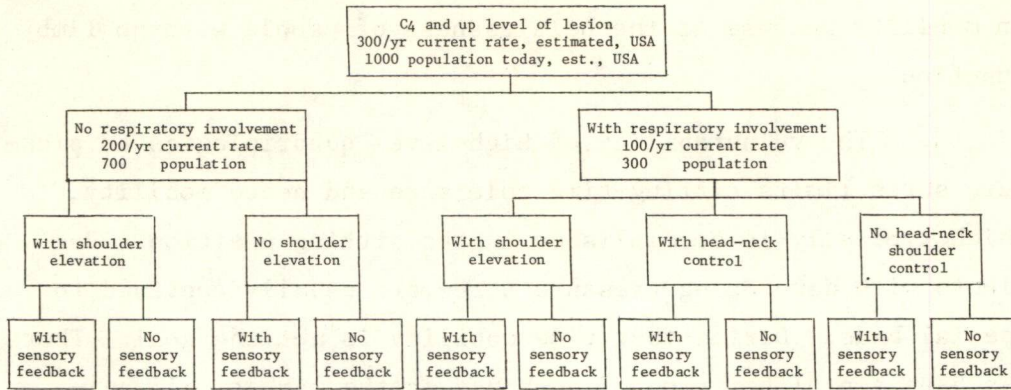


Fig. 1

to bed. The functions of the attendant have not been automated or placed under the control of the patient. Any deficiency in the availability of attendants clearly places a constraint on the mobility of totally dependent people.

C. Very-high-level quadriplegics have a total dependence on life-support systems. Those with spinal cords severed just below the base of the skull cannot breathe without a respirator because the respiratory muscles are paralyzed, as are basic reflexes such as coughing and swallowing. Such patients are sentenced to a precarious and artificial existence. They can do nothing for themselves and require extended care to take care of all life-supporting needs. In such high-level quadriplegics basic survival is more the concern than mobility about the community.

D. Public transportation systems do not easily lend themselves to mobilizing nonambulatory people. There are access problems, on-off loading problems, equipment restrictions, and attendant requirements.

E. Architectural barriers such as doors, curbs, steps, and environmental controls greatly limit mobility both inside and outside the home.

Group II

F. The potential of an emergency situation places limits on mobility because of the helplessness of people with no limb function.

G. The vulnerability of high-level quadriplegics to pressure sores limits sitting-time tolerance and hence mobility, which typically is accomplished in the sitting position. Patients with developing pressure sores are usually confined to special beds. During that time mobility is not the goal. There has been a proliferation of cushions on the market, all purported to distribute body weight in order to reduce pressure and increase sitting-time tolerance. Many centers are buying and trying cushions by trial and error in order to select suitable ones for their patients. A list of limitations in some wheelchair-cushion designs is included as an attachment to this report. The United States Army Medical Bioengineering Research and Development Laboratory (USAMBRDL), Fort Detrick, Maryland, one of the centers evaluating cushion materials, found that many commercial cushions provide a pressure gradient in the wrong direction. The greatest pressure is on the areas that can least accept the pressure. Also, most wheelchair cushions are far too shallow to make use of the available area for weight distribution.

H. Some quadriplegics require a means for alternating areas of weight support in the sitting position or a means of reclining periodically.

I. The spine does not have adequate muscular support in high-level quadriplegics so trunk and/or head and neck support is required for sitting in a wheelchair. Either an orthosis or special supporting structures on a wheelchair are required in order to achieve mobility in the typical sitting position.

J. Transfer of a high-level quadriplegic from bed to chair, from chair to bathtub, auto, train, bus, or plane, or transfer from one vehicle to another is one of the major obstacles to mobility.

Group II

K. There is currently a problem of offering crash protection to high-level quadriplegics while traveling in vehicles. For example, a means of anchoring a wheelchair in a van has not yet been developed.

CONCLUSIONS AND RECOMMENDATIONS

A. Mobility systems should have the following characteristics:

1. Few restrictions on use
2. Pleasing appearance
3. High degree of reliability
4. Easy for transfer operation to be effected
5. Easy to operate

B. Pressure distribution systems

1. Further development of support systems which make use of the maximum available area for weight distribution are needed.
2. Studies are needed to determine whether controlled pressure distribution is better than uniform pressure distribution.
3. Comparative evaluation of present weight-distribution systems in order to determine the desirable characteristics should be continued. These studies are currently being undertaken by Rancho Los Amigos Hospital, USAMBRDL, and N.Y. State Rehabilitation Hospital (Helen Hayes Hospital), Haverstraw.
4. Evaluation of the two commercially available, alternating pressure-point wheelchair cushions, the GRANT and the LAPIDUS, should be initiated.

C. Position--reclining systems

Both self-controlled and attendant-controlled systems for positioning and reclining require further development and evaluation.

D. Body support for head, neck, and trunk

The wheelchair seat should be customized to serve the function of a spinal orthosis when such an orthosis is required. The body support--correction system

Group II

could be integral with the wheelchair seat and backrest design. Such an approach would permit seat transfer along with the patient.

E. Transfer

1. Bed $\longleftrightarrow$ Chair $\longleftrightarrow$ Tub

A lift and attendant are needed. As much of the transfer as possible should be done in the lateral plane to reduce energy-consuming vertical movement.

2. Chair $\longleftrightarrow$ Auto $\longleftrightarrow$ Plane
Bus $\longleftrightarrow$ Train

Common vehicles have not been designed for acceptance of high-level quadriplegic patients.

High priority should be given to a new design concept in which a custom-fitted chair module detaches from the wheelchair frame and is transferred with the patient. The chair-module approach would reduce transfer problems. The chair module should be capable of transfer between powered and nonpowered wheeled chassis, and onto a well-anchored base in a car, van, or other vehicle.

F. Nonlicensed vehicles for outdoor use

1. Top speed is yet to be determined but is probably between 5 and 10 mph.
2. The vehicle should have rough-terrain capability.
3. More bikeways would help to accommodate more outdoor vehicles more places.
4. Traction systems for snow and mud are needed. Simple snap-on lugs may be satisfactory.

G. Licensed vehicles

1. Quick recharge batteries should be standard equipment.
2. Gel-type electrolytes are desirable.
3. Use of sealed batteries should be mandatory.
4. Presently there are totally inadequate tie-down provisions for wheelchairs in vans. Needed is a design of a safe system.

Group II

5. Standards for wheelchair frames and seat fixation in terms of G-loads in various directions are needed. This should be given high priority.

H. Public transportation

The same standard for wheelchair and seat fixation in licensed vehicles can be used for designs for public vehicles.

I. Architectural design

1. Automatic doors for all public buildings should be mandatory.
2. Inclines at curbs should be provided.
3. Elevator buttons and hall light switches should be placed for easy access to the wheelchair-bound. Patients will still need some way to control the buttons and switches such as by a mouth stick.

J. The modular approach

Single solutions are being sought for several independent design problems creating the risk that more hardware and money will be required to improve mobility than is probably necessary. An example of an integrated solution is the use of a chair-module design approach to solve problems of the patient transfer, pressure distribution, positioning, spinal correction, and safety within a moving vehicle in a single system.

A customized chair-module system similar to "Contourpedic seat," molded to the patient's body, could be detachable from the chassis for transfer along with the patient to another chassis or to a van or auto where provisions are available for anchorage. Trunk and head support may also be incorporated in the chair module.

One-piece molded wheelchair seat and frame permits customized widths at no extra cost if the wheelchair frame is molded along with the customized chair shell. The module should have a quick-disconnect method for interchange with:

- a. nonmotorized wheels
- b. motorized wheels (Dudley)(Fig. 2)
- c. a well-anchored seat base in vehicle.

Group II

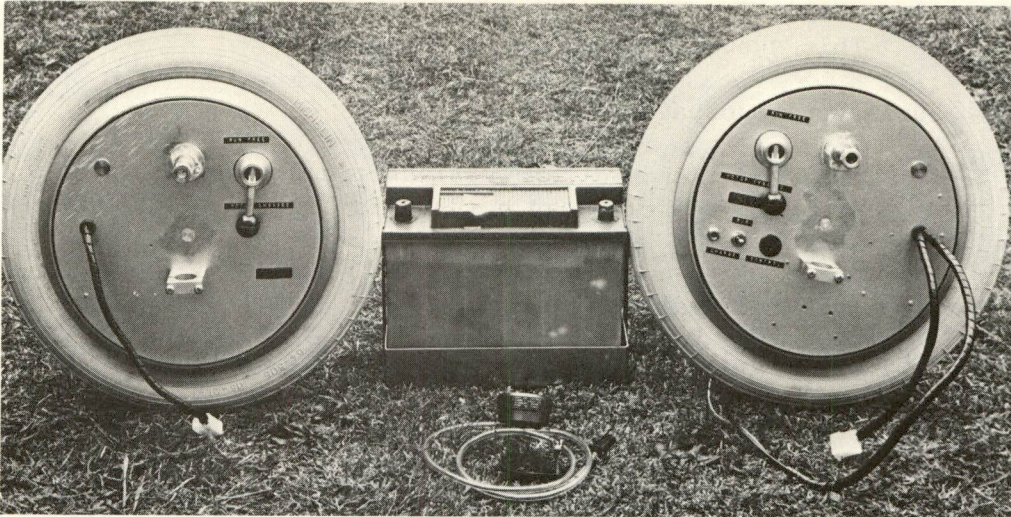


Fig. 2. Wheel hub motor system (Dudley Controls Ltd.).

A means could be developed for locking the wheels with respect to the ground and powering a double-axis turret base so the chair module could be rotated and inclined with respect to the ground.

K. Fail-safe design

1. Call-for-help system in case patient is stranded should be mandatory.
2. Electrical fire protection must be assured.
3. A respirator back-up system should be required.
4. A secondary braking or "Dead Man Control" system should be required.
5. A monitor for state of battery charge to determine whether a trip can be completed should be considered.

L. Free-wheeling externally powered wheelchairs should also have a free-wheeling mode in case the wheelchair has to be pushed.

M. Power source

1. Batteries are presently the best power source. Battery power may improve as a result of electric commuter car research and development.

Group II

2. Gel electrolyte and nickel-cadmium batteries which are sealed to prevent spillage are now available. They are safer and are all allowed on airplanes. They also offer faster charge rates than wet-cell lead batteries.

N. Self-control mode

It is not possible to make general recommendations of which control source should be used. The selection should be based on measurements of each patient with respect to cosmesis, learning ease, reliability, and amount of residual function. It is recommended that proportional control rather than on-off control be used.

The chart below shows control types presently available and those in the experimental stage or considered possible. While bioelectric control is listed, it has serious drawbacks such as tendency for inadvertent switching, difficulty in positioning of electrodes, and possible sacrifice of normal function.

	ON-OFF		Proportional	
	<u>Avail.</u>	<u>Exp.</u>	<u>Avail.</u>	<u>Exp.</u>
<u>Mechanical Switch Control</u>				
eyebrow		X		
eye blink		X		
eye position		X		
blow--suck	X			
audio		X		
proximity		X		
tongue internal		X		
tongue external	X			
head motion		X		X
shoulder motion		X		X
breath - temp		X		
breath - humidity	X			
chin control	X		X	
<u>Biomechanical Control</u>				
skin motion				X
muscle bulge				X
implanted (IM) pressure				?
implanted (IM) length				?
<u>Bioelectric Control</u>				
EMG				?
EOG (Electro ocular)				?

LIMITATIONS IN SOME OF THE CURRENT CUSHION DESIGNS

1. Elastic cushion materials have a stress-strain relationship such that the greatest pressure is at the area of greatest deformation. Since bony prominences create the greatest deformation they receive the highest pressure.

2. Gels have been promoted for their unique behavior of "flowing" away from bony prominences rather than compressing. However, gels have a similar stress-strain relationship to elastic materials, and, therefore, the highest pressure is on areas which can least tolerate it--the bony prominences.

3. Viscoelastic materials have a time-dependent stress-strain relationship. As with the elastic materials, the greatest pressure is on the bony prominences, even after the strain-time curve has plateaued. Viscoelastic materials only appear to conform to the body better than elastic materials because they take a while to recover their original shape when unloaded.

4. Tension in the cushion cover creates added pressure on bony prominences as prominences distort the cover. The added pressure due to this "hammock effect" tends to be greater in fluid- or air-filled cushions because bladder tension is created to contain the fluid. Added pressure on prominences due to the hammock effect tends to be greater over deep soft cushions than shallow hard cushions because of the greater distortion of the cushion surface under the prominence. The hammock effect is greater when thick, nonelastic cover materials are used.

5. Body area available for weight distribution in the sitting position is considerably less than in the supine position. With 3/4 of total body weight delivered to the cushion, the least uniform pressure required to support a sitting subject is nearly three times the uniform supine pressure.

Group II - Attachment A-2

6. Most wheelchair cushions do not make use of the greatest possible area for weight distribution. Anthropometric data* indicate that it is possible to reduce sitting pressure to approximately 30 mmHg provided that: the seat cushion allows for ischial tuberosity penetration of 10 cm; the cushion supports 3/4 of body weight; and the weight is uniformly distributed over the entire sitting surface. Most seat cushions are far too thin to provide maximum area for weight distribution.

Impression Depth of Ischial Tuberosities in Cushion cm	Calculated Pressure mmHg
3	99
4	74
5	58
6	46
7	38
8	33
10	30

NEW DEVELOPMENT

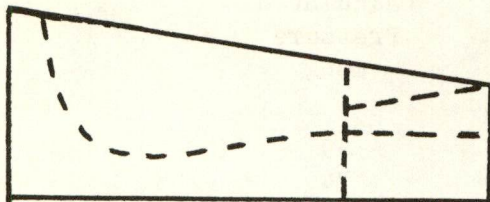
LUBRICANT FLUIDIZED SOLID WHEELCHAIR CUSHION

A lightweight, inexpensive wheelchair cushion that readily conforms to the body and uses nearly all of the sitting area available for weight distribution was developed at USAMBRDL. The container confines the fluidized material in such a way that there is no bladder tension at critical areas so that bony prominences imbed deeply without encountering the hammock effect. The material flows from high- to low-pressure areas while maintaining enough flow resistance to provide sitting stability. Since the contact surface is so large and there is very little pressure gradient, the uniform pressure is low--approximately 35 mmHg, depending on sitting position. The wheelchair cushion is easily made of commercially available materials which cost \$4

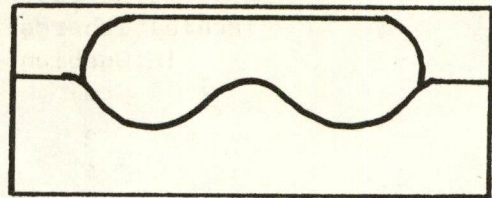
* USAMBRDL

Group II - Attachment A-2

and weigh 3 pounds. No customizing is required. The plastic deformation or flow provides a perfect form fit regardless of sitting-reclining position, regardless of who uses the cushion, and regardless of changes in the amount of soft tissue. The cushion is not recommended for use in vehicles because the material cannot absorb shock.



side



front

GROUP III
NO LOWER-LIMB FUNCTION AND PARTIAL
UPPER-LIMB FUNCTION

Group Leader: Colin A. McLaurin

Group Recorder: Ronald Lipskin

Members:	James Allen	Yves Lozac'h
	Raymond Biddle	Martin Prast
	W. F. Bryant	Steven Reger
	Scott Deacon	John E. Rogers
	Peter Hofstra	John Walker
	Hector W. Kay	

DEFINITION AND PATIENT POPULATION

Quadriplegics with lesions between the C5 and C7 levels are considered here. Lesions at the C6 level are the most common.

There are approximately 50,000 patients in this group. The incidence rate is about 3500 per year. Poliomyelitis, amputation, other trauma, and congenital anomalies provide patients in this category but they are small in number in relation to patients with spinal-cord injury.

NEEDS

AT HOME

Beds: Relatively inexpensive beds that prevent formation of pressure sores. (New materials may provide the solution.)

Transfer between bed and wheelchair preferably without assistance.

Mobility: Pegs or power.

Bathroom accessibility and aids.

Dressing: C6-7 patients can usually manage.
C5 patients usually have problems.

General mobility in the home: Moving about can usually be managed, but moving around while doing chores (e.g., cooking) presents problems.

Group III

Manipulation: Lifting substantial weights, reaching out and up, opening doors, etc.

Stairs

NEIGHBORHOOD

There is no need to enter an automobile in this range but ice, snow, mud, gravel, and curbs must be anticipated.

INTRACITY

Automobile use accessibility and hand controls.

Public transportation accessibility

buses

rapid transit systems

INTERCITY

Public transportation accessibility

trains

buses

CONCLUSIONS AND RECOMMENDATIONS

LEGISLATION

Realistic laws that encourage independence of the severely disabled should be promulgated and encouraged, and enforcement of existing and new legislation should be demanded.

DESIGN AND DEVELOPMENT

Mobility in the Home

Special chairs should be designed for use in the home.

Research and development in the use of electrical stimulation of the neuromuscular system to provide function should be expanded.

Neighborhood Mobility

Special chairs should be designed for use out of doors. Transfer as we know it today should not be necessary.

Group III

Long-Distance Mobility

For use in vehicles, wheelchairs should be designed to withstand 4G impact loading.

Concept

A modular system built around the seating component of the home unit, compatible with other units for outdoor and vehicle uses, should be considered.

MANUFACTURING INCENTIVES AND REQUIREMENTS

Government funds are probably needed to insure adequate design, manufacturing, performance specifications, and quality control.

GROUP IV
PARTIAL LOWER-LIMB FUNCTION AND PARTIAL
UPPER-LIMB FUNCTION

Group Leader: Warren G. Stamp

Group Recorder: Eugene F. Murphy

Members:	Peter Arballo	Don M. Cunningham
	Henry G. Bouman	Roy Snelson
	Peter W. Bressler	

DEFINITION AND PATIENT POPULATION

FUNCTIONAL DISABILITIES

The group realized that its population, with "partial" as the chief characteristic, obviously covered unusually diverse conditions, wide ranges, and complex interactions of multiple handicaps. Endurance of the patients varied widely. The chief attention was given to the serious end of the spectrum.

Position, i.e., sitting in a wheelchair, may require the handicapped person to perform a task in an inefficient position, with poor leverage or at an inefficient point on the force-length curve for remaining muscle.

The group assumed that because of partial functions remaining, the patients would be able to operate controls even if unable to exert substantial forces. In some cases, such as polio, sensation would remain. No special attention was given to presence or absence of spasticity. The group realized that in many cases of partial disability, prescription of the best available present orthoses and preferably improved devices would greatly reduce the problems faced; for example, in self-care, transfer, or mobility in various areas.

PATIENT POPULATION

Patient population was not analyzed because those present had no accurate statistics.

Group IV

PROBLEMS, CONCLUSIONS, AND RECOMMENDATIONS

The group first analyzed problems, primarily of a severely disabled person. It then analyzed potential solutions, primarily involving devices but also considering training of professionals and patients, improvement in mass transit, reduction or elimination of architectural barriers, importance of motivation, etc.

Major or composite problems along with suggestions for possible solutions are listed in the table at the end of this group report.

The complexity of the problems and the value of potentially available solutions obviously vary with terrain and climate.

The group recognized the desirability of early identification of patients, prevention of complications, improvement of partial recovery, and improvement of psychological outlook. It is important that insurance companies, government agencies, and other "third parties" recognize the importance of early transfer to specialized centers and the value of investment in appropriate equipment and services.

Group IV

PROBLEMS	SOLUTIONS
HOME	
Devices for all transfer problems need improvement	Movable contour seat to aid transfer between wheelchair and other vehicles. Elevation control for seat in chair to aid transfer between bed and chair
Self-care (Weakness; inadequate training)	Electrically powered servo reaching aid Transfer between ADL training program
Limited reach and inability to stand without aid	Stand-up wheelchair exoskeletal device (motorized orthosis) improved orthoses (generally)
Pressure sores	Oscillating pressure transplanted tissue cushions implanted artificial cushions (e.g., silicone rubber) improved seating systems training and motivation for changing of pressure areas
Inadequate prescription and service of equipment	Revision of prescription standards. It should be cooperative effort between engineering and medicine in consultation with patients
Inadequate training of staff	Special training for professional personnel to better indoctrinate patients in activities of daily living and self-care
Inadequate past standardization	Wheelchair manufacturers should convert to the metric system
NEIGHBORHOOD	
The use of either a powered or manually operated wheelchair is assumed. It is recognized that a patient may need more than one wheelchair, each having specific capabilities	
Exterior and interior architectural barriers	Movements to eliminate architectural barriers should be accelerated and expanded to include provisions for non-wheelchair users as well, e.g., handrails, holds, etc.
Limited reach and inability to stand (while shopping, etc.)	Design and manufacture of consumer products that incorporate provisions for the handicapped should be encouraged
Inaccessibility to automobile	A transfer system using all or part of the wheelchair
Breakdown of powered chair or auto	Citizens' band radio radio telephone
Rough terrain	(Covered elsewhere. <i>Ed.</i>)
CITY	
Transporting of powered wheelchair; limited range manually	Short-range vehicle for use by handicapped and nonhandicapped for possible link in mass transit system
Architectural barriers as related to employment, education, recreation	Same as suggested under "Neighborhood"
Range of motion (standing, etc.)	Same as suggested under "Home"
INTERCITY	
Long-range transport inaccessibility; high-speed jostling, luggage, small bathrooms	Elimination of architectural barriers rental plan for batteries, sealed battery case training of airline and rail staffs adequate porters
Auto rest areas	Elimination of architectural barriers

GROUP V
SPECIAL PROBLEMS: CEREBRAL PALSY, SPINA
BIFIDA, MUSCULAR DYSTROPHY, ETC.

Group Leader: Douglas A. Hobson
Group Recorder: Margaret L. Young

Members:	John Bell, Jr.	Warren Nellis
	Patricia Cass	Barrie Payne
	Pamela Cluff	Shawn Solomon
	E. E. Harris	Hank Tietje
	Deborah Hirsch	Morey Weinberger
	Götz-Gerd Kuhn	

Although the group was charged with the responsibility of identifying mobility aids for specific physical dysfunction caused by cerebral palsy, spina bifida, muscular dystrophy, and, at our inclusion, multiple sclerosis, it became evident early in the discussion that most of the problems of mobility apply generally to all the above disabilities. Therefore, most of the time was used to identify broader ranging problems followed by the formulation of recommendations; mentioning a specific disability only when it was an exception. During the course of discussion cognizance was given to the mobility problems that arise in the home, neighborhood, city, and during intercity travel. The identity needs seem to fall into categories of:

- Education
- Transportation
- Environmental considerations and shelter
- Functional aids

Accurate population figures are always difficult to establish. However, from various sources the following statistics were obtained which are good approximations of the number of patients in the United States in each of the categories:

Cerebral palsy	-	750,000
Myelomeningocele	-	27,500
Muscular dystrophy	-	200,000 (2/3 between 2-13 years)
Multiple sclerosis	-	500,000

Group V

EDUCATION

PROBLEMS

Need to inform the family regarding the total management of a child or adult, including present and future goals, as well as information about community resources, special programs, etc.

The need for changed attitude on the part of the school systems in order that handicapped children in particular be given the option of attending regular schools and thereby allowing them to compete in the real world with their non-handicapped peers.

Lack of knowledge by the public at large and even how to talk to physically handicapped people, and thereby approach them as people with normal intelligence.

The discrimination exists against handicapped people regarding their use of public facilities, i.e., telephones, washrooms, movie theatres, etc.

The lack of information in the design professions (engineers, architects, etc.) who are not taking into account enough variability in designing for a wider ranging norm, which could include some of the needs for the handicapped and therefore obviate the need for special adaptations, i.e., adjustable sink heights, accessibility to homes, bathroom door widths, etc.

RECOMMENDATIONS

Information centers should be set up in towns and cities as a resource for parents, professionals, and consumers themselves for information regarding transportation, clinics, treatment centers, equipment suppliers, schooling, recreation programs, etc.

Clinical resources should be established and identified where special knowledge and expertise exist for managing distinctive disabilities, i.e., muscular dystrophy, cerebral palsy, spinal-cord injuries, burns, etc.

Clinic teams should be encouraged to think in terms of realistic management goals for their patients, and to work with the family to establish both short-term and long-term goals and prepare them for possible changes in life-style immediately or in future years.

Group V

Design professionals plus public transportation and recreation personnel need to be educated on the rights of the physically handicapped to engage in and enjoy the events of life such as travel, cultural activities, sports, and general entertainment.

Insurance agencies should be encouraged to develop policies which have special risk premiums or disclaimers so that the physically handicapped may participate in activities which are now denied to them due to the liability risk, i.e., swimming pools, bowling alleys, etc.

The attitudes of school boards in general should be encouraged towards more integrated school systems thereby allowing the handicapped to interrelate with normal children whenever possible.

TRANSPORTATION

PROBLEMS

Most communities do not have adequate public transportation facilities for someone who must remain in his wheelchair to travel to and from work, recreation facilities, shopping centers, etc.

There is a problem of accessibility to both urban and inter-urban trains and buses which includes both access (due to the height and number of steps) and the narrow width of aisles.

Wheelchair-bound physically handicapped are unable to use airline toilets and when on flights longer than three hours this may become a serious problem.

There is no standard policy amongst airlines by which a person using an electric wheelchair can take his batteries along with him--either the acid must be drained before departure and filled again on arrival or the person must arrange to have a new set of batteries on arrival.

RECOMMENDATIONS

Through thoughtful planning between state and federal transportation authorities, transportation systems must be evolved to serve both the urban and interurban transportation needs of the handicapped. This may be an accommodation of all existing systems in some areas, or a totally new system, depending on the need and the numbers to be

Group V

served. Dial-a-bus feeder system to available transportation, total dial-a-bus system, totally accessible buses, trains, and subway systems are a few possibilities that require continuing evaluation and development.

Reevaluate the present safety standards regarding airline seats in order to investigate the possibility of wheelchairs being used as the seating arrangement for handicapped people with the necessary auxiliary safety equipment in the aircraft to make this possible.

In larger aircraft (Boeing 747, DC-10) the possibility of two lavatories being joined into one should be investigated. This would assist not only wheelchair users but also parents of young children.

Mandatory educational programs should be given to customer service personnel of public transportation systems as to the needs and rights of handicapped people.

Buses and trains should be encouraged to make at least one space available for a wheelchair user, along with a means of getting the wheelchair into the vehicle.

A leak-proof battery should be found which will be acceptable to the airlines for purposes of baggage storage during flight thereby eliminating the problem of battery transportation for the powered-wheelchair users.

ENVIRONMENTAL CONSIDERATIONS AND SHELTER

PROBLEMS

Lack of suitable shelter for someone who is on low to medium income and wishes to live independently.

Lack of small community residences to serve the shelter needs of partially handicapped people, or to act as a family-crisis center in which temporary relief could be found for families taking care of the dependent handicapped in the home.

The lack of available household appliances and fixtures which have adjustable features allowing for the wheelchair-bound homemaker.

General lack of implementation of various existing federal and state building codes regarding access to public buildings for the handicapped.

Group V

The lack of an established bibliography on design criteria for buildings and furnishings for the handicapped ranging from childhood to advanced age, which could act as a reference source for the designing professions.

RECOMMENDATIONS

A choice of totally accessible long- and short-term shelter should be made available to various disability groups which takes into account access from roads, sidewalks; availability to shopping centers, and educational and recreational facilities.

Cognizance should be taken of the existing codes on accessibility to buildings for the handicapped and a mechanism should be devised by which these standards will be implemented throughout the United States.

The establishment and updating of a comprehensive bibliography on a design criteria for buildings and furnishings for the handicapped. Particular attention should be paid to accessibility, modular adjustable fixtures, space requirements for wheelchairs and crutches; with further emphasis on newly available material and with pleasant color and texture.

FUNCTIONAL AIDS

PROBLEMS

General lack of knowledge as to what is commercially available in practical functional aids.

Need for assimilation of known available catalogs, i.e., Disabled Living Foundation, ICTA, Equipment for the Disabled, Preston's, etc.

Need for efficient multipurpose lifting/transfer device to assist mother attendant in the home care of the handicapped.

Need for a bed-turning device, especially for the muscular dystrophied, which would provide comfort as well as eliminate the need for manual turning throughout the night.

The lack of finances available to purchase commercially available devices which can greatly assist and make the severely involved handicapped independently mobile. (It was determined that a high-level quadriplegic could be made independently mobile in the community at a cost of

Group V

about \$8,000 beyond that required for the same level of community mobility for a nonhandicapped person.)

The complete lack of an effective delivery system for getting newly developed prototypes to needy consumers.

The lack of consideration in the design of aids regarding their need for: light weightness, simplicity of operation, pleasant appearance, safety, low cost, and ease of maintenance.

The deficiency in standard wheelchair designs to provide adequate support for seating, prevention of deformities, ease of mobility for the severely involved.

RECOMMENDATIONS

Federal, state, and private agencies should encourage a greater involvement of commercial manufacturers and developers of functional aids through provision of development grants, assisting in marketing surveys and field testing and encouraging product utilization.

Financial resources must be established or reallocated in federal and state programs to provide the available functional aids to handicapped individuals as deemed necessary by a competent medical team. Several progressive schemes are now functioning in countries such as England and Sweden.

Annotated bibliographies of functional aids and play materials should be established in key centers, kept up to date, and their existence advertised in professional journals and consumer magazines to be used by those providing services to the handicapped.

Wheelchair designs should be evolved which take into account the special needs of the severely involved regarding: growth adjustment, spinal support, sitting support and comfort, need to recline, modes of propulsion depending on extended disability, portability, utilization with evolving transportation systems, cost, and, last but not least, pleasant appearance.

Technical/therapy programs must be evolved in specific centers with large patient population through the country to develop new functional aids in addition to providing the necessary services to modify and fit available devices to patients. These programs should have a close working relationship with medical clinics, coordinating bodies such as CPRD, consumer associations, and the commercial sector.

SECTION IV. APPENDIXES

- A. AGENDA
- B. LIST OF PARTICIPANTS
- C. GROUP SESSIONS
- D. ADDITIONAL SELECTED REFERENCES

AGENDA

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT

Workshop on Mobility for Spinal-Cord-Impaired People

Rancho Los Amigos Hospital

Downey, California

February 22-24, 1974

James B. Reswick, Chairman

<u>Friday, February 22</u>		<u>Conference Room</u>
9:00 a.m.	Purpose and Goals of Workshop	Reswick
	Particular Interest and Role of:	
9:10	Veterans Administration	Murphy, Peizer
9:20	Social and Rehabilitation Service	Traub
9:30	Department of Transportation	Laster
	Selected Papers on Mobility:	
9:40	Ambulation	Motloch
10:10	Positioning and Seating	Rogers, Edberg
	Personal Vehicles--	
	Wheelchairs (emphasis on smooth terrain)	Hotchkiss
	Other Nonlicensed Vehicles (emphasis on rough terrain)	Prast
11:40	Licensed Vehicles	Reichenberger
12:10 p.m.	LUNCH	
1:30	Public Transportation	Cass
2:00	Architectural Consideration in Home and Public	Cluff
2:30	Economics of Independence	Shworles
3:00	Swedish Attitudes and Solutions to Mobility Problems	Hansson
3:30	Psychosocial and Learning Considerations in Using Mobility Systems	Vash
4:00-		
5:00	Open Discussion of Ongoing Work	
<u>Saturday, February 23</u>		<u>Conference Room</u>
9:00 a.m.	Plenary Session	Reswick
9:15	Group Sessions to Discuss Needs *	Group Leaders
12:15	LUNCH	
1:45--		
4:45	Group Sessions to Discuss Solutions*	Group Leaders

* See next page

Sunday, February 23

Conference Room

Reports by Groups on Needs and Solutions

9:00 a.m.	Group I	Hahn
9:20	Group II	Mortimer
9:40	Group III	McLaurin
10:00	Group IV	Stamp
10:20	Group V	Hobson
10:40--	) Open Discussion on Needs and Solutions	All Participants
12:00 noon	) Recommendations	All Participants

LIST OF PARTICIPANTS

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February 22-24, 1974

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GROUP SESSIONS

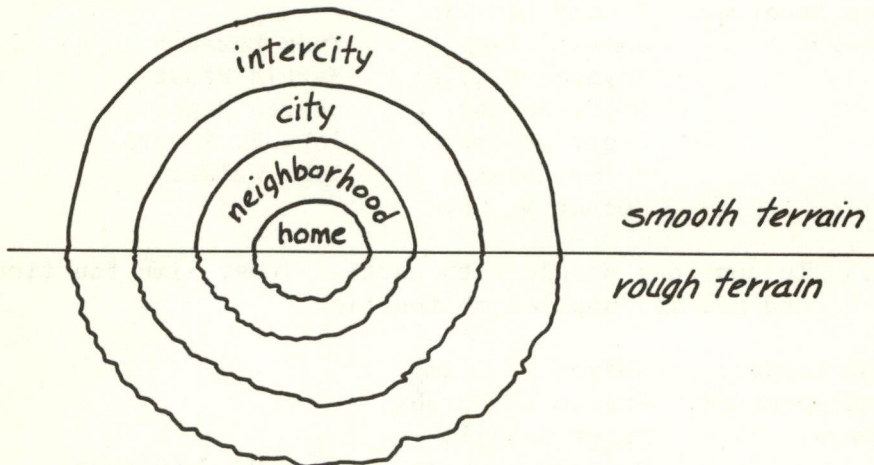
Workshop on Mobility for Spinal-Cord-Impaired People

The leader of each group is to guide the discussions to produce answers to the questions outlined below. The recorder of each group is to assist by putting down on paper the results of the discussions for presentation on the last day and for the report of the meeting.

NEEDS

1. How is each group characterized in terms of functional disability?
2. What is the patient population of each group?
3. In following spinal-cord-impaired people of the particular dysfunctions through the various spheres of activity, what problems are encountered in: ambulation; positioning and seating; transfer; use of nonlicensed vehicles; use of licensed vehicles; public transportation; architectural limitations; other?

Sphere of activity:



4. What are the needs of each group? (Translate the problems into concise statements of functional need.)

SOLUTIONS

The format for discussion will be left entirely up to each group leader to arrive at meaningful solutions to the problems previously discussed. However, each group is urged to make sure it has a clear understanding of the needs, to consider mobility comprehensively, to seek innovative solutions, and to brainstorm.

Appendix C - p. 2

GROUP I: To consider people with no lower-limb function and unimpaired upper limbs

Group Leader:	Harry Hahn	
Group Recorder:	Michael Quigley	
Members:	Ralf Hotchkiss	Paul H. Newell
	Ira Laster	D'Arcy O'Connell
	Edward Malmstrom	Anton J. Reichenberger
	Wallace Motloch	Joseph E. Traub

GROUP II: To consider people with no lower-limb function and no upper-limb function

Group Leader:	J. Thomas Mortimer	
Group Recorder:	Sheldon Bajema	
Members:	Reinhard Daher	
	Geoffrey Dudley	Thomas Shworles
	Ake Hansson	E. Shannon Stauffer
	Charles Scott	A. B. Wilson, Jr.

GROUP III: To consider people with no lower-limb function and partial upper-limb function

Group Leader:	Colin A. McLaurin	
Group Recorder:	Ronald Lipskin	
Members:	James Allen	Yves Lozac'h
	Raymond Biddle	Martin Prast
	W. F. Bryant	Steven Reger
	Scott Deacon	John E. Rogers
	Peter Hofstra	John Walker
	Hector W. Kay	

GROUP IV: To consider people with partial lower-limb function and partial upper-limb function

Group Leader:	Warren G. Stamp	
Group Recorder:	Eugene F. Murphy	
Members:	Peter Arballo	
	Henry G. Bouman	Don M. Cunningham
	Peter Bressler	Roy Snelson

GROUP V: To consider people with special problems: cerebral palsy, spina bifida, muscular dystrophy, etc.

Group Leader:	Douglas A. Hobson	
Group Recorder:	Margaret L. Young	
Members:	John Bell, Jr.	
	Patricia Cass	Warren Nellis
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	E. E. Harris	Shawn Solomon
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	Götz-Gerd Kuhn	Morey Weinberger

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