



Space Requirements for Wheeled Mobility

An International Workshop

Report Prepared for:

**U.S. Access Board
Washington, DC**



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March 29, 2004

This report, the workshop's papers and the presentations are available on the World Wide Web:

<http://www.ap.buffalo.edu/idea/Anthro/index.asp>

Preface

Anthropometry, the measurement of the physical characteristics and abilities of people, provides information that is essential for the appropriate design of occupational, public and residential environments, as well as for the design of consumer products, clothes, equipment, tools and equipment. However, the lack of anthropometric information about many disability groups severely limits the design of environments and products that are usable by as many as feasibly possible.

Recently, U.S. government agencies, particularly the U.S. Architectural and Transportation Barriers Compliance Board (Access Board), and the U.S. Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR) have devoted a great deal of attention and resources toward understanding the physical abilities of those with disabilities. In the summer of 2001, the Access Board and NIDRR co-sponsored an international workshop that provided new ideas about data collection, analysis, computer modeling, and use of anthropometric data in the design of environments and products. In 2002, the Access Board funded a multi-year project to provide anthropometric information that will be used to help improve building guideline and standards making decisions.

A workshop sponsored by the US Access board was held in October of 2003 as a follow-up to the 2001 Workshop. This meeting was specifically structured to help the Access Board define its short-term and long-term research objectives in determining the space requirements necessary for users of mobility aids in built environments.

Papers were prepared in advance to structure presentations and stimulate active discussions among Workshop participants. The papers and presentations focused on the following areas:

- Anthropometry and accessibility guidelines
- International research efforts
- New anthropometric research activity related to wheeled mobility
- Trends and issues of wheeled mobility technologies
- Trends and issues of lift and deployed ramp technologies
- Trends and issues in disability data and demographics
- Human modeling applications for inclusive design
- Preliminary plans for US Access Board research activities

At the meeting's conclusion, Workshop participants provided recommendations to the Access Board about how to prioritize research needs and what activities to include in a four-year research agenda.

This report summarizes the activities and major findings of the Workshop. A peer-reviewed publication of selected papers and presentations is currently being organized to ensure that the results of the Workshop are disseminated to a broader audience.

We acknowledge the diligent efforts of the staff of the Center for Inclusive Design and Environmental Access who helped to organize the Workshop. We thank the authors who provided the Workshop's papers, others who volunteered to make presentations, and all of the workshop participants who contributed to the productive discussions that took place during the meeting. Finally, we are extremely grateful to the U.S. Access Board for sponsoring the workshop and to Lois Thibault, in particular, for her extremely valuable advice during the planning of the Workshop.

Disclaimer

This report was developed with funding from the US Access Board (contract # TPD-02-C-0033). The contents do not necessarily represent the policy of the US Access Board and readers should not assume any endorsement by the Federal government.

Table of Contents

Executive Summary	6
Introduction	14
Guidelines and Standards	16
Anthropometry and accessibility guidelines, Edward Steinfeld, Arch. D..	16
BS 8300 – The research behind the standard, Robert Feeney	17
Compliance analysis for disabled access, Charles Han, John Kunz and Kincho Law, Ph.	17
Working area of wheelchairs – Details about some dimensions that are specified in ISO 5, Johann Ziegler	18
Development of Australian Standards and Unmet Research Needs, Murray Mountain.	19
Anthropometric Research in Australia, Rodney Hunter.....	19
Disability Discrimination Act 1995, Donald MacDonald	20
Challenges with the ADAAG, Marsha Mazz	20
General Discussion of Guidelines and Standards	21
Trends and Issues in Technologies	22
Trends and issues in wheeled mobility technologies, Rory Cooper, Ph.D., and Rosemar Cooper, M.P.T., A.T.P.	22
Trends and issues in platform lifts, David Balmer	24
Demographics of Wheeled Mobility Users	26
Trends and issues in disability data and demographics, Mitchell La Plante, Ph.D.	26
Human Modeling of Wheeled Mobility Aid Use	29
Wheelchair simulation in virtual reality, Michael Grant, Ph.D.	29
Virtual reality and full-scale modeling – a large mixed reality system for participatory des Roy Davies, Elisabeth Delhom, Birgitta Mitchell, Ph.D., and Paule Tate.....	29

HADRIAN Human Modeling Design Tool, Mark Porter, Ph.D.	30
Mannequin Pro Human Modeling Design Tool, Dan Helt	31
General Discussion of Human Modeling Applications to Determine Space Requirements Wheeled Mobility	31
Anthropometric Research	33
Anthropometry of users of wheeled mobility aids: A critical review of recent work, Bruce Bradtmiller, Ph.D.	33
Access Board’s Preliminary Research Plans	35
Long range research plans, Victor Paquet, Sc.D.....	35
Recommendations to the Board	37
Conclusions	39
References	40
Appendix – Workshop Participants	41

Executive Summary

In 2002, the Access Board funded a multi-year project to provide anthropometric information that will be used to better inform decisions made during the guideline and standards development process. The Center for Inclusive Design and Environmental Access, working closely with the Board, developed a preliminary long-range plan to address these needs.

A Workshop titled “Space Requirements for Wheeled Mobility” was held in October 2003. The Workshop was specifically designed to inform, exchange, and validate research aimed at collecting anthropometric data for wheeled mobility users that can be used in developing accessibility guidelines, standards, and building codes. One important goal of the Workshop was to obtain validation from stakeholders for a proposed consensus methodology to determine the space needs of wheeled mobility devices in use of the built environment and in transportation vehicles.

Four commissioned papers were written by experts to address key issues and promote discussion at the workshop:

1. “Anthropometry of users of wheeled mobility aids: A critical review of recent work” by Bruce Bradtmiller, Ph.D., Anthrotech. This paper was a follow-up report to a US Access Board report that Dr. Bradtmiller wrote in 1997 titled “Anthropometry for Persons with Disabilities: Needs for the Twenty-first Century”. Key aspects of recent anthropometric research performed Canada and the United Kingdom were summarized. Methodologies used in the studies were critiqued in terms of sampling selection, sampling strategies, and methods. Guidelines for how to use anthropometric data for the accessible or universal design of environments were given using the illustrative example of an automatic bank teller machine.
2. “Trends and issues in wheeled mobility technologies” by Rory Cooper, Ph.D., and Rosemarie Cooper, M.P.T., A.T.P., Department of Rehabilitation Science and Technology, University of Pittsburgh and Human Engineering Research Laboratories, VA Pittsburgh Healthcare System. This paper focused current and emerging technologies and trends in wheeled mobility, including engineering and environmental opportunities and limitations. Attention was also given to the demographics of wheelchair use, issues of consumer choice, and transportability.
3. “Trends and issues in platform lifts” by Mr. David Balmer, Accessibility Equipment Manufacture’s Association. This paper reviewed technologies used for vertical changes in elevation in buildings and transit vehicles. Issues of platform size, device weight, and regulations were covered. Insights were provided about how space requirements in lifts are determined in the AMSE - A18 standard.

4. "Trends and issues in disability data and demographics" by Mitchell La Plante, Ph.D. Department of Social and Behavioral Sciences and the Disability Statistics Center, University of California, San Francisco. This paper addressed trends in disability data and demographics, including information about wheeled mobility user health, function, perceived disability, financial resources and unmet needs.

Papers were distributed to attendees prior to the workshop. Two to four participants were assigned to each paper to serve as paper discussants in order to promote discussion about the paper's contents and direct discussion towards recommendations for the Board's research agenda. All participants were given the opportunity to respond to the papers after the presentations that were made by the authors during the Workshop.

An international group of human factors and ergonomics researchers, standards developers, designers, and computer modelers, many whom attended the 2001 workshop, participated in the follow-up meeting. Sixty-seven registered participants from the United States, Canada, the United Kingdom, Australia, Austria, Sweden, and The Netherlands took part. A list of registered participants is given in the Appendix.

The meeting began on Thursday evening, October 9 and concluded on Saturday afternoon, October 11, 2003. In addition to the commissioned work, a number of other topics were presented and discussed at the Workshop. These specifically addressed accessibility guidelines and standards, advancements in human modeling, and the Board's preliminary plans for anthropometric research of mobility aid users.

Eight presentations addressed accessibility guidelines and standards:

- "Anthropometry and Accessibility Guidelines" by Edward Steinfeld
- "The research behind the standard" by Robert Feeney
- "Compliance analysis for disabled access" by Charles Han, John Kunz and Kincho Law, Ph.D.
- "Working area of wheelchairs – Details about some dimensions that are specified in ISO" by Johann Ziegler
- "Development of Australian standards and unmet research needs" by Murray Mountain
- "Anthropometric research in Australia" by Rodney Hunter
- "Disability Discrimination Act of 1995 (UK)" by Donald MacDonald, and
- "Challenges with the ADAAG" by Marsha Mazz

Several others addressed human modeling of wheeled mobility aid users:

- "Wheelchair simulation in virtual reality" by Michael Grant, Ph.D.

- "Virtual reality and full scale modeling – a large mixed reality system for participatory design" by Roy Davies, Elisabeth Delhom and Birgitta Mitchell, Ph.D., and Paule Tate
- HADRIAN Human Modeling Design Tool, Mark Porter, Ph.D.
- Mannequin Pro Human Modeling Design Tool, Dan Helt

The final presentation by Victor Paquet, Sc.D., described the Access Board's preliminary plans for anthropometric research, "Long range research plans". This included detailed plan of work for the collection of two- and three- dimensional anthropometric data, human modeling, and maneuverability research developed by the IDEA Center/RERC on Universal Design at Buffalo. Participants provided detailed feedback about the preliminary plans and offered recommendations for the Board's research agenda.

The information gathered from the papers, presentations, and discussions was organized into the following topics:

1. Guidelines and Standards
2. Trends and Issues in Technologies
3. Demographics of Wheeled Mobility Users
4. Human Modeling of Mobility Aid Use
5. Anthropometric Research
6. Access Board's Preliminary Research Agenda

A summary of the key points for each is given below.

Guidelines and Standards

- Anthropometric data have historically been used to develop reach limits, recommendations for maneuvering clearances, grab bar location, and ramp slope for ANSI and ADAAG.
- The anthropometric data typically used by designers is extremely outdated, with many of the data sources and tools developed in the 1970s or earlier. Since this time, there have been important changes in the physical characteristics of the population, the demographics of the population and in the technologies used by wheeled mobility users.
- Standardized methods of anthropometric study are needed for standards development. A number of important anthropometric studies have been recently completed in the United States, Australia, United Kingdom and Canada, but these suffer from several important limitations. User groups, measurement methods, and research environments vary greatly from one study to the next, which makes comparing results or pooling results across studies extremely difficult.

- ISO standard 7176-5 provides a framework for ensuring that consistent language and measurement methods are used in data gathering across multiple sites. The ISO 7176-5 defines 35 dimensions, including occupied length, occupied width, occupied height, minimum space, turning diameter, reversing width, required width for angled corridor, required doorway entry width, required width for side exit and ramp angle.
- Use of multiple approaches about the physical size, function and preference of user groups is needed in the development of design standards. For example, use of percentiles in univariate analyses of even the key parameters alone do not provide a good estimate of the percent of individuals capable of successfully maneuvering in a space, and therefore such limited analyses should not be heavily weighted in standards development.
- Another approach to development of guidelines involves the dissemination of “Best Practices”. For example, Dave Rapson developed such a guide that included recommendations for the design of environments to accommodate powered scooters that was developed by the Province of Manitoba and city of Winnipeg.
- Although simulation tools are very welcome for use in comparison of standards and help bring the results to the designer and user, their use in the development of standards is not yet clear. The tools need to be validated to insure that they reflect actual wheeled mobility behavior. Use of such tools will also require new ways to interpret the data, an important element of the standards development process.
- The costs and benefits of space-requirements guidelines and standards are not considered in a rigorous way across countries.

Trends and Issues in Technologies

- Only 20-25% of people worldwide who use wheeled mobility devices report that their mobility needs are met.
- There is a high degree of variability in the turning radius and stability of powered wheelchairs. Those with rear-wheel drive typically have a larger turning radius, those with mid-wheel drive have a shorter turning radius but are more susceptible to tipping, and those with front-wheel drive offer both a tight turning radius and stability, although they are more difficult to control during straight travel.
- Market trends suggest that the space requirements for wheeled mobility will increase. For example, the market for both manual and powered “bariatric” or high weight capacity chairs is expected to grow the most rapidly of all chair categories, and markets for PAPA or power assisted chairs and specialized seating for chairs, although currently small, is expected to also grow rapidly.

- Because environments are not standardized in their level of accommodation to wheeled mobility needs, individuals who use wheeled mobility aids adapt by, for example, owning more than one wheeled-mobility device. On average wheeled mobility users have two devices and 50% of wheeled mobility users also use a walker.
- The U.S. Access Board has played an important role in ensuring that the AMSE A18 standard appropriately addresses the needs of those who require lifts.
- The increasing size and weights associated with newer powered mobility devices need to be considered in design standards.
- While use of platform lifts has vastly improved accessibility to the built environment, their operation can be difficult and time consuming. Efforts need to be devoted to universal design alternatives that eliminate the need for lifts.

Demographics of Wheeled Mobility Users

- There are approximately 2 million users of wheeled mobility users, and trends suggest that this number may exceed 4 million users by 2010. This growth is likely due to changing social and technological trends, such as improvements in the design of mobility aids, improved accessibility to devices, and social acceptance of device use, rather than an increased prevalence of disability or the number of elderly people.
- The effects of the growing aging population on the use of wheeled mobility devices are uncertain due, in part, to the limitations in the current national survey methods. However, those 65 and over make up 56% of the users of wheeled mobility aids, and are more likely to use manual versus powered mobility devices.
- There are higher overall proportions of women who use wheeled mobility devices, particularly among the elderly. However, the number of male users exceeds the number of women users among younger adults.
- The device and environmental needs of wheeled mobility users in health care facilities will need careful consideration in the future. When compared to non-wheeled mobility aid users, people who use wheeled mobility devices are much more likely to report poor health (40% compared to 2%), a greater frequency of hospitalization and more frequent use of health care services. The most frequently reported building needs are usable doors and elevators, lifts and chair lifts for stairs.

- Revisions to the national surveys are needed to improve the quality and detail of information collected related to the frequency and severity disability and selection of assistive technologies. For example, the last NHIS-D survey did not distinguish between powered or manual wheeled mobility-aid users. Additionally, national surveys do not inquire about why a particular device was selected and what alternatives were considered.
- The research community and sponsors are strongly encouraged to ensure the information about those with mobility impairments remains a priority and is improved in future survey efforts.
- A registry of wheeled mobility users could be developed from the survey respondents, provided that the appropriate consent could be obtained. Such a registry could provide a valuable resource for future surveys designed to capture detailed information about barriers in design and factors that affect the selection of wheeled mobility devices.

Human Modeling of Mobility Aid Use

- Digital human modeling packages such as HADRIAN are powerful design tools in which a design can be evaluated against the body sizes and capabilities of “whole” virtual individuals rather than individual dimensions (an important limitation of conventional anthropometric data use). Based on the structural and functional anthropometric data, designers can test virtual tasks in virtual environments to determine the percentage of individuals who have the ability to complete a task in the specific context of the environment.
- An automated prescriptive system for code-checking can be an extremely valuable design tool, but requires the designer to more completely define the objects in CAD models. The International Alliance of Interoperability (IAI) has provided a framework for defining sets of objects called Industry Foundation Classes (IFC’s) that support this object-oriented approach.
- While digital human models and computer simulations are useful in design, it is not clear if use of such tools will be of great value to the regulators. Typically, the design questions do not require the level of detail provided by digital human models and simulations. Further discussion is needed to explore how digital human modeling and simulation methods can be used effectively in code development.
- Additionally, digital human models are only useful if they are validated. Usually only components of the models (e.g., posture prediction for specific tasks) are evaluated, and there is not very much information about the errors associated with using digital human models in design.

Anthropometric Research

- Standard procedures for combining data from multiple data sets are needed. It is unlikely that funding for a major anthropometric study of persons with disabilities is going to be available, so it will be necessary to combine the results of smaller studies performed at multiple sites to understand the body sizes and physical abilities of these user groups. This is also important since anthropometric information from multiple geographic regions can be collected and compared.
- It is very important to continue to include the type of mobility aid device used by the individual in the collection of the information to allow data to be stratified by device type in addition to age and gender subgroups.
- Policy makers and designers need to clearly identify the target user population, critical anthropometric characteristics of the user population, and the measurement methods to make informed design decisions. Regulators should report how the information was used in the standards documents.

Access Board's Preliminary Research Agenda

- The approach proposed emphasizes a high degree of accuracy in data collection, builds on an ongoing RERC anthropometry research project but includes a multi-site effort for research tasks, emphasizes the development of valid human models, and ensures that the results can be used readily by regulators.
- The proposed work plan includes five projects that would be completed over several years. The first is a 3-D anthropometric study to provide data useful for testing designs through three-dimensional virtual environments or for human modeling applications, and could involve at least 2 more sites to collect data on at least 200 additional people. The second is a 2-D anthropometric study performed by 2 research teams to gain basic structural anthropometric dimensions of two very large samples of wheeled mobility device users. These would use digital photography-based approaches for rapid data collection. The third project proposed is a study of wheeled mobility device and accessory weights that would require one research group to work with manufacturers of chairs and accessories to develop a database of dimensions and weights of current models of wheeled mobility devices and their accessories. The fourth project would focus on maneuvering studies of wheeled mobility device users in small but realistic mock-ups of built environments, and could involve up to three research sites. A dissemination project would require analyzing and systematically integrating anthropometric data collected previously in the United Kingdom, Australia, Canada, the United States and in other countries. Results of the dissemination project would include a DVD production demonstrating how individuals use different mobility aids and accessories, and the space requirements associated with different devices.

- Overall, the preliminary research plans were well-received by Workshop participants. There was no criticism about the specific methods proposed in any of the projects summarized during the presentation. Strengths identified by participants were the multi-site approach proposed in many of the projects, the inclusion of a variety of wheeled mobility devices, the emphasis on consistent data gathering methods, and the inclusion of both simple and highly sophisticated approaches.
- The major limitation of the approach identified by some participants was the scope of the research plan. They argued that to provide the information needed for standards development requires even greater numbers of individuals, a greater variety of individuals and a more information about functional task performance. Workshop participants also emphasized the need for more work in the field versus the laboratory.

There were six major recommendations about the preliminary research agenda:

1. Partner with other sponsors in the U.S. and other countries to expand the research plan. The current plan is a good start but much more needs to be done. Use of anthropometry in the development of space requirements for standards requires that all variables include demographic and device characteristics are considered in the evaluation of the design parameter.
2. Include field research activities designed to provide a better understanding of the most important environmental barriers in commercial and public buildings, as well as transportation systems.
3. Ensure that the plans for keeping data efforts consistent across multiple sites are sound so that data from these different sources can be combined.
4. Ensure that careful attention continues is paid to the demographic variables, including the types of wheeled devices and categories of disability, so that informed design decisions can be made.
5. Continue to explore the potential value of digital human modeling in space requirements for standards development.
6. The experimental protocols used for this research agenda should be peer-reviewed be peered reviewed. A process should be developed to allow input from an international group of stakeholders.

In conclusion, the increasing prevalence of wheeled mobility device users and the trends towards larger and heavier devices suggest that the current space requirements for wheeled mobility accessibility need to be re-evaluated. The current research plans are a good start but more thought must be given to how to expand the plan. It is likely that a combination of basic anthropometric research,

experimental trials, field observations, and computer aided design analysis are needed to provide the necessary information about the physical size, function and preference of user groups for the development of effective design standards. More discussion is needed to determine exactly how digital human modeling and simulation can be used to inform standards development.

Introduction

Guidelines and other documents currently used in the United States in the course of regulatory activities incorporate dimensional data based on anthropometrics research conducted in the 1970's (Steinfeld, et al, 1979). Simultaneously, new developments in assistive technology, trends in rehabilitation practice, the ongoing demographic shift toward an older society, and changes in stature of the population due to nutritional improvements and genetic shifts suggest that current anthropometric databases themselves are no longer appropriate for application in contemporary design. A study commissioned by the Access Board in 1997 entitled Anthropometry for Persons with Disabilities: Needs for the 21st Century concluded that available data no longer represent the range of the using population (Bradtmiller, 1997).

In June 2001, a workshop titled "Anthropometrics of Disability" was held in Buffalo, NY to assess the state of the knowledge in anthropometric methods, data collection projects and human modeling efforts related to disability (Steinfeld, et al., 2002). The Workshop was underwritten by the US Access Board, with support from the National Institute on Disability and Rehabilitation Research through the Rehabilitation Engineering Research Center on Universal Design at Buffalo and the Rehabilitation Engineering Research Center on Workplace Ergonomics. The format of the workshop was a series of paper presentations and discussion sessions concluding with a final summary discussion session. Papers were prepared prior to the Workshop and distributed to participants in printed form. All participants submitted written recommendations based on the discussions at each paper session. A summary report of the results of the Workshop was written. Both this document and the proceedings are available on the web site of the RERC on Universal Design at Buffalo. The workshop identified "gaps" in the state of knowledge about the collection, organization and application of anthropometric data as it relates to those with physical disabilities and the design of built environments. Areas identified as needing further attention included:

1. Developing databases that contain three-dimensional data
2. Improving our understanding of the functional anthropometry of disability
3. Ensuring the collection of reliable, valid and useful data
4. Organizing data into comprehensive and accessible databases

In 2002, the Access Board funded a multi-year project to provide anthropometric information used to help inform decisions about accessibility guidelines and standards. The Center for Inclusive Design and Environmental Access, working closely with the Board, developed a preliminary long-range plan to address these needs. Phase I of the work involved developing a preliminary work plan. The workshop described in this report is Phase II of the work. Subsequent Phases will involve focused research and dissemination activities.

This report summarizes the activities and recommendations of a follow-up Workshop titled “Space Requirements for Wheeled Mobility” that was held in October 2003. The Workshop was designed to inform, exchange, and validate research efforts intended to provide information about the space requirements in wheeled mobility use. The specific goals of the workshop were to:

- Explore the relationships between research to codes, standards development, and design
- Expand the community of interest further to other stakeholder groups and additional researchers
- Inform key stakeholders about the work being done around the world
- Review and discuss key issues that will affect a plan of work to address the U.S. Access Board’s needs for determining the space requirements of wheeled mobility users
- Develop an agenda for continuing dialogue

This report is organized in the following way:

The information gathered from the papers, presentations, and discussions has been organized into the following six topics.

1. Guidelines and Standards
2. Trends and Issues in Technologies
3. Demographics of Wheeled Mobility Users
4. Human Modeling of Mobility Aid Use
5. Anthropometric Research
6. Access Board’s Preliminary Research Agenda

For each topic, abstracts of the written papers, key points, and summaries of the discussions about the presentations are provided. Recommendations about the Board’s research agenda and conclusions are collected at the end of the report. The list of workshop participants is provided in the Appendix. The interested reader is encouraged to review the full papers, which are posted on the World Wide Web:

<http://www.ap.buffalo.edu/idea/space%20workshop/>

Guidelines and Standards

Anthropometry and accessibility guidelines, Edward Steinfeld, Arch.D.

Abstract

This presentation provided an overview of how anthropometry is used in design and policy making, described advantages and limitations of anthropometric measurement methods, and made preliminary recommendations to improve the use of anthropometric data to better understand the space requirements of wheeled mobility users. A brief history of anthropometric research that had an effect on codes was summarized. Recent advancements in the collection of anthropometric data including the use of photography, three-dimensional data collection including whole-body scanning, and kinematic analysis methods were described. Limitations that prevent effectively using the information in standards development were covered. An argument is made to standardize data collection across multiple research sites and projects, including the development of international standards, in an effort to improve the overall quality and generalizability of anthropometric data so that the space requirements of wheeled mobility devices can be determined.

Key Points

- Anthropometry allows regulators to identify the user groups who will be accommodated by design and those who will be excluded. Understanding the range of body sizes and abilities of people also can help designers make decisions about accommodating the widest range of individuals possible with their designs.
- Anthropometric data have historically been used to develop reach limits, recommendations for maneuvering clearances, grab bar location, and ramp slope.
- Anthropometry provides the source data needed to develop digital human models, and develop reliable simulations for use in testing and evaluation using virtual environments.
- The anthropometric data typically used by designers is extremely outdated, with many of the data sources and tools developed in the 1970s or earlier. Since this time, there have been important changes in the physical characteristics of the population, the demographics of the population and in the technologies used by wheeled mobility users.
- Newer approaches to data collection since the 1970s include the use of digital photography, 3-D manual digitizing, 3-D scanning, and 3-D motion analysis. Other approaches such as full-scale modeling also involve collecting information about user preferences, and systematic observations of task

difficulty for tasks performed by individuals in mock-ups of actual built environments.

- A number of important anthropometric studies have been recently performed in the United States, Australia, United Kingdom and Canada, but these suffer from several limitations. User groups, measurement methods, and research environments vary greatly from one study to the next, which makes comparing results or pooling results across studies extremely difficult. Standardized methods of anthropometric study are needed for standards development.
- Anthropometric studies conducted today will need to address the design challenges of tomorrow and therefore trends in the changing demographics need to be considered. For example, the use of scooters as a mobility aid is increasing and these devices generally are longer and have larger turning radiuses than other powered mobility aids.

BS 8300 – The research behind the standard, Robert Feeney

Abstract

This paper and presentation provides an overview of the research used in the development of the British Standard BS 8300: 2001, "Design of buildings and their approaches to meet the needs of disabled people – Codes and practice". Research that informed the standard includes basic anthropometry studies, experimental trials and computer aided design analysis.

Key Points

- The use of systematic analyses of environmental needs for people with disabilities and validated research on how those with disabilities use environments is still needed.
- Studies in the United Kingdom sponsored by the Department of Environment, Transport and Region (DETR) involved basic anthropometric research, experimental trialing, field observations, and computer aided design analysis specifically designed to ensure a wide range of disabilities and wheeled mobility technologies were included in the analyses.
- Use of multiple approaches focused on physical size, function and preference of user groups is needed in the development of design standards.

Compliance analysis for disabled access, Charles Han, John Kunz and Kincho Law

Abstract

This paper and presentation described a computer based approach that uses encoding of prescriptive-based provisions and performance-based methods to support compliance and usability analysis for accessibility. Prescriptive provisions include the recommended clearances and reach thresholds for building components given in the ADAAG. Performance-based simulations are used where prescriptive provisions appear to be inadequate. A framework for support of on-line code checking in building design was developed that would allow a designer to send a design to an automated code-checking system. The code-checking software would generate an analysis report that can be used by the designer to resolve conflicts with the building requirements. The performance-based simulation approach would test the design for usability using a robotics approach known as "motion planning". The approach was demonstrated using the accessibility and usability analysis of men and women's bathrooms.

Key Points

- Since prescriptive methods of building design do not guarantee usability or accessibility, use of performance-based simulations in combination with prescriptive methods may offer additional benefits in design.
- An automated prescriptive system for code-checking can be an extremely valuable design tool, but requires the designer to more completely define the objects in CAD models. The International Alliance of Interoperability (IAI) has provided a framework for defining sets of objects called Industry Foundation Classes (IFC's) that support this object-oriented approach.
- Motion planning requires quantitatively determining the path of use for the target users, and simulating the use of the environment along the path. The size and maneuvering characteristics of the wheeled mobility device can be quantitatively modeled to test different user scenarios in the simulations.

Working area of wheelchairs – Details about some dimensions that are specified in ISO 7176-5, Johann Ziegler

Abstract

This paper and presentation summarizes portions of the International Standardization Organization's ISO 7176-5: Wheelchairs – Determination of dimensions and masses that are most relevant to the determination of the space requirements of wheeled mobility aid users. The purpose of the standard is to provide technical definitions and procedures for measuring dimensions and masses of wheelchairs and powered scooters. Recommended designs and design limits for wheeled mobility device dimensions are included.

Key Points

- ISO standards provide a framework for ensuring that consistent language and measurement methods are used in data collection across multiple sites. The

ISO 7176-5 defines 35 dimensions, including occupied length, occupied width, occupied height, minimum space, turning diameter, turning width, required width for angled corridor, required doorway entry width, required width for side exit and ramp angle.

- The recommended design and design limits described in the standards can be used to inform the design of corridors, door widths, and maneuvering spaces. However, more complete anthropometric information could be used to improve the recommendations made in the standard. The current data is based on the engineering properties of wheeled mobility devices alone without occupants and without consideration of differences in posture or maneuvering ability.

Development of Australian Standards and Unmet Research Needs, Murray Mountain

Abstract

This presentation summarizes some key aspects of the Australian 1428 Standards: "Design for Accessibility and Mobility". While a total of 10 parts are currently planned, 4 parts have been completed. These cover: 1. general requirements for building access, 2. enhancements to the built environment, 3. design requirements for children with disabilities, and 4. design for people with visual impairments. The anthropometric research used in the development of each of the standards is described.

Key Points

- Anthropometric research conducted in the 1980s and 1990s was used in the development of the Australian 1428 Standards. AS1428.1 – 1991 – General requirements for access – New building work was based on research by John Bails in the mid 1980's using approximately 500 subjects between the ages of 18 to 60 years, which included wheelchair users, people with ambulant disabilities and those who were blind or had a vision impairment. AS1428.2 – 1992 - Enhanced and additional requirements – Buildings and facilities was also developed from Bails' research and gives data on how to enhance the built environment. AS1428.3 – 1992 - Requirements for children and adolescents with physical disabilities, was based on research in the early 90's by Barry Seeger including manual and electric wheelchair users, and children with ambulant disabilities. AS1428.4 – 2002 – Tactile Indicators covers design issues particularly relevant for with people who are blind who have visual impairments.
- The design issues covered include door design and clearances including clearances in vestibules, the dimensions of landings and ramps, and some control locations based on reach ranges.

Anthropometric Research in Australia, Rod Hunter

Abstract

This presentation provides a brief overview of recent anthropometric research performed in Australia to help inform building standards. Key parameters in maneuvering were described and implications on policy decisions in Australia were summarized.

Key Points

- Key parameters that affect the maneuvering abilities of wheeled mobility device users include the overall length and width of the wheelchair, turning radius, and axle design.
- The shape of the front portion of the wheeled mobility aid and orientation of the user on the chair will have a dramatic effect on the space needed for approaches.
- Use of percentiles in univariate analyses of even the key parameters do not provide a good estimate of the percent of individuals capable of successfully maneuvering in a space, and therefore such analyses should not be heavily weighted in standards development.
- Standards cannot be based on a standardized wheelchair design since there are so many different designs available and the design affects functional capabilities.

Disability Discrimination Act 1995 (UK), Donald MacDonald

Abstract

This presentation provides a brief overview of key aspects of the United Kingdom's 1995 Disability Discrimination Act that are particularly relevant to wheeled mobility space requirements in transportation systems. Part 3 covers transportation infrastructure at bus stations and bus stops, and Part 5 covers accessibility regulations related to buses, coaches, trains and taxis.

Key Points

- The 1995 Disability Discrimination Act provides accessibility standards for transportation systems in the United Kingdom. Standards were phased in for different vehicle types (e.g., single deck buses, double deck buses, coaches, taxis, etc.).
- On buses, protected space with a backrest is used instead of tie downs to enhance safety of wheeled mobility device users during travel. Coaches do have securement systems.

- More information about the Mobility Inclusion Unit of the Department for Transport is on the web: <http://www.mobility-unit.dft.gov.uk/>. Information about the Disabled Persons Transport Advisory Committee can be found at <http://www.dptac.gov.uk/>

Challenges with the ADAAG, Marsha Mazz

Key Points

This presentation provides a brief overview of key features and design challenges of the ADAAG.

- The ADAAG provides minimum design requirements and is not a building code. Therefore, designers should attempt to develop environments that surpass rather than simply meet the requirements of ADAAG.
- Revisions to the ADAAG are being challenged because of a lack of needed data. Key issues include lowering the controls on vending machines, design issues to allow wheeled mobility users to use forward approaches when accessing water fountains, space requirements for transfers in shower facilities, handrail shapes, clearances and orientations, and the design of the appropriate sight lines in assembly areas.

General Discussion of Guidelines and Standards

Another approach to development of guidelines involves the dissemination of “Best Practices”. For example, Dave Rapson developed such a guide that included recommendations for the design of environments to accommodate powered scooters that was developed by the Province of Manitoba and City of Winnipeg.

Although simulation tools are very welcome for use in comparison of standards and help bring the results to the designer and user, their use in the development of standards is not yet clear. Use of such tools will require new ways to interpret the data and the data interpretation is an important element of the standards development process.

The costs and benefits of guidelines and standards for space requirements are not considered in a rigorous way across countries.

The need for standardizing research methods and the way that information is applied to design was emphasized.

Trends and Issues in Technologies

Trends and issues in wheeled mobility technologies, Rory Cooper, Ph.D., and Rosemarie Cooper, M.P.T., A.T.P.

Abstract

This commissioned paper and presentation summarized the state of current technologies, trends and market indicators of wheeled mobility devices, and their potential impacts on the design of the built environment and transportation systems. Manual wheelchairs can be categorized as depot, light weight, ultra-light weight, bariatric, standing and specialized. The depot manual chair is the most common manual chair due to its low cost and high durability. Powered mobility aids include lightweight devices for indoor use, those used for indoor and light outdoor use, those used for active indoor and outdoor user, powered scooters, bariatric, standing, push rim power activated (PAPAW) and specialized seating devices. The market for both manual and powered bariatric chairs is expected to grow the most rapidly of all mobility device categories due to the increasing prevalence of obesity in the U.S. Bariatric chairs are generally much wider than other types of chairs. Thus, users of this type of chair can encounter unique barriers in the environment. Markets for other types of chairs are also expected to grow, although not as rapidly as the bariatric chair market. The various trends will most likely lead to an overall increase in chair size and in space requirements. There are technological limitations associated with the design of wheeled mobility devices that require additional research and design work. Further research should focus on reducing risks to secondary conditions associated with wheeled mobility device use, determining utilization rates of wheelchairs in different settings, and new mobility aid technologies to accommodate a greater range of individuals who need assistance such as the elderly, the obese and those with multiple sclerosis. Research focused on improving safety during a wide range of functional activities is also needed.

Key Points

- Current manual chairs range in quality, comfort, performance, durability and cost. Although the Center for Medicare and Medicaid Services is among the top purchasers of wheelchairs in the U.S., its selection of wheelchairs is based on durability, use in the home and cost, rather than the full range of needs of wheeled mobility aid users. Therefore, it is not surprising that depot chairs are by far the most common chair.
- Only 20-25% of people worldwide who use wheeled mobility devices report that their mobility needs are met.
- There is a high degree of variability in the turning radius and stability of powered wheelchairs. Those with rear-wheel drive typically have a larger turning radius, those with mid-wheel drive have a shorter turning radius but are

more susceptible to tipping, and those with front-wheel drive off both a tight turning radius and stability, although are more difficult to control during straight travel.

- There is a great variety in power wheelchair configurations since the seating systems of one manufacturer can be used with the frames of another manufacturer to customize the chair to the needs of the user.
- Because pressures sores and pain are problems associated with conventional chair designs, chairs that provide greater postural adjustability may be beneficial to users but these chairs increase the variability of space requirements for different tasks.
- Scooters and powered wheelchairs are going to become increasingly similar as efforts are made to make powered wheelchairs more transportable and modular.
- Even the most advanced wheeled mobility systems have important limitations with respect to their use in the built environment. For example, the Independence 3000 IBOT Transporter uses a variety of electronic sensors to adjust maneuverability, stability and function to the terrain, but currently has a seat surface too high to be used easily at work surfaces at conventional heights.
- Given that the number of individuals in nursing homes is expected to double in the next 30 years, the use of wheeled mobility technologies that improve function of older people in these environments is an important priority.
- Market trends suggest that the space requirements for wheeled mobility will increase. For example, the market for both manual and powered bariatric chairs is expected to grow the most rapidly of all chair categories, and markets for “PAPAW” chairs and specialized seating in chairs, although now small, is expected to also grow rapidly.
- Laboratory-based data collection on function as performed in conventional anthropometric studies may not reflect function in actual commercial, public or residential environments. Therefore, other types of studies designed to evaluate the space requirements of wheeled mobility devices are needed.
- Further research should focus on reducing risks to secondary conditions associated with wheeled mobility device use, determining utilization rates of wheelchairs in different settings, and new mobility aid technologies to accommodate a greater range of individuals who need assistance such as the elderly, people who are obese and those who have multiple sclerosis. Research focused on improving safety during a wide range of functional activities is also needed.

Discussion

Discussions focused on the role of technology in affecting wheeled mobility device use trends in the United States and elsewhere, and how this could affect environmental design policies.

For example, it was reported that powered scooter use will soon exceed power wheelchair use in the United Kingdom and a similar trend is predicted for the United States. Scooters were originally designed for outdoor environments, but they are being increasingly used indoors. What impact will scooters have on the design of environments in the future? Will the industry adapt designs to reflect increase use of scooters indoors?

Because environments do not accommodate all devices with uniform accessibility, individuals who use wheeled mobility aids adapt by, for example, owning more than one device. On average, wheeled mobility users have two devices and 50% of wheeled mobility users also use a walker.

Trends and issues in platform lifts, David Balmer

Abstract

This commissioned paper and presentation summarized the current state of technology in platform lift design and standards. While elevators are currently the most effective vertical transportation system in terms of speed, capacity, rise and safety, they have some major drawbacks for accessibility - cost and space required, particularly for short-range vertical changes. Platform lifts and stairway chairlifts are the “device of choice” for small elevation changes in existing buildings, but, their use is limited by the Americans with Disabilities Act Accessibility Guidelines (ADAAG) to very specific circumstances in new buildings. Platform lifts are ADA compliant, but chairlifts are not since they do not provide access for a wheeled mobility device. The A18 Standard of the American Society of Mechanical Engineers (ASME), under the sponsorship of the Accessibility Equipment Manufacturers Association (AEMA) was published in January 2000 with key input from the U.S. Access Board. It has had a very important impact on the requirements for lift equipment and other related standards. This standard eliminated the use of keys that restrict access to lifts, allows the use of inclined vertical lifts that can be more effectively incorporated into existing stairways with little impact on other stairway traffic, promoted new developments in the design of vertical lifts, increased the allowable vertical travel of a lift, and strengthened the lift approach ramps to improve safety and accessibility. But, there are still important design problems related to lifts that need to be addressed. The increases in size and weights of powered mobility devices may require some changes to the standard. This could include, for example, increasing the currently required 1.67 m² of floor space to 2 m², and increasing the minimum weight capacities of lifts. Allowing the use of lifts in new construction, as has been suggested for the new ADA requirements, would be extremely problematic. This

would eliminate or reduce accessibility in buildings or building additions that are not required to have elevators. Finally, ASME is attempting to simplify the code changing process so that innovative vertical lift solutions can more quickly be brought to market.

Key Points

- Vertical lift technologies are important to the accessibility of existing and new commercial and public buildings.
- The U.S. Access Board has played an important role in ensuring that the AMSE A18 standard appropriately addresses the needs of those who require lifts.
- The increasing size and weights associated with newer powered mobility devices need to be addressed in future revisions of the design standards.
- NAFTA drove harmonization between Canada and the United States in terms of the standards for lift design, and, it is an example of the emerging globalization in standards development for assistive technologies.

Discussion

There appears to be a need for more communication between researchers and standards developers, so that standards can better address the needs of the users. Since many standards are quite restrictive, one fear is that standards such as those related to lift design would limit innovation.

While use of platform lifts has vastly improved the accessibility to built environments, use of these devices can still be difficult and time consuming. Efforts need to be devoted to universal design alternatives that eliminate the need for lifts in built environments.

Demographics of Wheeled Mobility Users

Trends and issues in disability data and demographics, Mitchell La Plante, Ph.D.

Abstract

This commissioned paper and presentation summarizes the current demographic status and trends of mobility aid users in terms that can be used by policy makers to identifying current and/or future needs of this user group. The trends and recent status among mobility aid users in health and functional limitation, perceived disability, financial resources, unmet device needs, and unmet environmental needs are summarized from national surveys conducted repeatedly in recent years. These surveys include the U.S. National Health Interview Survey and the U.S. Census Bureau's Survey of Income and Program Participation. The number of wheeled mobility users has more than quadrupled in the last 30 years to approximately 2 million users. This number may exceed 4 million users by 2010. Growth in the number of users is likely due to changing social and technological trends, rather than an increase in the prevalence of disability or the increased numbers of elderly people. The effects of the growth in the older population on the use of wheeled mobility devices is uncertain due, in part, to limitations in the current national survey methods. There are higher overall proportions of women who use wheeled mobility devices, although the number of male users exceeds the number of female users among young adults. The most frequently reported needs related to building design are improved doors and elevators, lifts and stair glides. Finally, improvements to national surveys that include questions on wheeled mobility devices are needed to improve the quality and detail of the information available related to the frequency and severity of impairments and the utilization of assistive technologies. The research community and sponsors are strongly encouraged to ensure that obtaining more thorough and more accurate information about those with mobility impairments is a priority for future survey efforts.

Key Points

- There are approximately 2 million users of wheeled mobility users, and, trends suggest that this number may exceed 4 million users by 2010. Approximately 17% of the wheeled mobility device users use powered wheelchairs or scooters.
- Growth in the number of users is likely due to society and technological trends such as improvements in the design of mobility aids, improved accessibility to devices, and social acceptance of device use, rather than an increased prevalence of disability or the number of elderly people in the population.
- The effects of the growing aging population on the use of wheeled mobility devices is uncertain due, in part, to the limitations in the current national

survey methods. However, those 65 and over make up 56% of the users of wheeled mobility aids, and are more likely to use manual versus powered mobility devices.

- The relationship between the proportion of those having difficulty walking without assistance and the proportion of people who used wheeled mobility aids changes with age. This may be due, in part, to changing expectations of mobility. For example, there is a disproportionate number of elderly people who are more likely to use canes and walkers rather than wheeled alternatives but have fairly low mobility requirements, as compared to younger adults who are more likely to select wheeled devices to improve mobility over long distances.
- There are higher overall proportions of women who use wheeled mobility devices, particularly among older population. However, the number of male users exceeds the number of women users among younger adults.
- The patterns of mobility aid use are similar across different categories of ethnicity.
- The device and environmental needs of wheeled mobility users in health care facilities will need careful consideration in the future. When compared to non-wheeled mobility aid users, people who use wheeled mobility devices are much more likely to report poor health (40% compared to 2%), a greater frequency of hospitalization and more frequent use of health care services. The most frequently reported building needs are usable doors and elevators, lifts and stair glides.
- Just over one quarter of wheeled mobility device users drive a vehicle, which often requires special assistive equipment. A large majority of wheeled mobility aid users report difficulty gaining access to public transportation and very few actually use it.
- Revisions to national surveys are needed to improve the quality and detail of the information related to the frequency and severity of impairments and the utilization of assistive technologies. For example, the last NHIS-D survey did not distinguish between powered or manual wheeled mobility device users. Additionally, national surveys do not inquire about why a particular device was selected and what alternatives were considered.
- The research community and sponsors are strongly encouraged to ensure that obtaining information about mobility impairments remains a priority and is improved in future survey efforts. Proposed questions, for example, could be pilot tested and validated among groups of wheeled mobility aid users and then submitted for inclusion in the national survey efforts.

Discussion

The discussions focused on the need to better understand the demographic variables associated with choice of mobility type and limitations in the national data gathering process.

There are many different types of mobility devices. There are many reasons why an individual selects a particular device type. Surveys need to inquire about the reasons for specific choices in order to inform purchasing policies, design practices and standards.

Currently, the National Health Interview Survey combines different accessibility problems into one question, "Do you have problems with accessibility?" Such questions provide very limited useful information and may encourage a response bias that results in an underestimation of the prevalence of wheeled mobility device use. Improvements to this survey are needed.

A registry of wheeled mobility users could be developed from the survey respondents, provided that the appropriate consent could be obtained. Such a registry could provide a valuable resource for future surveys designed to capture detailed information about barriers in design and factors that affect the selection of wheeled mobility devices.

More information about the use and selection of wheeled mobility devices in institutions is also needed.

Human Modeling of Wheeled Mobility Aid Use

Wheelchair simulation in virtual reality, Michael Grant, Ph.D.

Abstract

This paper and presentation summarized the results of a project at the University of Strathclyde involving the development of a wheelchair motion platform which, in conjunction with a virtual reality (VR) facility, can be used to address issues of accessibility in the built environment. The development of the approach is a collaborative effort between architects, bioengineers and user groups and has investigated topics related to platform design and construction, interfacing, testing and user evaluation. Current research is directed towards developing this prototype, extending existing simulation capabilities and exploring its utility in a design environment. The outcome of the project has been the development of a haptic interface that allows manual and powered wheelchair users to navigate within VR simulations of buildings through the use of their own wheelchair and provides the user with feedback related to the sense of effort required to propel the wheelchair. User testing has demonstrated that the system provides a realistic depiction of wheelchair use in different environments.

Key Points

- The use of a wheelchair motion platform used in conjunction with virtual reality can be a useful design and education tool that allows manual and powered wheelchair users to navigate safely within VR simulations of prototype buildings using their own wheelchairs. Collisions with virtual objects combine visual and non-visual stimulation in a manner that is analogous to real world.
- Future research should be directed at extending the capabilities of such a system by increasing the ability of the wheeled mobility device user to interact with the virtual world.

Virtual reality and full scale modeling – a large mixed reality system for participatory design, Roy Davies, Elisabeth Delhom, Birgitta Mitchell, Paule Tate

Abstract

This paper and presentation summarized a general approach to simulation known as “The Envision Workshop.” This approach integrates tools that encourage participatory technical support in the design process. It utilizes full scale modeling of the environment and an optical tracking system that feeds information on position and movement of people and objects into a virtual reality model for real-time analysis of virtual designs. While the methods appear to provide unique and potentially valuable design information, challenges related to the limitations of the tracking system, how to track environmental features and integrating the tools

effectively still remain. The system has great potential for combining functional anthropometry of wheeled mobility use with qualitative studies that explore perceptions and attitudes toward design features.

Key Points

- Full scale modeling techniques allow designers and researchers to capitalize on the user's experience. They can be used to identify the most important design challenges and rapidly develop effective solutions to overcome them.
- These tools that can be used collectively to facilitate an effective participatory design process including the use of brainstorming and improvisational drama.
- Virtual reality and full-scale modeling can be integrated effectively in research and design. Motion tracking systems can be used to collect kinematic information that is then used in virtual reality software for real-time virtual evaluations of the full-scale models. Features of the environment can be manipulated post-hoc after data collection to evaluate alternative design scenarios.
- Challenges in developing the system further are related to the limitations of the tracking system, how to track environmental features that change during the task simulations, and integrating the tools effectively.

HADRIAN Human Modeling Design Tool, Mark Porter, Ph.D.

Abstract

This presentation provided an overview of how anthropometric data and task simulation were used in the development of the SAMMIE and HADRIAN software packages, and how these two software tools can be used effectively in design. The packages combine video, animations and structural dimensions in ways that improve the use of anthropometry in the design process. Link lengths, range of motion, posture prediction algorithms and functional task information provide key information to the digital human models used in the software. The designer can "build a task" in a virtual environment and the interface can be used to estimate the number of virtual users who would "fail" the task based on fit between their abilities and sizes and the characteristics of the design. An example of an automatic teller machine was used to illustrate the benefits of the approach. One of the most important limitations of the current software is of the relatively small set of user groups and tasks that have been incorporated. More research is needed to expand the software package capabilities by adding tasks and virtual user groups that can be incorporated in evaluations.

Key Points

- SAMMIE and HADRIAN are powerful design tools in which a design is evaluated against the body sizes and capabilities of "whole" virtual individuals rather than individual dimensions.

- Potential benefits include the possibility of making ergonomic evaluations of the person-environmental fit using virtual techniques during the design process. This can improve communication between designers, consumers and policy makers.
- The HADRIAN software package currently includes link lengths, range of motion, posture prediction algorithms and functional task information of 40 individuals without disabilities, 40 ambulant individuals with a disability, and 20 users of wheeled mobility devices.
- Based on the structural and functional anthropometric data, designers can test virtual tasks in virtual environments to determine the percentage of individuals who have the ability to complete a task in the specific context of the environment and also people with specific characteristics, e.g. an older frail person with left side paralysis due to stroke. Reasons why a design cannot be used by a user group or individual become clearly obvious in the virtual task simulations.
- Perhaps the largest limitation of the approach is the limited amount of data that is currently available for testing. Additional individuals and tasks are needed for the design tool to provide a more accurate understanding of how a design will affect usability. The software is designed to accept new activities and new people with little difficulty.

Mannequin Pro Human Modeling Design Tool, Dan Helt

Abstract

This presentation provided an overview of the Mannequin Pro ergonomic design tool. Early versions of a digital wheeled mobility user model were described. The software allows the user to examine the fit between a fairly simple static virtual model of a user and the environment to be evaluated. The current version of the software also allows simple three-dimensional biomechanical analysis.

Key Points

- Currently the Mannequin Pro software assumes that the structural dimensions of an ambulant adult are similar to the wheeled mobility user. Negotiations are underway with the Center for Inclusive Design and Environmental Access to obtain structural data of wheeled mobility users that would introduce more accurate digital "Mannequin" models of this user group.

General Discussion of Human Modeling Applications to Determine Space Requirements for Wheeled Mobility

While digital human models provide information that cannot be collected with conventional anthropometric methods, it is not clear to the standards developers if use of such tools will be of great value. Typically, the questions that designers

and code officials need answered do not require the level of detail provided by digital human models and simulations, and, development and purchase of digital human models is costly. Further discussion is needed to explore how digital human modeling and simulation methods can be used effectively in code development.

For both design and code development, digital human models must be validated. Usually only components of the models (e.g., posture prediction for specific tasks) are evaluated, and there is not very much information about the errors associated with using digital human models in design.

Anthropometric Research

Anthropometry of users of wheeled mobility aids: A critical review of recent work, Bruce Bradtmiller, Ph.D.

Abstract

This commissioned paper and presentation summarized recent advancements in the anthropometric study of wheeled mobility aid users, and addressed how this information should be used appropriately in design and standards development. The strengths and weaknesses of studies performed by Ringaert, et al. (2001) and Stait, et al. (2000) are described in terms of their target populations, sampling strategy, and measurement methods. Among the strengths of both studies are clear definitions of the target populations, and the consideration of the mobility device and device user as one unit. Weaknesses included potential measurement error and lack of detailed information about how the measurements used were taken. The example of an automatic teller machine was used to demonstrate the design challenges that are associated with accommodating both mobility aid users and ambulatory individuals through one “universal” design. It also demonstrated the need for policy makers to have clear understanding of the target user population, the anthropometric characteristics of the user population, and the measurement methods used to collect the anthropometric data to effectively apply anthropometric data in standards development.

Key Points

- Standard procedures for combining data from multiple data sets are needed. It is unlikely that funding for a single major anthropometric study (with respect to the sizes of samples typically used for the general population) of persons with disabilities will become available, so it will be necessary to combine the results of smaller studies performed around the world to understand the body sizes and physical abilities of these user groups. Pooling data across studies requires clear definitions of sample inclusion criteria and measurement definitions.
- Recent anthropometric studies on wheeled mobility aid users consider the mobility aid device and device user as one unit, and allow data to be stratified by device type in addition to age and gender subgroups. This is very important since there is evidence to suggest that the demographics of wheeled mobility aid users and the types of chairs used has changed in recent years (e.g., Stait et al., 2000); and, the physical characteristics of mobility devices are likely to increase the variability in anthropometric dimensions and therefore will effect recommendations in the development of guidelines.
- Some recent anthropometric studies on wheeled mobility aid users include children, while others do not. While children need to be accommodated in

design, differences in inclusion criteria make pooling data from different studies very challenging.

- Some recent anthropometric studies do not describe their measurement definitions and sample characteristics clearly enough. This limits the usefulness of the data for developing guidelines.
- When using anthropometry to determine what percentage of a user population will be accommodated by a particular design, it may be more appropriate to use the raw data than summary statistics (e.g., mean and standard deviation) to make the estimate, since this requires no assumptions about the distributional characteristics of the data.
- Policy makers and designers need to clearly identify the target user population, critical anthropometric characteristics of the user population, and the measurement methods to make informed design decisions. Regulators should report how the information was used in the standards documents.
- Anthropometric differences of user groups across geographical regions are likely to be important since national surveys have demonstrated that the types of wheeled mobility devices purchased vary geographically. Future studies should address this by sampling from multiple geographical regions.

Discussion

Workshop participants indicated the need for more functional anthropometric information. Suggestions included conducting field research activities to identify the important design challenges associated with using commercial and public buildings and transportation systems, use of different outcome indicators in the evaluation of designs such as balance and avoidance of pain during use.

New approaches to designing environments that are usable for a broad range of people are needed. Additionally, participants indicated that there is need to educate designers about the use of anthropometry in 3-D design.

Expectations for accommodation are rising. In Australia, for example, space requirements standards are put in place in an attempt to accommodate 90% of mobility device users.

Access Board's Preliminary Research Plans

Long range research plans, Victor Paquet, Sc.D

Abstract

This presentation summarized a preliminary research agenda that was developed collaboratively between members of the U.S. Access Board and staff of the Center for Inclusive Design and Environmental Access of the University at Buffalo, SUNY. Seven objectives of the Board's research agenda were described. These covered a range of issues designed to develop better information about the space requirements of wheeled mobility devices available to policy makers. The preliminary research agenda is based on a multi-site approach to data collection to take advantage of the expertise and equipment of several teams, improve the representativeness of samples, and increase the variety of information available for human models. This requires that multiple sites receive training to ensure that the methods of data collection are consistent and the development of a plan and tools to merge the data from all of the data collection sites. The plan would incorporate social and behavioral approaches to data collection such as focus groups, and other methods for encouraging feedback on methods from wheeled mobility aid users. The short-term objectives of the Board's research agenda include organizing a consortium of research centers and expert consultants, refining the list of research projects for the near future, and developing detailed work plans and research protocols for each of the projects. The proposed work plan includes projects involving a 3-D anthropometric study, 2-D anthropometric study, a study of wheeled mobility device and accessory weights, maneuvering studies, and outreach and dissemination activities geared towards policy makers and potential research participants.

Key Points

- Objectives of the Board's long-term research agenda include:
 1. Implement useful research to determine the space requirements for use of buildings, facilities and transportation vehicles,
 2. Incorporate end user anthropometry and device dimensions (including accessories) into design guidelines,
 3. Complete human modeling studies to test design guidelines,
 4. Prepare reports that can be used effectively by regulators and designers,
 5. Develop an understanding the full range of devices and how they are used today,
 6. Develop new tools for utilization of research results so that design scenarios can be evaluated more precisely, and
 7. Develop an effective classification language and methods for describing the space and maneuvering requirements of wheelchairs and scooters.

- The approach proposed emphasizes a high degree of accuracy in data collection and builds on the foundation of an ongoing RERC anthropometry

research project, but, it includes a multi-site effort for data collection, emphasizes the development of valid human models, and ensures that the results can be used readily by regulators.

- Key variables proposed for study include the characteristics of wheelchairs, sample demographics, univariate and three-dimensional structural anthropometric dimensions, one-handed reaches and lifts and their alternatives, maneuverability measures that provide standard measures of task difficulty for general maneuvering, door use and transferring tasks and three-dimensional interaction with the built environment, and new methods of data presentation designed to communicate information effectively to policy makers and designers.
- The importance of data presentation for effective use by policy makers and designers cannot be underestimated. Without useful tools to simplify the application of anthropometric data in design, the data are not useful.
- The proposed work plan includes five projects that would be completed over several years.
 1. A 3-D anthropometric study to provide data useful for testing three-dimensional virtual environments developed in CAD or for human modeling applications; this would involve at least 2 more sites to collect data on at least 200 people in addition to the 200 already studied at the RERC on Universal Design at Buffalo.
 2. A 2-D anthropometric study performed by 2 research teams to gain basic structural anthropometric dimensions of two very large samples of wheeled mobility device users. This study would use digital photography-based approaches for rapid data collection.
 3. A study of wheeled mobility device and accessory weights that would require a research site to work with manufacturers of chairs and accessories to develop a database of photographs, dimensions and weights of wheeled mobility devices and their accessories.
 4. Maneuvering studies of wheeled mobility device users in small but realistic mock-ups of built environments; this could involve up to three research sites.
 5. A dissemination project that would include analyzing and systematically integrating anthropometric data collected previously in the United Kingdom, Australia, Canada, the United States and in other countries. Results of the dissemination project would include a DVD production demonstrating how individuals use different mobility aids and accessories, the space requirements associated with different devices and an analysis of the differences in findings from country to country.

Discussion

General comments were given on how anthropometric data are applied in design and standards. For example, using anthropometry only to understand the space requirements alone may not provide enough information for the development of effective guidelines. Visual data appear to be important for designing and education, but their value in standards development still is not fully clear. The types of anthropometric information and the level of detail required in design will depend on the stage of design. However, standards development does not necessarily follow the same iterative process that designers typically use, and the detail and quality of information acceptable for standards making still remains unclear.

Overall, the preliminary research plans were well-received by Workshop participants. There was no criticism about the specific methods proposed in any of the projects summarized during the presentation. Strengths identified by participants were the multi-site approach to many of the projects, the inclusion of a variety of wheeled mobility devices, the emphasis on consistent data gathering methods, and the inclusion of both simple and highly sophisticated approaches.

Some participants argued that the scope of the research plan should be expanded to provide the information needed for standards making on space requirements. There is a need to include greater numbers of individuals, a greater variety of individuals, and a more information about functional task performance. Workshop participants also emphasized the need for more work in the field versus the laboratory.

The use of terms in the experimental protocols and measurement approaches should be consistent with current ISO standards on anthropometric term definitions, measurement methods, database design, and wheelchair dimensions. The research team leaders should be involved in the ISO activities in order to transfer the lessons learned to the broader international arena.

The final portions of the discussion focused on how to continue the dialogue started in the first two workshops. Suggestions included linking future meetings about the Board's research agenda and specific projects to professional conferences such as those held by the Rehabilitation Engineering Society of North America, the Human Factors and Ergonomics Society, the International Ergonomics Association, and the Society of Automotive Engineers Digital Human Modeling group.

Recommendations to the Board

Several recommendations for the research agenda evolved from the discussions about the preliminary research plans. These were:

1. Partner with other sponsors in the U.S. and other countries to expand the research plan. The current plan is a good start but much more needs to be done.
2. Use of anthropometry in the development of space requirements for standards requires that all variables include demographic and device characteristics are considered in the evaluation of the design parameter.
3. More sites are needed to help ensure that samples are regionally representative of the population of wheeled mobility users in the U.S. and elsewhere. However, it is recognized that the use of non-U.S. data in standards may not convince U.S. policy makers and this should be considered further.
4. Include field research activities designed to provide a better understanding of the most important environmental barriers in commercial and public buildings, as well as transportation systems. Observational or ethnographic studies investigating the design needs of wheeled mobility users for tasks outside of the home are needed.
5. Studies that evaluate useful outcomes in design such as the increased activity and participation afforded by design are also needed.
6. Ensure that the plans for keeping data efforts across multiple sites consistent are sound so that data from these different sources can be combined. This will require a sophisticated data management and quality assurance process.
7. Ensure that careful attention continues to be paid to the demographic variables, including the types of wheeled devices and categories of disability, so that informed design decisions can be made.
8. Continue to explore the potential value of digital human modeling in space requirements for standards development. While there is no question that use of digital human modeling provides an extremely valuable design tool, the benefits to the development of the standards is still unclear. More information is needed about what the key inputs are to standards making, whether or not these can be changed, and how digital human modeling can be applied effectively to supply useful decision aids.
9. The experimental protocols used for this research agenda should be peer-reviewed by a peer-reviewed document. A process should be developed to allow input from an international group of stakeholders.
10. Many of the recommendations above would lead to expansion of research efforts beyond the current scope of work planned by the Board in the next few years but perhaps some of these ideas could be performed as exploratory projects in parallel to the planned research activities.

Conclusions

The increasing prevalence of wheeled mobility device users, the trends towards larger and heavier devices and research findings in anthropometry in other countries imply that the current space requirements for wheeled mobility accessibility in the U.S. need to be re-evaluated. The current research plans are a good start but more thought must be given to how to expand the plan. Such expansion will require partnering with other sponsors in the U.S. and ideally in other countries as well. International cooperation may be extremely important over the long term to ensure that the full range of research needs is met.

It is likely that a combination of basic anthropometric research, experimental trials, field observations, ethnographic studies and computer aided design analysis are needed to provide the necessary information about the physical size, function, and priorities of user groups for the development of effective design standards.

Digital human modeling may be extremely useful in design but difficult to apply to standards development because the individuals not modeled may unknowingly be excluded by the design. One effective application area for digital modeling may be in the evaluation of specific standards including the comparison of alternatives. More discussion is needed to determine exactly how digital human modeling and other simulation techniques can be used to inform standards development.

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APPENDIX

Space Requirements for Wheeled Mobility An International Workshop

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