A WEB-BASED DESIGN RESOURCE FOR WHEELCHAIR ANTHROPOMETRY AND ACCESSIBILITY IN THE BUILT ENVIRONMENT

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ABSTRACT

This paper describes a development project designed to update the anthropometry evidence for accommodating users of wheeled mobility devices (WhMDs) in the built environment. An interactive web-based design tool was developed for determining the dimensions of clear floor area and knee-toe clearance to achieve a user-specified level of physical accommodation based on dimensions such as occupied device length and width measurements taken on 500 users of WhMDs. The web-based design tool is now available to practitioners who seek to accommodate a wider range of users of WhMDs in the built environment than the minimum standards required by regulations.

Interactive web 2.0 technologies provide an opportunity for the research community to rethink our methods of communicating information about the anthropometry and functional abilities of WhMD users to design practitioners, rehabilitation engineers, and accessibility standards developers so that they understand the limitations of current accessibility standards and work to address these limitations through updated standards and policies.

INTRODUCTION

Users of WhMDs experience unique challenges for physical accessibility in the built environment because of concerns over large spatial requirements for floor area and maneuvering. Accessibility standards and codes are used throughout the US and in other countries to implement laws that mandate accessibility to buildings (e.g. public restrooms, bus stops, transit facilities, etc.) and transportation (e.g. buses, vans, trains, etc.). The Americans with Disabilities Act Accessibility Guidelines (ADAAG) (US Access Board, 2004) is the key document used for design of accessible built environments, and transportation vehicles and facilities. The technical criteria in these standards are based on body sizes and functional abilities (i.e., anthropometry) of adults and sometimes children with disabilities.

This paper describes a development project designed to update the evidence for the technical criteria in accessibility guidelines and standards, and communicate them to design practitioners and accessibility standards developers in a manner that would facilitate making good design and policy decisions.

METHODS

The data underlying this development project used anthropometry measurements previously taken on 500 adults in the US who relied solely on manual and powered wheelchairs and powered scooters for mobility (Steinfeld et al. 2010). This data collection was part of a larger research effort initiated at the University at Buffalo's Center for Inclusive Design and Environmental Access (IDeA Center) to develop an anthropometry database of WhMD users in the US in order to understand the spatial implications of contemporary wheeled mobility technology and user populations (Steinfeld et al. 2010). Users of WhMDs were recruited through many sources, including a local independent living center, a United Cerebral Palsy Association, a geriatric day care center, and local hospitals, including Veterans Affairs Medical Centers in Buffalo and Pittsburgh. The university's institutional review board approved the study and all participants provided written informed consent prior to participation.

Recently, the University of Michigan's Inclusive Mobility Research Lab (IMRL) developed an open-access website for designers and standards developers to visualize and interactively explore this anthropometry data (IMRL, 2018). A web-based graphical method incorporating the concept of accommodation models was prototyped to communicate research findings so that end-users could understand the effect of their design choices. Accommodation models are data-driven design tools that relate key design parameters to empirical human performance measures (D'Souza et al. 2010). Two accommodation models were implemented. The first model implementation relates to the ADAAG specification of 'clear floor space' (CFS) for WhMDs and the second model relates to 'knee-toe clearance' (KTC) for WhMDs.

Accommodation Model for Clear Floor Space

A key building block in the ADAAG is the specification of a minimum clear floor space, a rectangular space 760 mm wide by 1220 mm length needed to accommodate people using WhMDs. This 'clear floor space' is used to determine the size of the floor area planned for positioning an occupied wheelchair near building elements such a drinking fountain, the width of doorways and interior clearances for maneuvering a mobility device on accessible routes, and the space needed to accommodate users of WhMDs in buses, bus shelters, and in terminals - hence, a critical component for ensuring physical accessibility.

An accommodation model was developed (Figure 1) for statistically estimating the minimum CFS to achieve a user-specified level of accommodation based on occupied device length and width measurements (Bharathy and D'Souza, 2018). The visual interface allows users to retrieve and display information on occupied width and occupied length as individual data points on a 2D scatter-plot for all 500 individuals in the study sample or filtered by mobility device type, sex, and age range. To provide context, a plan view of an occupied wheelchair and the standards-prescribed minimum CFS is superimposed on the display to highlight cases either accommodated or excluded.

Two modes for conducting "what if" analyses are implemented. First, end-users can slide the CFS boundary edges (dotted lines in Figure 1) to increase/decrease the area with the display updating in near real-time to show the proportion of the sample accommodated. Second, an end-user can specify on a slider-bar the intended percentile of users accommodated causing the CFS boundary on the 2D display to update.

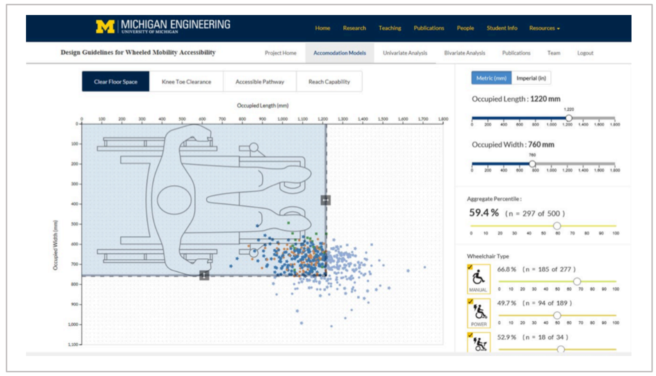

Figure 1: Scatter-plot of occupied length vs. occupied width, overlaid with the federal requirement for minimum clear floor space of size 760 mm x 1220 mm (30 in. x 48 in.). The panel on the right provides filter controls and information on the percent accommodated.

Accommodation Model for Knee-Toe Clearance

A second key building block in the ADAAG is the specification of minimum knee-toe clearances beneath building elements such as drinking fountains, lavatory sinks, information kiosks, ATMs, counter-tops and other work surfaces that require a forward approach. Sufficient clearance space needs to be provided under the work surface or structure to allow WhMD users to approach the element with minimal obstruction.

An accommodation model was developed (Figure 2) for statistically estimating the minimum knee-toe clearances for a user specified level of accommodation. The analysis used six critical dimensions relevant to knee-toe clearance spaces: knee clearance height, knee clearance depth, foot clearance height, foot clearance depth, abdomen depth, and occupied device width. The anterior-most aspect of the abdomen was used as the reference point for calculating depth dimensions, as it represents the closest that a person could approach to the edge of the surface if not restricted by knee and toe clearance.

The interface allows two modes of operation for end-users: 1) retrieve a clearance envelope for a specified accommodation level, 2) increase or decrease each of the six dimensions to determine the sample accommodated in the user-defined clearance envelope.

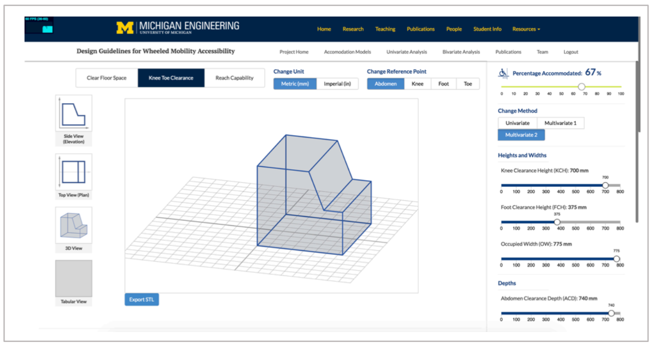

Figure 2: 3D model of the clearance envelope for minimum knee-toe clearance. The panel on the right provides filter controls, height and depth dimension controls, and information on the percent accommodated.

DISCUSSION

Research on the anthropometry and functional abilities of WhMD users has important implications for the improvement of accessible design practice. It provides the necessary data for architects, engineers, and designers of accessible environments (e.g., building interiors, workplaces, transit vehicles) and serves as an important knowledge-base for federal agencies when developing accessibility guidelines and standards (e.g., US Access Board, 2004; US DoJ, 2010).

The sizes and characteristics of WhMDs and their users have changed considerably since the 1970's when research on wheelchair anthropometry was first conducted, which later formed the basis for the current criteria for accommodating WhMD users (Steinfeld et al. 1979). Based on findings from the newly assembled anthropometry database and other considerations from stakeholders, the ICC/ANSI A117.1 Committee, which publishes a voluntary building standard for accessibility has revised its minimum requirements for clear floor area length in all new construction, increasing it from 1220 mm (48 in.) to 1320 mm (52 in.) (ICC/ANSI, 2017; Steinfeld et al. 2014).

Certain limitations of the assembled database are worth mentioning. First, the proportion of users of manual and powered wheelchairs and electric scooters measured does not represent the same proportion expected in adult U.S. population of wheelchair users. However, the web interface allows for stratifying results by type of mobility device.

The analysis of CFS and KTC was based on the assumptions of a rectilinear bounding area (or volume in the case of KTC) required for static positioning of a wheeled mobility device, akin to depictions in the ADAAG (US Access Board, 2004). Anthropometry measurements were taken with participants seated in a comfortable posture that they could maintain for the duration of the measurement process, typically lasting 15-20 minutes. These measurement conditions and postures may overestimate the occupied width, length and height dimensions since it does not take into account the ability of some individuals to move their limbs inboard of their devices, swing leg-rests and footrests out of the way or adjust back-packs and bags which may extend beyond the boundaries of their devices. However, such constrained postures may be difficult to maintain for long periods of time.

Lastly, space requirements for WhMD users to maneuver into and out of the CFS envelope were not considered in the current analysis and may require additional clearances (D'Souza et al. 2017).

CONCLUSIONS

New web 2.0 technologies allow for creating interactive and context-driven visual representations for visualizing, exploring, and communicating design information. The research community has been slow to leverage these technologies for knowledge capture and translation to accessibility standards developers and policy makers.

This paper draws attention to the opportunity presented by open-source, interactive web technologies of communicating anthropometry and design information to standard developers, policy makers, designers, and engineers. A development project is presented advocating the concept of interactive multivariate accommodation models to communicate anthropometry data so that end-users can understand the effect of their design choices. The website is available for free to practitioners who seek to accommodate a wider range of WhMD users than the minimum standards required by federal regulations (IMRL, 2018). Usability testing of the website with design practitioners is underway.

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