Increasing Personal Mobility for Wheelchair Users in Developing Countries
- a Wheelchair Prototype Evaluation Study in Indonesia

Erik Ohlson

Division of Design and Human Factors, Department of Product and Production Development, Chalmers University of Technology, Gothenburg, SWEDEN

Wheelchairs are one of the most commonly used assistive devices for increasing personal mobility, and an estimated 1% of the world population is currently in need of a wheelchair. Approximately 80% of the world population currently live in developing countries and being a wheelchair rider in such context differs substantially from an industrialized context. Developing wheelchairs that can handle this rather different environment means complex trade-offs for designers. This paper presents the results of a wheelchair prototype evaluation in Indonesia. The prototype had rough terrain features and the possibility to alter the seat into two different positions while riding. The backmost position was for normal riding, while the foremost both translates the centre of gravity 100 mm forward and changed the seat angle from twelve degrees to four degrees. This was to help users to overcome inclined slopes as small hills and ramps to access buildings, facilitate transfer procedures and to provide an ergonomically more beneficial posture when sitting at a table. The study showed that primarily paraplegic users could benefit from the alternating seat functionality, but that users with polio or amputated lower limbs also could be prospect users depending on their individual preferences. However, further similar studies are needed before this technology could be fully introduced to the market.

Practitioner Summary: This paper presents the results of a wheelchair prototype evaluation study in Indonesia. The prototype had a longer wheelbase than traditional wheelchairs and a seat that could be altered into two different positions while riding. The foremost position could be used to overcome slopes, facilitate transfer procedures and to get a better sitting posture when seated at a table. The study showed that primarily paraplegic users could benefit from the alternating seat functionality, but that users with polio or amputated lower limbs also could be prospect users depending on their individual preferences.

Keywords: Developing countries; Indonesia; Wheelchair; Evaluation; Personal mobility

1. Introduction

Wheelchairs are one of the most commonly used assistive devices for increasing personal mobility of people living with disabilities (Armstrong et. al., 2008), and an estimated 1% of the world population is in need of a wheelchair. Currently 80% of the world population are living in less developed countries¹ (Population Reference Bureau, 2014) and in 2003, it was estimated that 20 million of those in need of a wheelchair for personal mobility did not have one. There are indications on that only a minority of those in need of wheelchairs have access to them, and of these very few have access to an appropriate wheelchair (Sheldon & Jacobs, 2006). The problems in developing countries include insufficient production facilities and that wheelchairs often are donated without the necessary related services, such as fitting and distribution.

¹ According to United Nations (2014), there is no established convention for the designation of “developed” and “developing” countries or areas in the United Nations systems. They also note that the designations “developed” and “developing” rather are intended for statistical convenience and not necessarily expresses a judgment of the stage reached by a certain country in their development process. The UN considers Japan, USA, Australia, New Zealand and Europe as developed regions or areas.
Previous research has also pointed out that assistive devices that are incompatible with the environment may end up being abandoned by the user (Saha et al., 1990). Hence, providing wheelchairs that are properly designed for the intended context and fitted for the user would not only enhance mobility but also possibly open up for education, employment and social life. Previous studies have shown that wheelchair users with improved mobility seem to get better opportunities in the society (May-Teerik, 1999) and that a lack of mobility inhibits wheelchair users to integrate with society, resulting in limited access to employment and education (Shore & Juillerat, 2012).

The Convention on the Rights of Persons with Disabilities states that people in need of assistive devices must be able to access such equipment to ensure their full and equal enjoyment of all human rights and fundamental freedoms (UN, 2007). In general, people in developing economies enjoy human rights to a much lower extent than in richer economies (UNDP, 2000) and the challenge is even bigger for people with disabilities. The difficulties in managing everyday life situations result in many wheelchair users being isolated in their homes (Eide & Kalameri, 2009; Loeb et al., 2008). The rough outdoor terrain, including uneven pathways and inclined slopes, is a significant part of these difficulties, and is factor that causes many wheelchair users in developing countries to be dependent on assistance (Bremer & Ohlson, 2013). Most of the least developed nations are also having problems with overall basic public transportation rights and environmental access (Venter, Rickert, & Maunder, 2003). The result is that wheelchair users in developing countries have a very limited personal mobility, often caused by poor environmental access and insufficient wheelchairs.

This paper is based on a formative wheelchair prototype evaluation study in the region of Yogyakarta, Indonesia. The aim of the study was to evaluate the functionality of a wheelchair prototype, designed to generate an additional degree of freedom for its users and thereby increase the possibilities of becoming independent. The prototype included design features to manage rough riding terrain and to overcome everyday obstacles as ramps, small hills and other inclined slopes. Its design could also facilitate transfer procedures, which means entering and exiting the chair, and provide an ergonomically more beneficial posture when the user was seated at a table. The aim of this paper is to present the results of the study and to discuss the possibilities of increasing personal mobility for wheelchair users in developing countries through a wheelchair designed specifically for the challenges in these contexts.

2. Method

This study was a formative evaluation as a part of a wheelchair development process. The intention was to evaluate the functionality of an alternating seat on a long base wheelchair in order to understand possible advantages and disadvantages of implementing such functionality on future developing world wheelchairs.

2.1 Participants and Interpretation

In total, 20 Indonesian participants (15 males, 5 females) were selected to take part in the study and the recruitment was made through a local organization working for providing appropriately fitted wheelchairs for children and adults living with disabilities in Yogyakarta, Indonesia. The participants represented different disability types and were between 15 and 59 years old. All participants were considered potential users of the type of wheelchair used in the study. To the extent possible, participants were chosen so that the prototype could be fitted to their anthropometrical measures. A categorisation of the participants is presented in table 1.

<table>
<thead>
<tr>
<th>Disability</th>
<th>Participants</th>
<th>Male/female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polioyelitis</td>
<td>10</td>
<td>8 male/2 female</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>6</td>
<td>3 male/3 female</td>
</tr>
<tr>
<td>Paraparesis</td>
<td>2</td>
<td>2 male</td>
</tr>
<tr>
<td>One amputated lower limb</td>
<td>1</td>
<td>1 male</td>
</tr>
<tr>
<td>Two amputated lower limbs</td>
<td>1</td>
<td>1 male</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>15 male/5 female</td>
</tr>
</tbody>
</table>
All participants were fluent in Indonesian and had varying levels of communication skills in English. An Indonesian-English interpreter was present during all tests. The interpreter was also a wheelchair rider and the participants knew this person as a representative from the local wheelchair organization.

2.2 Equipment

The wheelchair prototype used in this study (figure 1) was designed to facilitate the encounter of inclined obstacles, such as uphill slopes and ramps, facilitate transfer procedures and to provide a more ergonomically beneficial posture when seated at a table. It had a rigid mild steel frame design and rough terrain features, including a 50% longer wheelbase than traditional wheelchairs and 4.5” x 3” solid rubber casters. These features were also accompanied by the possibility to temporarily translate the position of the seat forward. The seat was locked in position by a locking handle placed behind the seat and the seat position could be altered by unlocking the handle, moving the seat, and then locking the handle into the new position. The forward motion was limited to 100 mm with respect to the reachability of the hand rims. The foremost position also elevated the back of the seat (figure 2), which changed the seat angle from 12° in the rearmost position to 4° in the foremost. The material and production techniques were chosen with respect to currently used materials and techniques for producing wheelchairs for developing countries.

![Figure 1. Wheelchair prototype, Figure 2. Seat alternation](image)

2.2.1 Environment

All test scenarios were held in Yogyakarta or in villages located within a 20 km radius from the city centre. All participants were living in areas where they could be exposed to both rugged and urban terrain, and the tests were held in familiar environments for the participants. For 15 of the participants this meant visits to their homes, two were held at the working place of the participant and for the three youngest participants, the test was held at their school. All environments offered the possibility to ride the wheelchair in rugged terrain, encounter inclined obstacles, and to practice transfer procedures.

2.3 Procedure

All participants were notified of the test in advance and the research team (the author and another person) was welcomed to meet the participants at either their home, working place or school. Each session was initiated with that the research team introduced themselves and explained the purpose of the project. The participants were asked about their age, information about their disability and their experience as wheelchair riders. After this, the research team identified suitable challenges for the test scenario exercises while the participant was invited to get familiar with the prototype and its functionality.

Each test scenario lasted for approximately 30 minutes and consisted of three main exercises. The first was to encounter a ramp, the second to encounter an inclined slope in the nearby environment and the third to perform transfers in and out of the prototype. During the third exercise, the side protections were
removed from the chair in order to study the possible benefit of transferring with the seat in the foremost position.

During the exercises, the participants were encouraged to ‘think aloud’, i.e. speak freely about their experiences (cf e.g. Jordan, 1998). The research team also prompted the participants in order to encourage them to make helpful verbalisations. The research team was present during all tests, and the two members were given specific tasks. One of them served as a video photographer while the other was taking notes from both the conversation with the interpreter and observations made by the research team. After the test scenario, a semi-structured interview was made with each of the participants. They were asked to describe their experiences with the prototype and perceived differences between previously used wheelchairs and the prototype.

3. Results

An overview of the results from the study is presented in table 2 and the participants have been grouped according to their disability category. The categories “helped during inclines” and “facilitated transfers”, indicates notable differences between when the participants performed the exercises using the foremost position of the prototype and using their personal wheelchairs. In the cases where a participant has received a notation in the table, it was considered that this particular participant received help by the prototype in a way that substantially could facilitate the challenge described in the table.

Table 2. Categorised results

<table>
<thead>
<tr>
<th>User characteristics</th>
<th>Prototype performance</th>
<th>User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, Gender, Current chair</td>
<td>Active user</td>
<td>Independent transfer</td>
</tr>
<tr>
<td>15 F DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>15 F DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>17 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>30 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>34 M DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>37 M IS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>40 M DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>40 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>44 M DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>56 M DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>34 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>35 F DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>38 F DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>44 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>50 F DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>59 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>35 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>49 M DL</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>42 M DS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>40 M DL</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

DS: Developing country, short wheelbase  
DL: Developing country, long wheelbase  
*Long wheelbase more important
3.1 User characteristics

Participants with polio or amputated lower limbs were considered more active riders than participants with paraplegia or paraparesis. In general, users that freely used their wheelchairs in most situations without requiring assistance from others were considered active users. The reason to why participants were not considered active was primarily related to limited upper body strength and limited self-confidence in terms of trusting own abilities. Most of the less active participants rarely or never met other wheelchair riders and never got the chance to see others accomplishing challenging manoeuvres while riding wheelchairs.

Some participants expressed that they did not make any significant travelling outside of their residential property. The cause was generally physical limitations and they were dependent on assistance from someone in their family to leave their property. Results from both the interviews and observations indicated that there were several factors affecting the ability to travel independently. More experience as a wheelchair rider generally resulted in a higher degree of independence, but this could also be connected to the level of self-confidence and courage. Participants involved in disability organizations or other similar activities, where they met other wheelchair riders, seemed to have a higher level of manoeuvring skills, presumably due to that they there met other wheelchair riders with whom they could share experiences. Participants that never or rarely met other wheelchair riders often expressed anxiety over encountering obstacles that they independently could not manage as a reason to not leave the property alone. In four cases, the area in which the participant independently could manoeuvre the current wheelchair was even smaller than the property as a result of inaccessible stairs or steep ramps that was too inclined for the rider to climb. In these cases, the participants would not even leave the house without assistance.

3.2 General Prototype Performance

For all participants except one, the prototype was lighter than their current wheelchairs. In the case where the wheelchair of the participant was lighter than the prototype, a wheelchair designed for industrialized countries was used. This was also the only participant that performed better in his own wheelchair during the manoeuvring exercises than in the prototype. This is probably due to the combination of a high level of manoeuvring skills and the usage of a short wheelbase industrialized country lightweight wheelchair. All participants expressed a wish for a lightweight wheelchair during the interview sessions, and the benefits of a lighter wheelchair were also identified during the observations of the manoeuvring exercises. There were clear connections between the participants’ ability to manouevre their wheelchair and its weight. However, all participants would probably not benefit from having a lightweight wheelchair if it would be at the expense of design features that are more important for their respectively challenges, i.e. the long wheelbase. Results from both the observations and interviews highlighted the importance of the long wheelbase when riding in outdoor terrain. Several participants pointed out that the long wheelbase contributed to increased safety and mobility in rugged terrain, especially among those who currently is using another long wheelbase wheelchair. When used in an indoor environment, it was expressed that the long wheelbase had a negative effect on accessibility. This applied to both current long wheelbase wheelchair users and participants currently using short wheelbase chairs, which was also confirmed by the observations. The negative comments also included the inability to get close to furniture, and the perceived increase in weight.

Several users argued that the 12° angle of the rearmost position did not meet their personal preferences. No participants expressed a solely positive attitude towards the seat angle.

3.3 Inclined Obstacles

The observations showed that using the foremost position actively prevented users from falling backwards when riding inclined surfaces. Since the construction of the alternating seat also meant additional weight, the potential facilitation during inclines have primarily been considered in everyday situations. This included smaller inclined obstacles as ramps leading to buildings or small slopes in the participants’ nearby environments. Other wheelchair characteristics (weight, length of wheelbase, seat angle, etc.) might for some users be considered more important than an alternating seat. Therefore, the results are not showing the steepest possible inclines, but rather inclines that could be faced during a regular day. A majority of the participants who received help from the prototype when riding inclined obstacles was paraplegic, which possibly can be described by the general incapability of leaning the upper body forward according to limited
mobility in the trunk. However, the ability of such bodily movement varied between the paraplegic participants.

Limited trunk and pelvic mobility is possibly also an explanation of which participants could manage to alter the seat position, themselves while seated in the prototype. A majority of the participants that could not perform the alternation were paraplegic. Among the others, insufficient body strength and limited pelvic mobility seemed to be the main factors of not being able to complete the alternation. According to that paraplegic users generally were provided better help from the prototype, whilst also having bigger problems with completing the alternation, the seat alternation should be improved. In order to be able to use the functionality of the prototype independently, paraplegic users must have the opportunity to also be able to complete the alternation.

More than a third of the participants were able to overcome an incline in their nearby surroundings that they had never managed before, and two participants managed to enter their houses while seated in a wheelchair for the first time ever. These participants were represented in all the different disability categories. This is considered as an indication of the possible benefit with using the alternating seat technology. While some results indicate a more clear benefit for paraplegic users, this result shows that users from all the presented disability categories could benefit from an alternating seat. Individual preferences should therefore be considered more important than general information about specific disabilities.

Several participants expressed a negative attitude towards the functionality of the seat. This attitude changed for some participants during the test in some cases, but others were very determined in their negative opinions. One participant expressed that he was afraid of falling backwards when sitting in the front position, even though the observation clearly showed that he could overcome inclined obstacles in the front position that he could not manage in the backmost position or in his own wheelchair. Generally, the negative comments were related to not being comfortable or to the reachability of the handrims.

In the six cases where a participant expressed a wish to instantly get the prototype for personal use, the possibility to overcome inclined obstacles was always the main reason. The immediate improved ability to overcome inclined obstacles was expressed as a very appreciated advantage, and it was possible to see how these participants were very happy about their accomplishments.

### 3.4 Transferring

A majority of the participants were able to complete transfer procedures from or to the prototype independently. However, this was not always synonymous with that the participants actually made all their transfers independently. During the interviews it was revealed that some participants found these procedures problematic and preferred to get help from their family members if possible. When considering independence, independent transfers is perhaps not as important for the opportunities of getting improved access to education and employment as the ability to independently manoeuvre the wheelchair but it is possible that inability to perform transfer procedures could have a negative psychological effect on the user.

Participants with better trunk mobility experienced fewer problems with transfer procedures. The observations also showed that altering the seat forward provided notable help for paraplegic users. The characteristics of the transfer procedure varied between the participants, but a general conclusion is that more help was provided to participants that wished to transfer sideways. Steep seat angles were also mentioned among several participants as a problematic factor during transfers, and the possibility of changing the seat angle of the prototype from 12° to 4° were in these cases mentioned as an advantage.

### 3.5 Sitting Posture at a Table

The observations showed a clear disadvantage for long wheelbase wheelchairs compared to short wheelbase alternatives when trying to get close to tables, and several participants also expressed this during their interviews. When altering the seat forward, the observations showed an improved situation, where the participants could get closer to the table. Participants working with desk-related occupations, such as a TV-repairers, office workers, or participants that still went to school, mentioned the alternating seat as a promising feature for their needs. The comments would primarily describe the ability to get closer to the work top area, but some users also mentioned the perception of a more active sitting posture. The change in seat
angle meant an elevation of the rearmost part of the seat, and this change was perceived as better suited for
desk related jobs than what was offered by their current wheelchairs.
Participants that did not have desk-related occupations and normally used short wheelbase
wheelchairs mentioned that they preferred a shorter wheelbase to a longer while they were seated at a table
according to the possibility of betting closer to the table. However, the 4° seat angle was commonly
mentioned as more comfortable than both the rearmost position of the prototype and other wheelchairs while
sitting at a table.
The prototype was particularly described as positive by one of the participants. She mentioned how
her chest was elevated and allowed her to take deeper breaths, which also could be seen when observing
her behaviour. As being used to a wheelchair with a 12° seat angle, she experienced the foremost position of
the prototype as very beneficial for her ability to take deep breaths while working.

4. Discussion
The results of the study indicate that the functionality presented by the prototype could facilitate aspects
affecting the ability of a wheelchair rider in a developing country to be less dependent on assistance from
others. Paraplegic users would, according to the results, be better suited for using a wheelchair with the
functionality of the prototype but the results clearly indicate that there are users from all disability categories
that could benefit from using a wheelchair with an alternating seat. This may mean that it is more important
to study the individual characteristics of each user rather than focusing on a certain disability category when
targeting the primary users for the alternating seat technology. The specific characteristics of which users
are best suited to use this type of technology cannot completely be determined by the results of this study,
and further information on user profiles is required.
The duration of the test procedures leaves little room to evaluate the possible negative aspects of
the alternating seat. Possible disadvantages can be seen in the increased weight, compared to if the same
frame would be used with a fixed seat solution, or the usage frequency of the seat alternation. It is difficult to
estimate the usage frequency of the seat alternation by analysing the results of this study. The study has
given satisfactory results in terms of indicating that the prototype’s functionality could help some users with
certain challenges. It is, however, a notable difference between having the functionality available on your
wheelchair and actually using it. A desirable continuation of developing the prototype would therefore be to
custom longer studies. A follow up study could provide results on if the alternating seat actually is a feasible
solution to introduce to the market. Such evaluation should also include design updates of the prototype
identified by this study. The main finding is to establish an easy and reliable way of alternating the seat while
the user is seated, which would be very important for the functionality’s chances of becoming an
implementable feature on future developing world wheelchairs.

Parts of the result section mention self-confidence and trust in personal abilities as a wheelchair
rider as a potentially important factor of experiencing independency as a wheelchair rider in developing
countries. It is possible that a new wheelchair design is not enough to reach the desired level of perceived
independency. The results indicate that users that rarely meet other wheelchair riders also are less confident
in their own personal abilities. Providing adequate equipment may be one part of increasing confidence, but
it is important to consider the meaning of letting these individuals meet others facing similar challenges.
As described in the result section, several disability groups could benefit from this solution. Steep
ramps and other slopes are common obstacles for wheelchair riders in developing countries, and these are
part of excluding wheelchair users from being independent. However, insufficient equipment is not the only
important factor. Properly designed equipment is probably one step towards including wheelchair users in
developing countries to freely enjoy independence and take part in society activities, but more actions are
probably needed to reach a satisfactory result. Insufficient national infrastructure and a lack of environmental
access are problems that have major impact on personal mobility for wheelchair riders in developing
countries. However, these are problems on a completely different level. In order to overcome them, a lot of
resources in terms of money, time and political influence would be needed. Improving the wheelchair design
is a feasible immediate solution to the issue of making wheelchair users in developing countries more
independent.
5. Conclusions
The study shows that the prototype provides necessary functionality to facilitate the events of encountering inclined obstacles and performing transfer procedures for some users. The alternating seat also offers a possibility to get closer to tables while seated in a long wheelbase wheelchair. Primarily paraplegic users could benefit from the alternating seat functionality, but users with polio or amputated lower limbs could also be prospect users depending on their individual characteristics.

The most important design improvement during the next iteration of the wheelchair development process should be to find an easy and reliable way of altering the seat position while the user is still seated in the wheelchair. The user should be able to accomplish the alternation independently to fully enjoy the possible benefits of the prototype.

The prototype evaluated in this study is intended as a contribution to make wheelchair riders in developing countries less dependent on assistance from others. Providing adequate equipment in terms of wheelchairs properly designed for the intended context could increase the possibilities of making wheelchair riders in developing countries more independent and thereby increase their personal mobility, but further actions are needed to reach a satisfactory result.

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References