



Guidelines for Designing Wheelchair-Accessible Houses for People with Disabilities

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Abstract

Interior environmental design can improve the quality of life of people with disabilities, as it enables them to live normally like everybody else in both public and private places. Therefore, this study focuses on creating clear and practical guidelines for designing accessible houses that can accommodate wheelchair users in the most efficient way. The objectives of this research were 1) to explore the characteristics of interior architecture and accessible facilities for wheelchair users, 2) to study the problems and needs of wheelchair users in terms of environments, behaviors, and activities, and 3) to create clear and practical guidelines for designing accessible houses and environments for wheelchair users. A qualitative design was employed in this research. The preliminary data collected through the observational survey were used to analyze the feasibility of the project and improve the research tools before being used for further data collection. The obtained data were analyzed, summarized, and prioritized in order to find appropriate solutions and create design guidelines. The results suggested that the design of wheelchair-accessible houses should place importance on two main points: 1) accessibility, which enables wheelchair users to access all areas both inside and outside the building, including flooring height level, passage width or size, and flooring materials and surfaces, and 2) usability, which enables wheelchair users to use all spaces in a convenient and effective way. The design of wheelchair-accessible houses should take into account various related factors, covering the proportion of spaces suitable for wheelchair users, dimension of furniture, installation of wheelchair-friendly technologies and facilities, and special areas for disabled people that require a specific design, such as bathroom, bedroom, and kitchen. All elements should be designed based on the concept of easy-to-use, convenience, and safety. The findings of this research can be used to create practical guidelines for interior architectural design and to develop detailed designs for the construction of wheelchair-accessible houses for people with disabilities.

Keywords: Residential renovation, disability, wheelchair

Introduction

Currently, interior spaces and surrounding environments of most residential buildings and homes are not designed to support people with physical disabilities, including patients, the disabled, and the elderly. This group of people experience problems in everyday living and are unable to help themselves due to inappropriate interior and environmental design that limits them from accessing and using some spaces. As there are national research policies and strategies focusing on the development of ability, well-being, and security of people with disabilities, one way to develop their quality of life is to design or develop interior environment conditions that enable them to access every area of their houses and live normally in both public and private places. At present, the building control law requires that all types of public buildings have to be designed to accommodate people with disabilities. According to preliminary information, most disabled people or patients use wheelchairs as a mobility aid (National Statistical Office, 2017).



Therefore, this research aimed to create guidelines for designing wheelchair-accessible houses for people with disabilities so that they can access and use all spaces within their houses in a convenient and effective way and to explore the problems, needs, opinions, and suggestions of wheelchair users regarding appropriate interior design and functionality. The general public can use the results of this research as a guideline for renovating and improving their interior environmental conditions or similar building projects in order to accommodate wheelchair users and provide them with a good living environment so that they can rely on themselves and achieve a better quality of life and well-being in the long run.

Methods

In this research project, the data were collected, analyzed, and summarized in order to create guidelines for designing wheelchair-accessible houses that can be easily applied. The design criteria were determined according to the needs of users in terms of activities, behaviors, and space needs. This study employed a qualitative research design. Most of the data used were attributes. The collected data were analyzed using critical analysis and summarizing techniques based on the opinions of the researcher and informants. This research intended to study the needs of building users in the aspects of environments, activities, behaviors, daily living, and current problems in order to find appropriate solutions, to create interior design guidelines that can respond to the needs of users in various areas, and to maximize design efficiency and usability, contributing to a more convenient life of wheelchair users.

1. Research Procedures

In this research, the data were collected using multiple methods, comprising literature review, documentary research, area survey, observation, and interview, which can be summarized as follows.

(1) The literature review and documentary research were conducted in order to determine research problems, research objectives, research questions, and research hypotheses, which would be used to create research tools and perform data analysis.

(2) The pilot study was carried out to survey and measure the study areas. The obtained data were used to create an interior layout. The environmental conditions were also observed. The building users were informally interviewed. The internal environment were assessed after being used in order to understand existing problems and determine the project direction. Then all collected data were preliminarily analyzed and used to design and modify the research tools according to the research objectives.

(3) The data collection was conducted using the interview method. The interview form that was already modified based on the preliminary data analysis was used to gather data from the informants. The data were systematically collected for data analysis and summarization.

(4) The data were analyzed and summarized according to the research objectives. The research results were discussed. The recommendations were made.

(5) The research report was written together with a draft of guidelines for designing accessible homes for wheelchair users.

2. Sample Groups

The samples in this study can be divided into two main groups as follows.

(1) Area samples: this research intended to study the interior architecture of houses in Bangkok by focusing on the physical characteristics of buildings. The researcher selected only seven detached houses with similar size, proportion, model, and interior functionality without including any condominiums, dormitories, row houses, or commercial buildings with great differences in physical characteristics. The seven area samples consisted of the following:

1. A two-storey house, 86 square wah, located in Wang Thonglang with an interior space of about 165 m²



Figure 1 Detached House 1

2. A two-storey house, 120 square wah, located in Bangkok Noi with an interior space of about 300 m²



Figure 2 Detached House 2

3. A two-storey house, 56 square wah, located in Bang Kapi with an interior space of about 103 m²



Figure 3 Detached House 3

4. A single-storey house, 40 square wah, located in Nimit Mai with an interior space of about 90 m²



Figure 4 Detached House 4

5. A two-storey house, 56 square wah, located in Sai Mai with an interior space of about 125 m²



Figure 5 Detached House 5

6. A two-storey house, 65 square wah, located in Bang Khen with an interior space of about 160 m²



Figure 6 Detached House 6

7. A two-storey house, 78 square wah, located in Ladprao with an interior space of about 152 m²



Figure 7 Detached House 7



The floor plan of each house was created and the environmental conditions were surveyed in order to analyze space usage problems. According to the survey, the seven houses had similar problems, which could be analyzed altogether. The data collected through the survey study could be used to reflect and analyze the current conditions and problems of wheelchair users in the study areas and could be used to develop design guidelines.

(2) Personal samples: in this study, there were four personal samples or informants that were selected based on physical abilities without focusing on age, gender, occupation, and educational level. The researcher selected only the wheelchair users with a physical disability in the lower part of the body, excluding people with disabilities in other areas, such as eyes, brains, and muscles. All informants were in the researcher's contact network, which was convenient for data collection.

3. Research Tools

The data in this research were collected from two sources: 1) the physical characteristics of the area samples and 2) the data from the personal samples. The research tools consisted of the following.

(1) Survey and observation form was used to record the physical characteristics data, related persons, behaviors, interactions, general physical environment, survey plan, and dimension of each study area in order to create an interior space layout. The data obtained from the informal interviews with the informants regarding their satisfaction, problems, and needs were also recorded in this form.

(2) Interview form consisted of open-ended questions that required factual and logical answers from wheelchair users about space usage problems, daily life obstacles, activities and behaviors, and specific requirements in various areas. Similar questions with in-depth meaning were used to obtain clearer and more solid answers. The key questions that were used in the interviews are as follows.

- What are your main living problems? Please describe in details.
- Have you ever had accessible problems within the house? What should be done to solve those problems?
- When using interior space such as bathroom, kitchen, bedroom, or other areas, are there any problems or obstacles? Please provide suggestions on how to solve the problem in each area separately.
- What facilities are required in each area within the house?
- What are your suggestions on how to design wheelchair-accessible houses?
- Do you have any other needs for facilities that can make your life better?

In addition, during the interviews, the researcher used a model to make the informants see a clearer picture and provide useful comments and suggestions about renovating an existing house to be more accessible for wheelchair users.

Results

The research results showed that most of the houses in this study had similar obstacles and problems about wheelchair access and space usability, which can be summarized as follows.

- Different-level areas both inside and outside the house are major obstacles to wheelchair users because they need flat or ramped access to all areas.



- Some areas are too narrow and have too many corners and angles. Some areas do not have enough space for the wheelchair to move through or rotate, such as bathroom entrance and passageway.
- Some furniture is placed out of the reach of wheelchair users, such as floating cabinets, clothes racks, and shelves, which is considered one of their daily life obstacles.
- Stairs are a big problem in two-storey houses. Wheelchair users need lifts or other support devices to travel from floor to floor.
- Form, size, and proportion of some furniture and sanitary appliances are not suitable for wheelchair users, for example, there is no space to support the legs, the installation position is too high or too low, and the design is too deep to reach.
- Aiding devices that help to transfer the disabled from and to the wheelchair are not installed in the house. These devices are very important because they enable the disabled to access and use interior spaces in a more convenient way.
- Surfaces that are a barrier to the wheelchair are mostly outdoor, such as rough gravel surface, lawn, and soft ground that is difficult for the wheelchair to move around.
- Poor storage management in the house can hinder wheelchair mobility.
- Room doors or large cabinet doors are hard to use and inconvenient for wheelchair users.

The above obstacles and problems resulted from ineffective interior environmental design that did not pay attention to the needs of users. The research results suggested that designing wheelchair-accessible homes for disabled people should place importance on three main factors as follows.

1. Accessibility: wheelchair users should be able to access all areas both inside and outside the house like everybody else does. Therefore, in order to facilitate daily living of wheelchair users, it is important to design and arrange appropriate interior environment for them by taking account of the following elements.

- Flooring level: the floor should be flat and even without any curbs or joints that may hinder wheelchair mobility. In the areas with different floor heights, such as the entrance linking indoor and outdoor spaces and the threshold of the bathroom, ramps are required to be installed with an appropriate slope so that wheelchair users can safely access all areas in the house.
- Passage width or size: the interior environmental design should take into account wheelchair passage width and space requirements for wheelchairs. In addition, each house should have enough storage space and good storage management to ensure that all hallways and passages are free from obstruction to wheelchair users.
- Flooring materials and surfaces: flooring materials should be smooth, non-slip, and rigid enough to support wheelchair mobility. Wooden or tile floor in the house is mostly suitable for wheelchairs. Wheelchair mobility problems usually occur in garden, lawn, and gravel ground outside the house. Therefore, a concrete or tile floor with enough width that is rigid, smooth, non-slip, flat, and free from curbs should be built as part of the garden, while trees can be normally planted in the rest of the garden area, depending on the design and area suitability.

2. Usability: wheelchair users should be able to use all spaces, equipment, and appliances in the house. Thus, the interior environmental design should pay attention to the following elements.

- Proportional design: proportional design is vital to creating interior spaces for wheelchair-users. It enables wheelchair users to use spaces and furniture in an effective way like other people do. Proportional design covers area dimension, wheelchair turning space, appropriate height and depth, and height of furniture and other equipment, which are all essential design aspects that must comply with the required criteria.

- Furniture: furniture for wheelchair users should have a clear knee space beneath. The size and proportion of furniture should meet the required criteria in terms of width, length, and acceptable reach height for wheelchair users. Moreover, the design of furniture should be easy to maintain and easy to use because wheelchair users may not be able to do things like cleaning or maintaining furniture as efficiently as others.

3. Devices and technologies to support wheelchair users

The design of wheelchair-accessible houses is also associated with using technologies and modern devices to enhance convenience and safety of wheelchair users. The use of technological devices and equipment can facilitate daily life of both wheelchair users and people with disabilities in other areas. Although some devices are expensive, they are worthwhile, if they can be used to respond to the needs of users at suitable places in an effective way. Examples of technologies and devices for wheelchair users are handrails, body lifting devices, ramps, lifts, and automatic furniture and equipment that provide convenience to wheelchair users.

Design Criteria for Wheelchair-Accessible Houses

The research results were used to create the criteria for designing wheelchair-accessible houses for disabled people that can be easily and practically applied. The developed design criteria can be applied to actual residential renovation because the collected data reflect that all of the sample areas had similar problems, which can be solved with the same solutions. A house renovation model for wheelchair users was also developed to clearly present the pattern and characteristics of wheelchair-accessible houses. The design criteria for wheelchair-accessible houses can be described as follows.

1. Flooring

A key point for the design of interior space for wheelchair users is flooring. The floor both inside and outside the house should be level, flat, even, smooth, non-slip, and rigid enough for the wheelchair to move around. If the floor has a large difference in level, it is needed to install a ramp. The proportion, material, and installation of the ramp must meet acceptable standards. The slope of the ramp should not be steeper than 1:12 or 4.76 degrees. If there is no wall, a 15-cm-high curb must be built to prevent the wheelchair from slipping over the edge. The handrail alongside the ramp must be 90 cm high and at least 90 cm wide. If the ramp is longer than 6 m, it must be 1.50 m wide and has a resting area with a width of not less than 1.50 m.

The major problem of a two-storey house is transferring wheelchair users from floor to floor, as the slope is too steep to install a ramp. Therefore, in order to solve this problem, the ground floor should be renovated into a bedroom and functional area for wheelchair users. However, if the house does not have enough space or the ground floor area cannot be renovated, it is needed to use aiding equipment, such as wheelchair lift and small passenger lift, which may have a relatively high cost.

2. Pattern and Proportional Design

The design of furniture and functional areas in wheelchair-accessible houses must provide a clear knee space for wheelchair users to insert their legs. The width of the wheelchair and wheelchair mobility space should be taken into account. Furniture for wheelchair users should have a height of not less than 70 cm but not exceed 80 cm. The lower space for inserting the legs should not be less than 70 cm high, 45 cm deep, and 75 cm wide. If the furniture can be used without inserting the legs, it must be at a reachable height of not less than 40 cm and not over 120 cm. General passageways and entrance doors must be at least 90 cm wide. A turning space at corners and other areas should not be less than 120 cm wide. For the wheelchair to turn through 360 degrees, the space required is not less than 150 cm. Furniture and equipment should be placed at the acceptable reach height for wheelchair users. When sitting and leaning forward, the acceptable distance is 90–95 cm from the back of the chair and 120 cm from the floor. The acceptable distance for picking up objects is more than 38 cm from the floor.

3. Interior Space Design

In designing furniture and functional spaces in wheelchair-accessible houses, the five main areas that are important for daily life of wheelchair users are as follows.

(1) Kitchen: things to be considered when designing kitchens for wheelchair users comprise the following.

- The kitchen area should have clear circulation space for the wheelchair to turn around (1.50 m diameter) without bumping against any furniture or equipment in the room.



Figure 8 A model showing the kitchen area

- Kitchen counter should not be more than 90 cm high and 60 cm wide.
- Sink, stove, and cooking counter should have a clear knee space underneath. The knee space must be at least 70 cm high, 45 cm deep, and 75 cm wide. The sink must not be deeper than 17 cm.
- Control panel must be at the side or the front of the stove in order to avoid reaching over the stove while cooking.
- Storage units should be accessible for wheelchair users and should not be higher than 120 cm above the floor.

(2) Bedroom: in designing a bedroom, it is important to provide enough space for the wheelchair to move around. For example, there should be a clear space in front of the wardrobe and on the side of the bed and a

circulation space for the wheelchair to turn around must be provided. Doorway should also have enough space for the wheelchair. Furniture in the bedroom should have clear knee space with suitable height and should be placed within the reach of wheelchair users. The details are as follows.

- A clear circulation space for the wheelchair to turn around (at least 1.50 m diameter) should be provided.
- On either side of the bed, there must be a space for the wheelchair to move through (90 cm) from the foot to the head of the bed in order to facilitate wheelchair users when getting in and out of the bed.
- The height of the bed must be at the same or close to that of the wheelchair in order to facilitate transferring wheelchair users from and to the bed.
- Clothes racks that are out of the reach of wheelchair users should be replaced by foldable racks that wheelchair users can conveniently use.
- In front of the wardrobe, there should be a space of at least 110 cm for the wheelchair to move through. The wardrobe should not be placed in the corner of the room because that area is difficult for the wheelchair to enter. Wheelchair users have the maximum reach height of 120 cm and the minimum reach height of 35 cm.



Figure 9 A model presenting the bedroom area

(3) Bathroom: there are many details in designing a bathroom for wheelchair users. The following elements need to be taken into consideration.

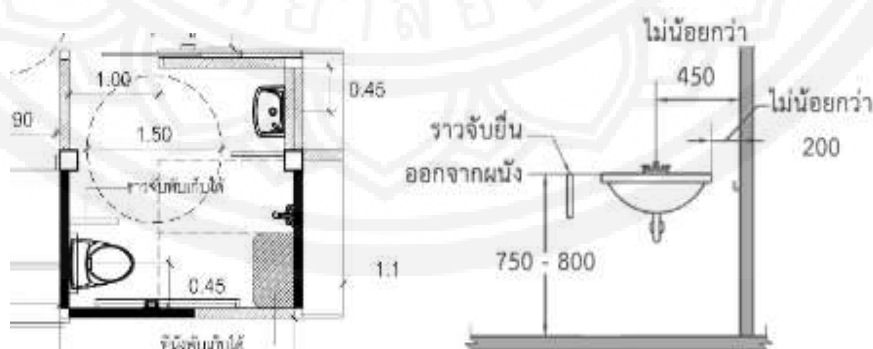


Figure 10 A model showing the bathroom area

- Washbasin should be installed for straight wheelchair approach at a distance of at least 45 cm between the center of the basin and the wall or nearest obstructions. A space of at least 90 cm in front of the basin and a



clear knee space beneath the basin should also be provided. The height of the basin must be 75 cm but not more than 80 cm. The depth of the basin must not more than 17 cm. Handrails should be installed on the walls on both sides at the same height as the top of the basin (75–80 cm).

– Toilet must be placed to allow for sideway transfers from the wheelchair. The center of the toilet must be 45 cm from the wall. The height of the toilet should be 45 cm but not over 50 cm above the floor. There should be horizontal and vertical handrails fitted to the side wall as detailed follows. A horizontal handrail of at least 1 m long must be installed 65–70 cm from the floor and not more than 30 cm from the back wall. A vertical handrail with a length of at least 60 cm must be installed upward from the end of the horizontal handrail. Another vertical handrail with a length of at least 60 cm should be fitted to the back wall at the center of the toilet with a distance of 75–80 cm from the floor. On the other side of the toilet, a foldable handrail should be installed with a minimum space of 55 cm from the wall and 15 cm from the toilet but not more than 20 cm. Toilet paper holder and toilet hose must be installed at a height of at least 55 cm but not more than 120 cm and a distance of 18–23 cm from the front of the toilet.

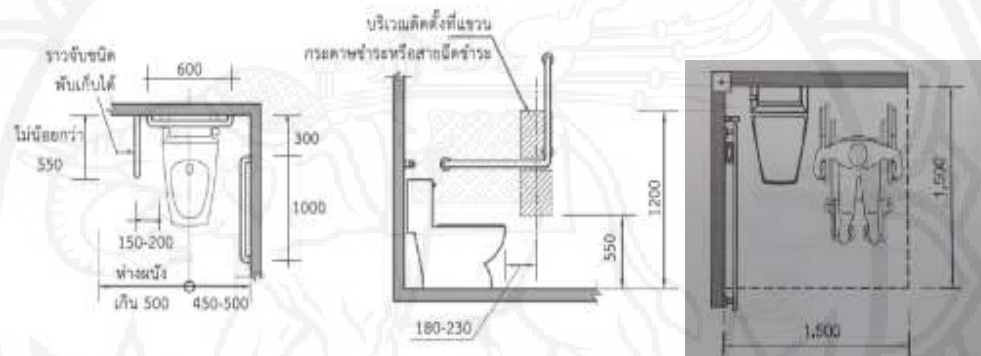


Figure 11 Toilet for wheelchair users (Association of Siamese Architects under Royal Patronage, 2014)

– Shower area must not be less than 75 cm wide and 1.50 m long. It must have a clear front space of at least 75 cm wide and 1.50 m long (1.50 x 1.50 m). If there is a shower seat, it must be foldable, close to a shower tap, and installed at least 45–50 cm above the floor. Shower tap should be positioned above a handrail but not higher than 1.20 m. Shower hose should be at least 1.50 m long. Handrails must be installed on all sides of the walls except where the shower seat is located at a height of at least 80 cm but not more than 90 cm above the floor.

– Bathroom area must have circulation space that is free from obstructions for the wheelchair to turn around (at least 1.50 m diameter). Handrails may be installed on the bathroom walls at a height of at least 80 cm but not more than 90 cm above the floor. The floor should be flat, smooth, dry, and made of non-slip materials.

– Bathroom doors must be sliding doors that can stay open with at least 90 cm wide. The lock should be operable from both inside and outside in case of emergency. Vertical door handles should be positioned on both sides of the door at a height of not less than 80 cm above the floor.

(4) General area: all areas of the house, including corridors, living room, dining room, and others, should be designed to support wheelchair mobility. For example, flat and even flooring and wheelchair turning space should be provided as mentioned above.

- Desks, dining tables, dressing tables, and other kinds of tables must have a minimum height of 70 cm but not more than 80 cm with a clear knee space of not less than 70 cm high, 45 cm deep, and 75 cm wide.
- Low cabinets and floating storage units must be at a height not exceeding the reach of wheelchair users (1.20 m).
- Doors must be at least 90 cm wide. All doors should swing beyond 90 degrees. There should be a clear space of 1.50 x 1.50 m between the opening edge of the door and nearest obstruction.
- Windows should be positioned within the reach of wheelchair users. Window handles and locks must be at least 40 cm above the floor but not more than 120 cm.
- Electrical switches should be placed at a height of not less than 90 cm but not higher than 120 cm. Sockets should be at least 40 cm above the floor but not more than 1 m.
- Strong and stable handrails should be installed at least 80 cm above the floor and not more than 90 cm. If the handrail is round, its diameter must be at least 3 cm but not more than 4 cm. If the handrail is not round, it must be at least 5 cm wide and positioned at least 5 cm from the wall.
- The height of seats, chairs, and sofas in the house must be the same or close to the height of the wheelchair in order to facilitate transferring disabled people from and to the wheelchair. There should be a clear space (at least 90 cm) for sideway transfers from the wheelchair.

Apart from the above design criteria, the researcher also created a model of wheelchair-accessible house in order to make the informants clearly understand all design details during the data collection process. This model shows how to renovate an existing house into a wheelchair-accessible house and also compare the renovated areas with the existing ones. Thus, this model can make interested persons better understand the characteristics of wheelchair-accessible houses.



Figure 12 A layout and renovation model of wheelchair-accessible house



Discussion and Conclusions

According to the survey of the buildings' physical characteristics and the building users' behaviors, activities, problems, and needs, it was found that the design of wheelchair-accessible houses should focus on providing functional spaces to accommodate the needs and activities of wheelchair users in all areas of the building based on the results of this study, which include the following key aspects: easy access, architectural proportion, furniture dimension, pattern design, furniture accessories, installation of wheelchair-friendly technologies and facilities, and special areas for wheelchair users that require a specific design, such as bathroom, bedroom, and kitchen, and outdoor environment. All elements should be designed based on the concept of easy-to-use, convenience, and safety. In addition, the dimension of functional spaces should be designed according to the size of wheelchair users in order to facilitate an easy access to every area in the house and enhance space usage efficiency. It is also important to place emphasis on interior tidiness, adequate storage units, and good storage management both inside and outside the house in order to ensure that there is no obstruction to wheelchair users. These design approaches can solve existing problems in the study areas and respond to the needs, behaviors, and activities of the building users, including both normal and disabled people, and also help to reduce stress and inconvenience. As a good interior environmental design is able to improve the quality of life and mental health of building users, all data obtained from this study can be used to create practical guidelines for interior architectural design and develop detailed designs for the construction of wheelchair-accessible houses.

The results of this research are in line with the literature review in terms of the size and dimension of the wheelchair, wheelchair mobility space, wheelchair accessible space (Association of Siamese Architects under Royal Patronage, 2014; Boonwong & Niamsap, 2002; Office of Rights and Potential Promotion and National Office for Empowerment of Persons with Disability, 2010; Office of Tourism Development, 2009.), wheelchair users' behavior, wheelchair-friendly facilities (Chowsungnearn, 2017), and daily problems of wheelchair users regarding wheelchair access and space usability. (Tinmala, 2011; Wattanakij, 2015; Koisakul, 2015; Kongsaktrakul, 2015). The collected data were analyzed and summarized to create the criteria for designing wheelchair-accessible environment in order to increase space usage efficiency and enhance a better life for wheelchair users. The research results are consistent with the actual needs, behaviors, and activities of building users and, therefore, can be applied to residential adaptation and renovation.

And by comparison with the design requirements for facilities for the disabled of Building & environments design recommendation for all. (The Association of Siamese Architects) with this research found to be consistent for the most part But there are some details that the Association of Siamese Architects has not yet specified or is not clearly stated. This can be added to the application for people with disabilities to make it more convenient. Can be summarized as a table as follows.

**Table1** Comparison with the design requirements for facilities for the disabled of Building & environments design recommendation for all. (The Association of Siamese Architects) and research results

Topic	Building & environments design recommendation for all (Association of Siamese Architects)	Research results
Door	Not specified	The door should be a sliding door, it is most convenient to use. But if it is an open door, it must be able to be held open and the door lock device must not be within reach, i.e. not higher than 1.20 m. And not less than 40 cm.
Toilet	Not specified	<ul style="list-style-type: none"> - The lavatory must have space under the sink. The gap must not be less than 70 cm high and not less than 40 cm deep. - The mirror above the lavatory must not be higher than 1 m. - The toilet bowl must have at least 75 cm of free space on either side for the wheelchair to be mounted on its side. - Installation of the device holder in the shower area must not be higher than 1.20 m.
Kitchen	Not specified	<ul style="list-style-type: none"> - The kitchen counter part used for cooking can insert legs into the under. The space below must not be less than 70 cm high and not less than 45 cm deep. - The drawer at the bottom should not be less than 40 cm. And depth not more than 20 cm. - The floating cabinet above the counter cannot be used conveniently. Should be a floor standing cabinet with a height not higher than 1.20 m.
Bedroom	Not specified	<ul style="list-style-type: none"> - Clothes rail should not be higher than 1.20 m. If there is a high hanger, must be used a device that can be folded down. For easy picking of clothes - The drawer at the bottom should not be less than 40 cm. And depth not more than 20 cm. - The bed height should be at the same level as the wheelchair seat. To facilitate the movement of people with disabilities

In addition to a good physical design, good environment and atmosphere are also vital to building users. Therefore, it is needed to design and create a good internal environment that is conducive to rest and relaxation in order to provide a better quality of life for building users, including both normal people and wheelchair users.

Research recommendations can be divided into four main areas as follows.

(1) Future research should expand the sample population to include more diverse groups other than wheelchair users so that the research results can be applied to a wide variety of projects. Future research should pay attention to the design that is usable by all groups of people or can accommodate multiple user groups.

(2) The present research focuses on interior design only. In order to obtain more comprehensive results, future research should be conducted to study the exterior and landscape design, related work systems, and building structures.

(3) The application of the findings of this study to other design and construction projects should be done with good construction management and supervision in order to ensure the safety of users and promote maximum efficiency.



(4) The design guidelines resulting from this study can be adapted and adjusted to suit the physical disabilities, needs, behaviors, work or usage styles, and activities of each group of users.

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