International Journal of Technology 13(1) 69-79 (2022)
Received September 2020 / Revised December 2020 / Accepted March 2021

International Journal of Technology

http://ijtech.eng.ui.ac.id

House-of-Quality Approach for the Design of a Minibus to Transport Visually Impaired and Wheelchair-bound Passengers

Sugiono Sugiono[1*], Adam Pratomo[1], Willy Satrio N[2]

[1]*Department of Industrial Engineering, Brawijaya University, Malang 65145, Indonesia*
[2]*Department of Mechanical Engineering, Brawijaya University, Malang 65145, Indonesia*

Abstract. In the modern era, machinery designed to assist people should satisfy the requirements of all users, including people with disabilities. This study aims to design an ergonomic vehicle that is comfortable and safe for people with mobility needs (wheelchair-bound passengers) or visual impairment. First, we conducted a literature survey on the definitions of terms such as disability, ergonomic design, house of quality (HOQ), and safe transportation. Next, we gathered anthropometric data of people with mobility needs or visual impairment, and their requirements for safe and comfortable transportation. We used HOQ to capture the voice of consumers and design a suitable technical response to their needs, and utilized computer-aided design (CAD) to convert all the designs into 3-D prototype vehicle models. Based on the needs of people with disabilities and on the results of anthropometric calculations, the vehicle should include a lift wheelchair (15.7%), four folding passenger seats (15%), a handrail dimension (11.4%), and a handle pole (10.4%) for people with visual impairment. This ergonomic vehicle design will result in increased overall user satisfaction.

Keywords: Computer-Aided Design (CAD); Ergonomic transportation; House of quality (HOQ); Mobility of people with disabilities; Wheelchair, infrastructure for people with disabilities

1. Introduction

Ergonomic vehicular design for the disabled can increase accessibility and transportation safety. In addition, it is an indicator of a nation's culture and its respect for human rights. Human health and safety have become a priority for industrial management in the last decade, and this trend is reflected in transportation in Indonesia (Lawalata and Agah, 2011; Sukapto et al., 2019). Moreover, Berawi et al. (2018) noted that infrastructure and regional development, which is closely related to human health and safety, will have a positive impact in terms of economic growth. Infrastructure and regional development correlate closely to each other in helping the economic growth of a nation. In this digital era, people need transportation for improved mobility. Here, "people" includes those with disabilities as well. There are four types of disability: physical disabilities, intellectual disabilities, mental disabilities, and sensory disabilities (blind disabilities, deaf disabilities, and speech disabilities). Also, the number of people with disabilities is not insignificant. According to data from the Ministry of Social Affairs, as of 2010, the total number of people

*Corresponding author's email: sugiono_ub@ub.ac.id, Tel.: +6281234729330, Fax: +62341551430
doi: 10.14716/ijtech.v13i1.4290

with disabilities in Indonesia was approximately 11,580,117 (Halimatussadiah et al., 2017). However, in this country, adequate transportation for people with disabilities is generally insufficient and aspects of the users' safety and comfort are not considered. It is widely accepted that people with disabilities have fewer opportunities and modes of transportation at their disposal, compared to those who are not disabled. This results in the former group of people experiencing a lower quality of safety and comfort in transportation facilities (Parragh, 2011). For people with impaired mobility, either sensory or cognitive, mobility relies on having access to transportation services when they want to travel anywhere and anytime, obtaining information about the services, having the knowledge of how to use them, having the ability to use them, and having the means to pay for them (Suen and Mitchell, 2000).

People with disabilities refers to those who have physical and/or mental disabilities that interfere with and hinder their daily activities. Such people have the right to receive equal treatment from the state and not feel excluded from general society in their own country. This can be achieved by fulfilling their right to access to public facilities, as stated in the ratification of the International Disability Rights Convention, whose mission is to protect, respect, promote, and fulfill the rights of people with disabilities (Bodaghi and Zainab, 2013). There are official technical guidelines for facilities, and accessibility in buildings (Gray et al., 2003; Contents, 2009), with the ultimate aim of: (i) providing equal standing, rights, and meeting obligations to the disabled; and (ii) increasing the societal role of people with disabilities and the elderly. Integrated, inclusive, and sustainable facilities and considerable effort are needed to ultimately help people with disabilities achieve independence and welfare.

Design of specialized vehicles for people with disabilities has been carried out by several institutions or researchers to increase accessibility for the disabled. Dejoux and Armoogum (2010) carried out a survey to analyze the difficulties faced by people with disabilities during travel. Their research mentioned that 8.2% of the disabled passengers faced difficulties when using a car. This study focused on physical disabilities (especially wheelchair users) and sensory disabilities for blind people and those with visual impairment. They considered an easy-to-use car design that would be accessible for various kinds of passengers. According to existing research into car design that includes easy access for wheelchairs, there are several important factors to be considered, for example, the height of the seats, doorway dimensions, distance between the seats, and suitable handholds. Petzäll (1993; 1995) conducted an experimental study to find the appropriate dimensions of a vehicle that was to be used as a taxi for the disabled. Chen and Wong (2014) produced a prototype design of a movable ergonomic seat for elderly and handicapped passengers. The seat had three primary functions, lifting, rotation, and shifting, for assisting the passenger with sitting down or leaving the vehicle. Haslegrave (1991) suggested that access into or out of the vehicle was a major issue for both disabled drivers and passengers. In contrast, there is little research on accessibility for blind people. Generally, individuals with blind disabilities are assisted by guiding blocks, sticks, handles, and layout in braille. Virgili et al. (2018) reported that lamination and high levels of color contrast can aid those with low vision to see objects more clearly.

There are numerous manufacturers trying to incorporate the concept of human comfort for the disabled into vehicle design. For example, Allied Mobility specializes in the design and manufacture of vehicles for the disabled, all of which are fully wheelchair accessible. Toyota, Honda, Mazda, General Motor, Nissan, etc. have made efforts to build vehicles that are fully accessible to wheelchairs and mobility scooters. In order to make a vehicle fully disability friendly, there are many areas that need to be modified, including the layout and other accessories. Most companies use minibuses as the basis for disability-friendly car designs due to the consideration of the limited capacity of people with disabilities that need to be served, such as with services in schools and universities. The research and development in automotive design for disabled passengers is an ongoing process. The primary goals of this research are the optimization of the number of wheelchairs that can be put into a vehicle and the increase of the comfort level of people with mobility needs and/or visual impairment. Vehicle design should be undertaken with a desire to provide safety, and easy and ergonomic access to accommodate both the wheelchair and the disabled person. Anthropometry–ergonomic approach coupled with quality function deployment (QFD) for the design of doors, seats, handles, and layout has emerged as a strong basis on which to provide innovative and comfortable vehicular designs for people with mobility needs and/or visual impairment. QFD is beneficial when creating new products and services, it can also be used to review and improve existing ones (Hartono et al., 2017). QFD has two main features: translating customer or user needs so that the product has the desired quality characteristics (design stage) and describing the identified quality characteristics so that control points in production are maintained (production stage).

2. Methods

Ergonomics is the science that regulates and deepens the relationship between humans (psychology and physiology), machinery and equipment, work environment, organization, and work procedures. It is used to complete tasks correctly, efficiently, comfortably, and safely (Patel and Karmakar, 2014; Wilson, 2014). The size of the human body varies greatly; there are many factors that influence this, such as age, gender, race, and perhaps disability (Wang et al., 2006). Anthropometric data are presented in percentiles by dividing the population into categories, with a total of 100%. The number of people per hundred, who have a specific body size or smaller, is indicated by the percentile statistical value (Panero and Zelnik, 1996).

House of Quality (HOQ) is a framework for design and redesign management known as Quality Function Deployment (QFD). HOQ is particularly effective for achieving innovation in a product (Zhang et al., 2014). Product development is a series of activities that begins with the analysis of market opportunities, and ends with the production, sales, and product delivery stages (Temponi et al., 1999). Product development is defined as a transformation of market opportunities and various assumptions related to product technology that is able to produce products that can be accepted by the market (Krishnan & Ulrich, 2001). According to McKim (2008), product development is an activity performed in driving a product's design in a better direction, so that it can provide greater usefulness and satisfaction. Park et al. (2008) stated that HOQ consists of several steps: consumer needs, planning matrix, technical response, relationship, technical correlations, and technical matrix.

This study has employed a quantitative method for achieving its objective. This is a research method that emphasizes measurement aspects objectively for the needs of ergonomic vehicle design for the target customers. This measurement can be done by dividing the vehicle design into several problem components, variables, and indicators. The variable level of satisfaction is determined and measured by entering the figures obtained from related information. From the data obtained, a calculation can be done to produce a generally accepted set of parameters. The information of user disability needs and objective measurements of anthropometry inputted according to the House of Quality (HOQ) method, worked to find the minibus design with the best accessibility.

The shape and type of vehicle to be designed was a minibus with a wheelbase of 2,650 mm, and a ground clearance of 165 mm. To create a full vehicle design, both primary and secondary data were collected. The primary data were obtained using questionnaires and interviews with 200 people with disabilities. The data consisted of their requirements for the design using the HOQ method and were garnered from physically disabled and visually impaired respondents. The secondary data consisted of vehicle dimensions, wheelchair dimensions, literature studies, and results from previous studies. Observation and measurements were used to ascertain the body dimensions of the 200 respondents. These dimensions were utilized as the basis for the anthropometric calculations. Buhalis and Darcy (2010) categorized disability into persons with permanent disability (20%), age-related considerations (8%), and temporal mobility limitation (e.g., pregnancy). The dimensions of the anthropometric data were then used to design the car layout, seat dimension and position, handrail dimension and position, and handle pole dimension. The dimensions used a set of standard parameters e.g., shoulder width (D17), hip width (D19), etc. Percentile concept was used to find the best option for selecting dimensions according to variety in the respondents' body shape.

Once all the required data were collected, they were processed and analyzed during the next stage. The data processing consisted of several steps, as follows:

1. House of quality (HOQ)
   a. Identifying the consumer needs
   b. Making a planning matrix
   c. Compiling the technical specifications
   d. Determining the relationship between the consumer needs and the technical specifications
   e. Coming up with the technical correlation
   f. Determining the priorities
2. Implementation process
   a. Exploring the disabilities requirements and limitations, e.g., wheelchair size.
   b. Collecting the anthropometry data
   c. Designing 3D CAD model
   d. Prototyping the model
   e. Testing prototype
   f. Evaluating the final product (vehicle)

3. Results and Discussion

This study followed the stages explained in the research methodology. The results consist of the answers to the ergonomic and safe vehicle design requirements for people with disabilities and are in the form of basic concepts of vehicle redesign, based on the results of the HOQ and the final prototype of the desired vehicle. The standard vehicle design was altered to aid accessibility while considering healthy and safe transportation. The initial stage of building the HOQ was to find specific consumer requirements for getting into or out of the vehicle and to create the passengers' space in the vehicle design, especially for those who use wheelchairs or those who are blind. In accordance with the steps set out in the research methodology, the needs of persons with disabilities were then identified. To identify customer needs, we employed an open-questioned interview to respondents with disabilities. The results from the answers to the questions were classified into two sets of data for wheelchair users and those with visual impairment. Various questions were forwarded, such as concerning obstacles that impact mobility in a car, what facilities are needed, etc. Based on the results, it was evident that disabled persons require a proper vehicle design that is accessible, ergonomic, spacious (for physically people with disabilities), simple (for the visually impaired) and safe. The level of importance of each need, on a scale of 1–5, was almost the same value, for example, safety = 4.18, ergonomics = 4.14, and large space = 4.00.

● = Strong = 9
○ = Moderate = 3
Δ = Weak = 1

Voice of Customer	Voice of the Design team	Wheelchair Lift 143 x 107 x 45 cm	1 slot Space for Passenger With Wheelchair	Handrail Length 76,15 cm	Handle Pole Diametre 3,19 cm	4 Foldable Chair for Passengers	A Wheelchair Securement
The vehicle has a good accessibility	3,04	●					
The vehicle is equipped with space for a wheelchair user	3,61	○				●	●
The vehicle is easy to embark for people with disabilities to ride in with a wheelchair	3	●		●			○
The vehicle has a special lane for disabled passengers with wheelchairs	3,79	●		●			○
The vehicle is designed simply	3,04		○			○	
The Vehicle have handrails for visually impaired people	3,79		○		●		○
The Vehicle is easy to operate	3,07	○					●
The Vehicle is safe to use	4,07				○	●	
The Vehicle is equipped with manual instructions for users	3,04	●					●
The vehicle was designed according to the dimensions of the human body	4,14		●		○		●
The vehicle has a large capacity	4	○				○	●
There is safety equipment for passengers with wheelchair disabilities	4,18			○	●		○
Absolute Importance		147,87	57,75	73,65	96,36	90,24	186,6
Relative Importance		22,66%	8,85%	11,29%	14,77%	13,83%	28,60%

Figure 1 House of Quality (HOQ) of the vehicle design

The relationship between the consumer needs and the design in the form of technical responses was created by using the matrix priority method. Each statement on the priority matrix was symbolized by the following relationships: ● = strong (value of 9), ○ = moderate (value of 3), and Δ = weak (value of 1). The technical responses had a strong value, which included a wheelchair lift with dimensions suitable for making the vehicle accessible to the physically disabled. The house of quality is presented in Figure 1. The diameter of the hand grip was in response to the users' stated need for the passenger space to have a hand grip for the blind, as well as other disabilities. Some examples from the priority matrix are that the relationship between the responses to the wheelchair list techniques and the wheelchair dimension is positive, while the relationship between the folding seats and the number of the hand grips is also positive. The relationships between the attributes in the technical response were used as documents in the substitute quality characteristics. The correlations between these attributes were established to identify the extent to which reinforcement or conflict needed to be considered in the design.

Next, we looked at the technical benchmarking, which is a technical comparison made between the expectations of the desired vehicle, and the features and performance of existing vehicles that are currently in use. The Daihatsu Luxio Sloper, as a special vehicle for people with disabilities, was used as a benchmarking product. The benchmarking for this study showed the level of conformity (1–5) of the existing vehicle and transportation products, currently in use, in meeting the expectations of the disabled and the blind, against the technical benchmarks determined by the design team. Based on the calculations of the levels of importance in the HOQ matrix, some of the most important needs were in the attributes of the wheelchair lift (15.7%), wheelchair elevator dimensions (15%), handrail dimensions (11.4%), and hand grips (10.4%).

The next step involved designing comprehensive vehicle details. Here, we collected 200 samples of anthropometric data from people with disabilities in Indonesia. The data were collected from persons with disabilities in the Malang region (students, disability communities e.g., Pertuni and DMI, and workers) between the ages 20-76 years old. The number of respondents were broken into categories: physical disability = 86 (64 wheelchair user, 22 stick user), elderly people = 70, deaf = 48, pregnant mother = 6. According to our statistical analysis, the standard deviation of the 36 anthropometric dimensions was an average variety of 4.30 cm. The smallest standard deviation was D29 (The distance between the two outer sides of the four knuckles of the right hand which are positioned straight and tight) with a value of 0.60 cm, and the largest variant was D34 (The vertical distance from the floor to the center of the cylinder rod which is gripped by the palm of the right hand), which value equals 16.92 cm. These data consisted of the shoulder height in sitting position, elbow height in sitting position, popliteal length, popliteal height, shoulder width, hip width, and forearm length. The research team collected the results of the average anthropometric data of respondents in various percentile sizes that would be used as the measurements of the vehicle design for people with disabilities. Based on the design requirements, the researchers needed to focus on the handrail for the wheelchair handles, the folding seats for the passengers, the wheelchair manual lifts, and a handle pole for the blind and visually impaired. The handrails must be accessible and easy to hold for wheelchair users, while the folding seats have to be of a comfortable size and should be conveniently positioned inside the vehicle. The handle pole shape should be matched with hand dimensions (D28) to increase the comfort and safety conditions for persons with visual impairment. The installation of the handrails, folding seats, and handle pole must accurately meet the criteria as previously explained; namely, the design should be simple, safe, and create a large and easily accessible space. The wheelchair used in determining the design and dimensions is a standard one that is often used by the physically disabled. Figure 2 explains the general dimensions of a wheelchair, such as length, width, and height. It was used to determine the dimensions of the wheelchair space inside the vehicle, to calculate the handrail height for the users based on the wheelchair height, and to calculate the wheelchair lift dimensions later on.

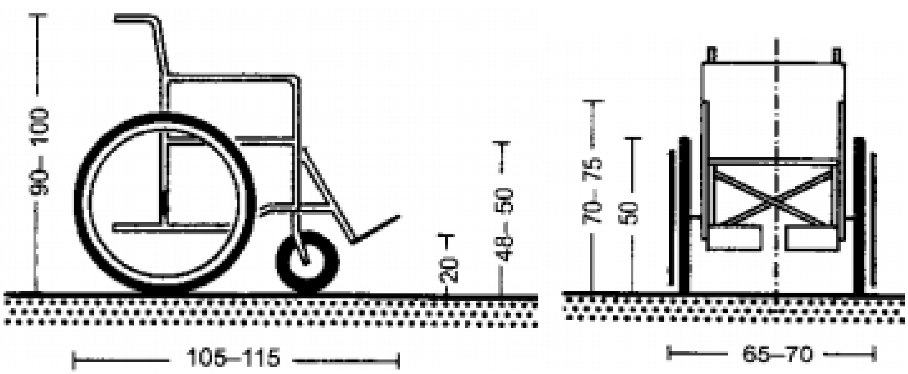


Figure 2 Dimensions of a standard wheelchair used by the disabled (Carrington et al., 2014)

The vehicle design layout was made based on the selected concepts and calculations thereof. We also considered the interior space and wheelchair accessibility. Figures 3a and b show the layout of the folding seats, manual wheelchair lifts, handrails, and handle pole. The recommended vehicle design could have as many as four units of folding seats and could accommodate two wheelchairs, while factoring in considerations of accessibility and ergonomics.

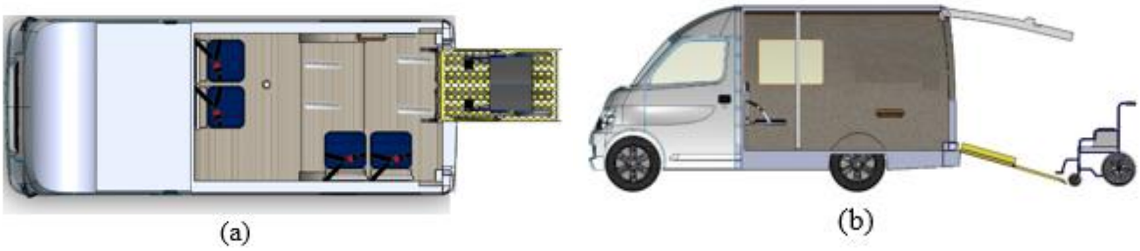


Figure 3 Layout of a disabled passengers' vehicle and its interior: (a) top view; (b) side view

The folding seat was made from the disabled customers' anthropometry. Several measurements of parts of the human body were needed to create an ergonomic folding seat design. They included the dimensions of the shoulder height in the sitting position (D10), popliteal length (D14), popliteal height (D16), shoulder width (D17), and hip width (D19). The percentiles used to determine the size of each body dimension would vary according to the various needs. For example, the hip width dimension (D19) used the upper percentile (95^{th}) so that people with large hips could use it safely and comfortably. On the other hand, the popliteal height dimension (D16) used a lower percentile (5^{th}). Figure 4 is a shop drawing of the folding seat.

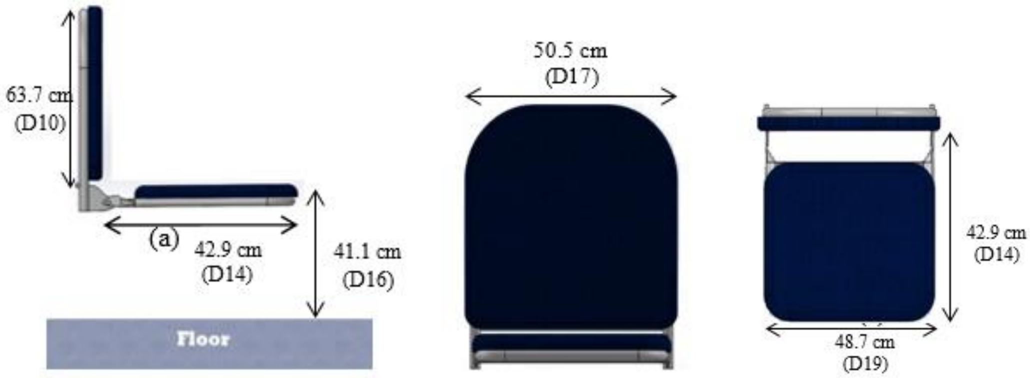


Figure 4 Design of a folding seat for the disabled: side view, front view, and top view

A handle pole was made to meet the needs of blind people; it is a substitute for a blind stick used for holding when the vehicle is moving. For its manufacture, the handle pole only required a maximum hand-held diameter dimension in the hand anthropometry to determine its design and size. From the results of 200 respondents' anthropometry, it was found that the 5^{th} percentile handheld diameter size was 2.61 cm, with a standard deviation (SD) of 1.07 cm. Therefore, the calculation for the handle pole resulted in a 3.11-cm diameter pole, with a 0.5-cm allowance.

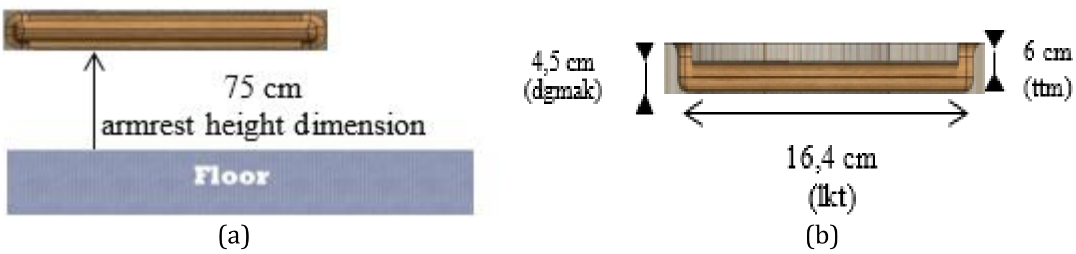
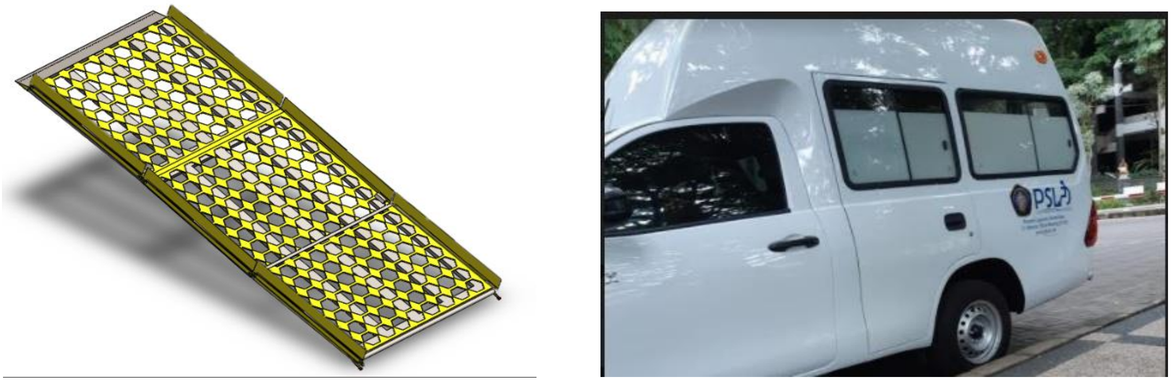


Figure 5 Dimensions of wheelchair users' handrail: (a) front view; (b) top view

Handrails were provided to increase the safety of the disabled passengers using a wheelchair, after getting into the vehicle before fastening the seat belt, or while getting out of the vehicle after removing the seat belt. The handrail design required only a few dimensions determined from the hand anthropometry, such as maximum hand diameter, thickness of the metacarpal hand, and width of the fist. From the results of the 200 respondents' anthropometry, it was found that the hand diameter at the 5^{th} percentile was 2.61 cm, with 1.07 cm SD; the metacarpal hand thickness, at the 95^{th} percentile, was 5.5 cm with 0.91 SD; and the fist-width, at the 95^{th} percentile, was 11.4 cm with 1.39 SD. D11 (elbow height in a sitting position) was also required with the 50^{th} middle percentile, while the armrest height when sitting in the wheelchair was 75 cm. Figure 5 shows the results of the design and positioning of the handrail on the vehicle for the disabled. The handrail length, diameter, and shaft thickness were 16.4, 4.5, and 6 cm, respectively.

The manual wheelchair lift (Figure 6a) was a ladder type to facilitate the wheelchairs and passengers getting into and out of the vehicle using manual power. Manual wheelchair lifts are simpler and cheaper to manufacture than their hydraulic counterparts. There are two aspects to be considered in the manufacture of this lift: safety, and low thrust power. Based on the calculations, it was found that the optimum platform length, width, and side divider were 170, 76, and 7 cm, respectively. To keep the wheelchair users safe, safety equipment, such as a wheel lock and belt were needed, so when the vehicle is in motion, the wheelchair should not move or shift. The surface track was placed at four points near the wheels of the wheelchair. It is used as a hook to fasten the wheelchair seat belt so that the wheelchair is steady when the vehicle is moving. Likewise, the wheelchair users use the seat belt on the wheelchair security system, which is attached to the surface on the upper right side of the vehicle.



(a) (b)

Figure 6 (a) Manual wheelchair lift design; (b) final product after the vehicle's interior design for disabled people was completed

The final product (Figure 6) was tested and used at Brawijaya University track for transporting people with mobility needs and/or visual impairment. The vehicle ran regularly (every 30 min) to help the disabled (mostly students) to attend their classes. During the prototype testing, the wheelchair stabilization was a critical point that needed investigation because the handrail and the seat belt were not adequate to handle the wheelchair. A suitable correction was installed in the form of a wheelchair tire lock, which eliminated the wheelchair displacement and vibration. An android-based application was implemented to allow the passenger to check the schedule and also to reserve the car, this system was named "Enablink". According to testimonies from the users (comprising 78 students), there was a recurring problem for the blind, some of whom had difficulties in finding a chair (±18%). Furthermore, the manual wheelchair lift needed a lot of space and its use proved time consuming as well (11%). The other negative feedback was non-technical, such as the schedule, and driver hospitality. The introduction of layouts for blind people was very helpful in facilitating their boarding. No complaints were received from them with regards to finding seats after they had used the bus more than once.

The design of a vehicle for the target customers started with the gathering of user needs and creating technical responses from the perspective of ergonomics and knowledge of layout. The comfort and design of the safety features developed in this study, such as handrails, wheelchair lifts, seats and handle poles can be implemented in other areas, for example they can be employer in creating more accessible buildings. The posture and body shape of participants in our study maybe specific to Indonesians, and therefore different from that of people from other ethnicities or countries; hence, this represents a potential variant in anthropometry data. Design infrastructure should be complete with provisions for special-needs vehicles like the one in this study, e.g., extra space for manual wheelchair lifts. Also, the attitude and cultural attributes of the driver contribute significantly to understanding the needs of the disabled and can eliminate any non-technical issues. Research by Rakauskas et al. (2009), Zaidel (1992), and Atchley et al. (2014) can be used as a reference for future research in this area.

4. Conclusions

Based on the explanation of the research goals and research results concerning the design of a safe and ergonomic vehicle for disabled people, the conclusions are: (1) There are several needs and wants of people with mobility and visual impairment. Requirements with the highest priority and with large percentage scores in our results are a wheelchair lift (15.7%), the wheelchair lift dimensions (15.0%), handrail dimensions (11.4%), and a handle pole for the blind (10.4%); and (2) The anthropometric data we collated regarding people with mobility needs and people with visual impairment were successfully used to design vehicles for people with disabilities, and to meet the users' need for a more accessible, ergonomic, spacious (for peoples with mobility need), simple (for people with visual impairment) and safe vehicle. The required large interior space can be created using ergonomic folding seats, so it can accommodate two wheelchairs and allows blind people to move and sit freely on the folding seats.

The ergonomic handrail and handle pole can increase the safety level of a vehicle while it is in operation. In the future, the interior (such as the design of the vehicle pedestal, buttons and so on) needs to be developed further so that we can improve passengers' accessibility and sense of security.

References

Atchley, P., Shi, J., Yamamoto, T., 2014. Cultural Foundations of Safety Culture: A Comparison of Traffic Safety Culture in China, Japan and the United States. *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 26(B), pp. 317–325

Berawi, M.A., Nabila, A., Gunawan, Miraj, P., Rahman, H. A., Berawi, A.R.B., 2018. Analysis of Life Cycle Cost and Public-Private Partnership in the Development of Walini City as Technology Park. *International Journal of Technology*, Volume 9(7), pp. 1469–1479

Bodaghi, N.B., Zainab, A.N., 2013. Accessibility and Facilities for the Disabled in Public and University Library Buildings in Iran. *Information Development*, Volume 29(3), pp. 241–250

Buhalis, D., Darcy, S., 2010. Accessible Tourism: Concepts and Issues. *Tourism Planning and Development*, Volume 8(4), pp. 467–468

Carrington, P., Hurst, A., Kane, S.K., 2014. Wearables and Chairables: Inclusive Design of Mobile Input and Output Techniques for Power Wheelchair Users. *In*: Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14, pp. 3103–3112

Chen, Q., Wong, S.F., 2014. Applied Human Factors Engineering in Advanced Vehicle Design for Elder and Handicapped People. *In*: Proceedings of the 24th International Conference on Flexible Automation & Intelligent Manufacturing FAIM 2014

Contents, T.O.F., 2009. *ADA Accessibility Guidelines for Buildings and Facilities (ADAAG)*. Recreation

Dejoux, V., Armoogum, J., 2010. Mobility Barrier for Disabled People. *In*: 12th World Conference on Transport Research

Gray, D.B., Gould, M., Bickenbach, J.E., 2003. Environmental Barriers and Disability. *Journal of Architectural and Planning Research*, Volume 20(1), pp. 29–37

Halimatussadiah, A., Nuryakin, C., Muchtar, P.A., Bella, A., Rizal, H., 2017. Mapping Persons with Disabilities (PWDs) in Indonesia Labor Market. *Economics and Finance in Indonesia*, Volume 6(3), pp. 126–149

Hartono, M., Santoso, A., Prayogo, D.N., 2017. How Kansei Engineering, Kano and QFD can Improve Logistics Services. *International Journal of Technology*, Volume 8(6), pp.1070–1081

Haslegrave, C.M., 1991. Driving for Handicapped People. Disability and Rehabilitation, Volume 13(4), pp. 111–120

Krishnan, V., Ulrich, K.T., 2001. Product Development Decisions: A Review of the Literature. *Management Science*, Volume 47(1), pp. 1-21

Lawalata, G.M., Agah, H.R., 2011. Traffic Conflict Analysis as a Road Safety Diagnostic Tool for Urban Road Facilities. *International Journal of Technology*, Volume 2(2), pp. 112–121

McKim, B., 2008. *Product Development*. *In*: Hartel R.W., Klawitter C.P. (eds) Careers in Food Science: From Undergraduate to Professional, Springer, New York, NY

Panero, J., Zelnik, M., 1996. *Human Dimensión & Interior Space*. A Source Book of Design Reference Standards Publicado por Watson-Guptill Publications, New York. Ediciones G. Gili, S.A. de C.V. México

Park, J., Shin, D., Insun, P., Hyemi, H., 2008. A Product Platform Concept Development Method. *Journal of Engineering Design*, Volume 19(6), pp. 515–532

Parragh, S.N., 2011. Introducing Heterogeneous Users and Vehicles into Models and Algorithms for the Dial-A-Ride Problem. *Transportation Research Part C: Emerging Technologies*, Volume 19(5), pp. 912–930

Patel, T., Karmakar, S., 2014. Introduction to Ergonomics. *International Journal of Industrial Ergonomics*, Volume 44(6), pp. 892–893

Petzäll, J., Chalmers University of Technology, S., 1993. Design for Accessibility - The Development of Public Transport Vehicles with Regard to Mobility Impaired Passengers. CHT Rapport

Petzäll, J., 1995. The Design of Entrances of Taxis for Elderly and Disabled Passengers. An Experimental Study. *Applied Ergonomics*, Volume 26(5), pp. 343–352

Rakauskas, M.E., Ward, N.J., Gerberich, S.G., 2009. Identification of Differences between Rural and Urban Safety Cultures. *Accident Analysis and Prevention*, Volume 41(5), pp. 931–937

Suen, S., Mitchell, C., 2000. *Accessible Transportation and Mobility*. Transportation in the

New Millennium.

Sukapto, P., Octavia, J.R., Pundarikasutra, P.A.D., Ariningsih, P.K., Susanto, S., 2019. Improving Occupational Health and Safety and in the Home-Based Footwear Industry through Implementation of ILO-PATRIS, NOSACQ-50 and Participatory Ergonomics: A Case Study. *International Journal of Technology*, Volume 10(5), pp. 908–917

Temponi, C., Yen, J., Tiao, W.A., 1999. House of Quality: A Fuzzy Logic-Based Requirements Analysis. *European Journal of Operational Research*, Volume 117(2), pp. 340–354

Virgili, G., Acosta, R., Bentley, S.A., Giacomelli, G., Allcock, C., Evans, J.R., 2018. Reading Aids for Adults with Low Vision. Cochrane Database of Systematic Reviews, Volume 12

Wang, J., Thornton, J.C., Kolesnik, S., Pierson, R.N., 2006. Anthropometry in Body Composition: An Overview. *Annals of the New York Academy of Sciences*, Volume 904(1), pp. 317–324

Wilson, J.R., 2014. Fundamentals of Systems Ergonomics/Human Factors. *Applied Ergonomics*, Volume 45(1), pp. 5–13

Zaidel, D.M., 1992. A Modeling Perspective on the Culture of Driving. *Accident Analysis and Prevention*, Volume 24(6), pp. 585–597

Zhang, F., Yang, M., Liu, W., 2014. Using Integrated Quality Function Deployment and Theory of Innovation Problem Solving Approach for Ergonomic Product Design. *Computers and Industrial Engineering*, Volume 76, pp. 60–74