Literature Review and primary design on Ergonomic Handgrip for Public Transportation

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Abstract

Private vehicles are a popular alternative to public transportation in Bangladesh for those who can afford them. During rush hour, it leads to significant delays. Handgrips that are both secure and comfortable can make a huge difference in whether or not your time spent riding public transportation is pleasant.

This study was undertaken to find solutions to the problems of passenger discomfort and hand fatigue on public transportation systems in the country. Research on ergonomic principles and hand anatomy is incorporated into the design process alongside an examination of the existing hand grips in use on public transportation vehicles in Bangladesh. The design was optimized and the functionality was guaranteed with the help of computer-aided design and simulation tools. Despite the availability of various designs, not one of them has taken into account Bangladeshi anthropometrics. The application of ergonomic principles to Bangladeshi anthropometric data is the focus of this research. This study's ergonomic hand grip was developed to meet the needs of commuters in Bangladesh and is adaptable for use in the country's public transportation network.

Keywords
Ergonomic, Handgrip, Congestion and Polyvinyl chloride.

1. Introduction
One definition of the phenomenon that is known as congestion is an oversupply of vehicles that causes the available road system to become overwhelmed and, as a result, unable to meet the demand in terms of space. This is one cause of congestion. Because there are so many vehicles on the road at any given time, one more way to look at this phenomenon is as a competition between the vehicles for the limited amount of time that is available. Because of this, they tend to hold each other back and make the situation more difficult.

As a direct consequence of the rise in the number of vehicles on the road in Bangladesh, traffic congestion has developed into a widespread issue in recent years. The lines in the congestion are typically quite long, especially during the times of day when there is the most foot traffic. When this time rolls around, the buses are packed to capacity with passengers, and there is frequently nothing for them to grab onto in many of the buses. The most important factor that has led to an increase in traffic congestion is the growing number of people who drive their own cars. In addition, in order to reduce the number of times that private automobiles are used, the number of options for public transportation should be increased, and an analysis of the convenience that is provided by each form of transportation should be carried out.

In addition, there is the possibility of increasing the number of seats that are available in order to accommodate passengers during peak travel times. However, there is a restriction on space within the vehicles used for public transportation; consequently, it is not always possible to find space for seats; consequently, handgrips will be the best solution for those instances in which they are required. Those passengers who are standing because there are no seats available are given something called a handgrip. However, it has been observed that 66.7% of users are only ever able to use a handgrip on occasion, 23.3% of users are never able to use a handgrip, and only 10.7% of users always get to use a handgrip. The majority of users are unable to use a handgrip at all. Because of this, ultimately 52.4% of the users

depend on standing near the door, 25.3% of the users try to grip onto other passenger's handgrips, and 22.3% of the users stand without holding onto anything at all. Therefore, ergonomic handgrips may play a significant part in the solution to these issues.

1.1 Objectives

Our goal is to make sure everyone is safe, make sure everyone is comfortable, and cut down on congestion. The development of an ergonomic handgrip makes it possible to accomplish these goals. In order for us to be successful in achieving these objectives, we ensured that we took into account the wide range of ages, heights, levels of mobility, and statures that are present in Bangladesh. And in the event that these objectives are not met, the passengers may become aggravated, particularly if the existing handgrips are not comfortable enough to be held for an abnormally extended period of time. In addition to circumstances in which two people are sharing a grip, touching the hand of another person can be stressful and unhealthy due to the fact that it spreads germs. Touching the hand of a stranger can also spread germs. Handgrips that are hung at a height that is not appropriate can contribute to a wide variety of musculoskeletal issues. In addition to this, there is a significant increase in the risk of falling if there is nothing to grab onto while standing. When the public transportation units suddenly start moving or stop, there is a greater chance of falling from the elevated platform. There is a high likelihood that you will suffer from health issues or numbness as a result of this. People who travel a lot show visible signs of stress in their bodies, the most prominent of which is tension in their arms. As a direct result of this, there are some people who come to the conclusion that the most suitable alternative for them is to make use of their own personal transportation rather than the public transportation that is available. In addition, the implementation of a handgrip that was designed keeping ergonomics in mind is a step in the direction of accomplishing the objective of ensuring adequate facilities in Bangladesh's public transportation systems.

2. Literature Review

The issue of traffic congestion is currently regarded as one of the most challenging and difficult challenges facing city administration in Bangladesh. It is a situation that can be found in virtually all of Bangladesh's cities and is extremely common. The situation with traffic congestion in Bangladesh is currently deteriorating at a startlingly rapid rate. The traffic situation in the cities of Bangladesh has reached a worrying level, which has already caused a great deal of anguish there. (Shamsher et al. 2013). According to Javid et al. (2016), the current surge in travel demand is putting a strain on the public transportation system, which is having trouble keeping up with the demand. Because there are not enough transportation options, 23 percent of people are forced to give up their opportunities for employment (Campion et al. 2003). People with disabilities are an essential part of any community; however, they are frequently ignored during the planning and construction of infrastructure in a variety of countries around the world (Abidi and Sharma 2014).

Concerns regarding accessibility in public transportation are among the most frequently encountered obstacles for people who have disabilities (Kett et al. 2020). According to Almada and Renner (2015), the most significant problem with public transportation was an inadequate number of workers who had received adequate training to assist people with disabilities, including wheelchair users. Certain train stations were not accessible to people with disabilities as a result of poor planning, layout, and maintenance (Isa et al. 2016). According to Harbering and Schlüter's research from 2020, a significantly higher percentage of women than men use the public transportation system of the city. According to research conducted by Iccha Indriyani and Taufik Roni Sahroni (2018), the high-range of the handle on the carriage that is used by women needs to be lowered. Inadequate ergonomic conditions in transport have been found to have a significant correlation with musculoskeletal disorders (Vytautas Obelenis 2013).

It has been determined that there are factors that may put a person at risk for skeletal muscle problems in the neck, shoulders, and upper back (Escalona, Evelin 2002). The expansion of the economy can be helped along by investments made in various modes of transport (Ambe J. Njoh 2000). The concept of sustainability needs to be applied to the expansion of the economy as well as the transportation sector 12. (Algirdas Jurkauskas 2005). Because of the insufficient height of the handgrips on public transportation, passengers must stretch their hands, which increases the risk of falling. Methodologies developed by Ulrich and Schnarch can be applied in order to locate a solution (Juan Camilo Conto-Campis et al. 2019). There is a direct correlation between the user's height and the amount of force required to turn a handle of a specific diameter.

The diameter of 3.8 centimeters is the most practical size for the grip (Katharyn A. Grant et al. 1992).

There are differences in the posture, height, and weight of the passenger, as well as a reduction in muscle strength, and the passenger grips the Grips with their thumb and ring finger rather than their index and ring finger (Eruo Uetake et al. 2006). Both grip strength and normal force are 46% higher for men than they are for women, and force is 2.3 times higher than divided cylinder grip strength. Grip strength is also 46% higher for men than it is for divided cylinders (Na Jin Seo et al. 2008). The results of HGS in females are dramatically impacted by the level of adiposity, and the HGS of pregnant women is significantly lower than that of non-pregnant women (Chidozie Emmanuel Mbada et al. 2015). The application of force incorrectly can cause musculoskeletal trauma, and the maximum velocity of contraction (MVC) is not proportional to grip diameter (Kun-Hsi Liao 2014). The electromyography technique is one that can be utilized for the purpose of determining the extent to which the muscles of the forearm have become fatigued. The diameter of the handle, which measures in at 1.5 inches, makes it an excellent choice for gripping (M. M. Ayoub & P. LO Presti 2007).

The application of scientific principles to improve a person's health, safety, and quality of life is known as ergonomics. The design characteristics of an object that derive the majority of their origin from the application of ergonomic science. The term "handgrip" refers to any implement that the hand can grasp. In the context of this study, "handgrip" refers to the support that commuters hold onto while they are on the move. (Westgaard et al. 1997).

The relationship that man has with the hand tools at his disposal has an immediate bearing on the health and safety of the workplace. Ergonomy, anthropometry, and any other relevant disciplines must be used in order to maximize the effectiveness of this connection. When defining the criteria for the most effective tool design, it is necessary to take into account a number of ergonomic concepts. Some of these include anatomical, physical, and anthropometric considerations. (Tichauer et al. 1977).

3. Methods

First, in order to design an ergonomic handgrip, the fundamentals of gripping and design had to be taken into consideration (Allen Marias et al. n.d.; Haslegrave & Holmes 1994; Skepper et al. 2000). The phase known as pre-design consisted of a few different steps. As an example,

1. Outlining the issue at hand the issue at hand was to improve the existing gripping system using ergonomic measurement. There is not a facility that is friendly to users in public transportation, such as buses and trains. The purpose of this project is to design a grip that not only provides comfort but also facilitates easy access and makes travel more enjoyable.
2. Determining Who the User Is The user demographic encompasses all of the passengers of public transportation who frequently have to stand for longer periods of time. The age range goes from 14 all the way up to 60. When it came to the design, a gender-blind approach was taken.
3. Define what the anthropometric data are: Anthropometry is the method of measuring a person's size, shape, and functional capacities using physical methods. In order to design the system, we needed specific data from Bangladesh. The information was extracted from previously published works. (Asadujjaman et al. 2019; Talapatra & Mohsin, n.d.). These types of documents provide information regarding typical sizing in addition to information regarding the allowable force for particular hand measurements and general styles of grip. During the process of designing, the average and standard deviation of all the published works were calculated. The values for the design dimensions were decided upon based on the 95th percentile.
4. Determining the structure of the grip architecture: The various options for grips always involve power and precise trade-offs. For power to be generated, the greater forearm muscles need to be utilized.
1. For precision, the minuscule finger muscles have to be brought under control. Taking into account the fingers that are required to operate controls and keep the product steady, in addition to finding the ideal combination of strength and precision. When thinking about this particular case, a spherical case was taken into consideration. The spherical grip is utilized whenever it is necessary to curl the fingers in order to grasp an object that is circular.
5. Choice of material the results of the simulation will have a significant impact on the choice of material.
2. In order to find a material that is suitable for the grip, several simulations are currently being run.
3. Hardness of the material is directly proportional to both grip security and reduced fatigue (durometer). The durometer is recognized as the gold standard for measuring the degree of abrasiveness in nonmetallic materials such as rubber, plastic, and other similar substances. It is determined by the quantity of the material that has been dented 16 after being subjected to a particular force for a particular amount of time.

4. Through careful application of soft-touch materials using over holding, it is possible to reduce the amount of grip strength and contact pressure that is required. Furthermore, these materials have the ability to absorb impact and to dampen vibrations. Simulations are going to be used in order to measure up to these benchmarks.
5. Testing of the prototype the validation of the design is essential for reducing the overall risk of the program. It is imperative that user-centric validation sessions use prototypes that look and feel as realistic as possible. In addition to assisting in the validation of the shape and functionality of the proposed design, they help to find minor errors or usability problems that might not have been noticeable with existing products. In order to create a prototype, we are going to use 3-D printing.
6. The process of validating the design the primary goal of verification and validation is to ensure that the final product complies with design specifications. Reduce the possibility of product failure and errors occurring. Validation will consist of testing out the fabricated model and comparing its results to models that already exist. After going through each of the models, the inputs from the users will be collected. Validation will be performed with the help of the comparison data.

4. Data Collection

Anthropometric data was acquired from the published works. (Asadujjaman et al. 2019; Talapatra and Mohsin n.d.) Figure 1 shows the main considerations were Palm length to middle finger length, hand breadth, finger lengths, hand length. The dimensions were taken in consideration to determine the dimension of the length, width, diameter of the grip. The Bangladeshi population are the main focus of the study. Thus, only recent published works of this geography were taken in consideration. Model Validation

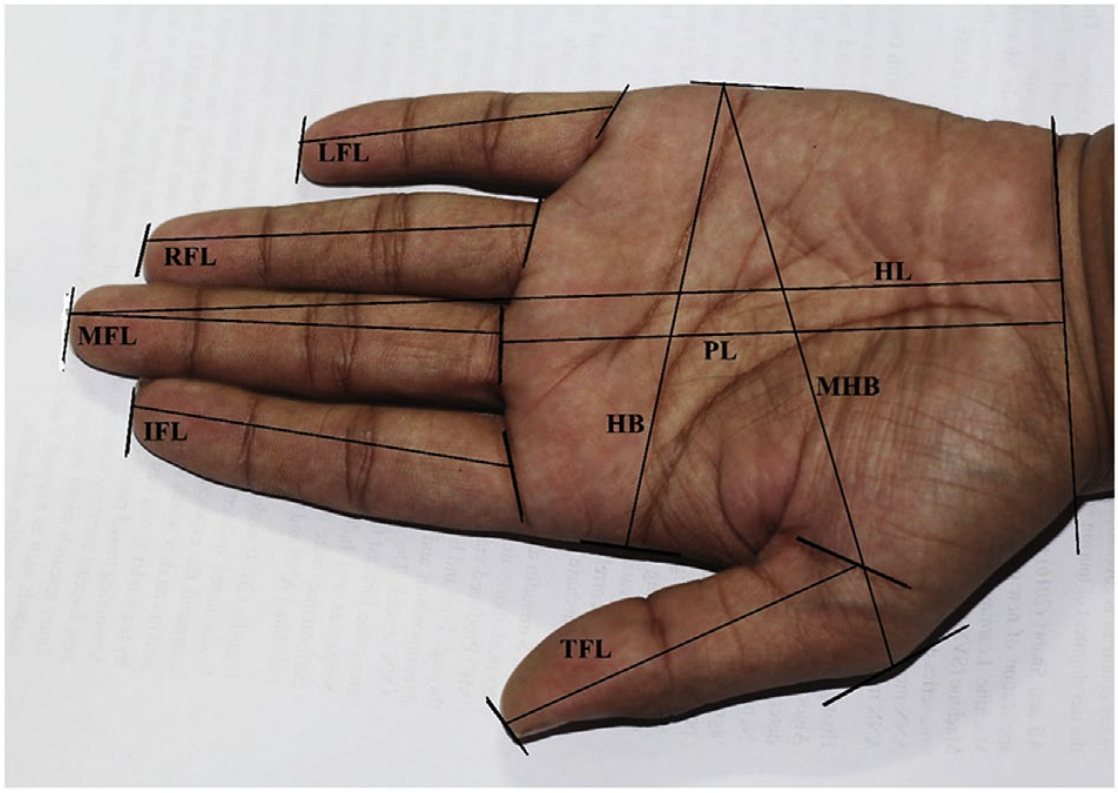

Figure 1. Hand anthropometric measurements. HL: Hand Length, HB: Hand Breadth, MHB: Maximum Hand Breadth, PL: Palm Length, TFL: Thumb Length, IFL: Index Finger Length, MFL: Middle Finger Length, RFL: Ring Finger Length and LFL: Little Finger Length.
(Figure taken from :(Asadujjaman et al. 2019))

5. Results and Discussion

5.1 Results: Figure 2, illustrates the proposed design based on the anthropometric data. Solidworks was used to model the grip. The dimensions are set to have a comfortable and firm grip. 3D modeling was done post the design.

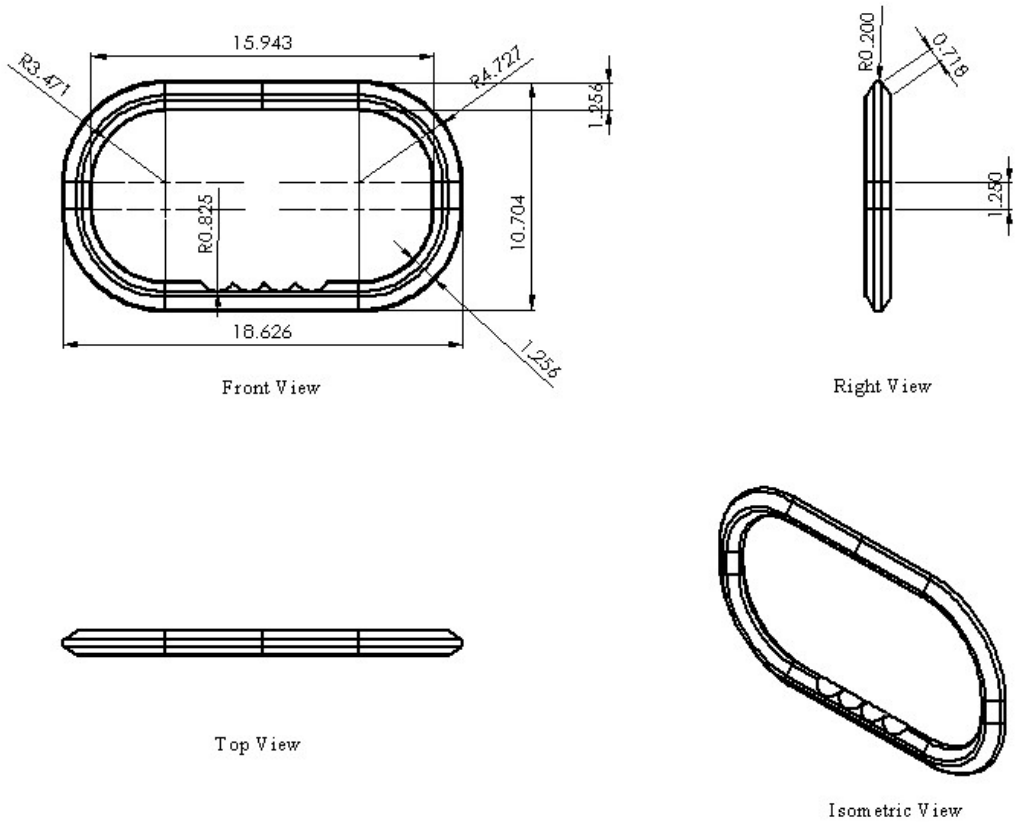

Figure 2. Design of ergonomically optimized hand grip

Simulation are being carried out to obtain a suitable material for the handgrip. Strength, buckling, FOS, resilience, durability are taken in consideration while running the simulations. Current results are not conclusive to comment on the suitable material. Further simulation is to be performed. Figure 3, Simulation samples Figure 3, illustrates the buckling and deformation under external load. The loads act as the weight of the passengers. The three different materials used in the above experiments are PVC, silicon, and rubber. It's still inconclusive to comment but PVC shows better with the 22 current results in hand.

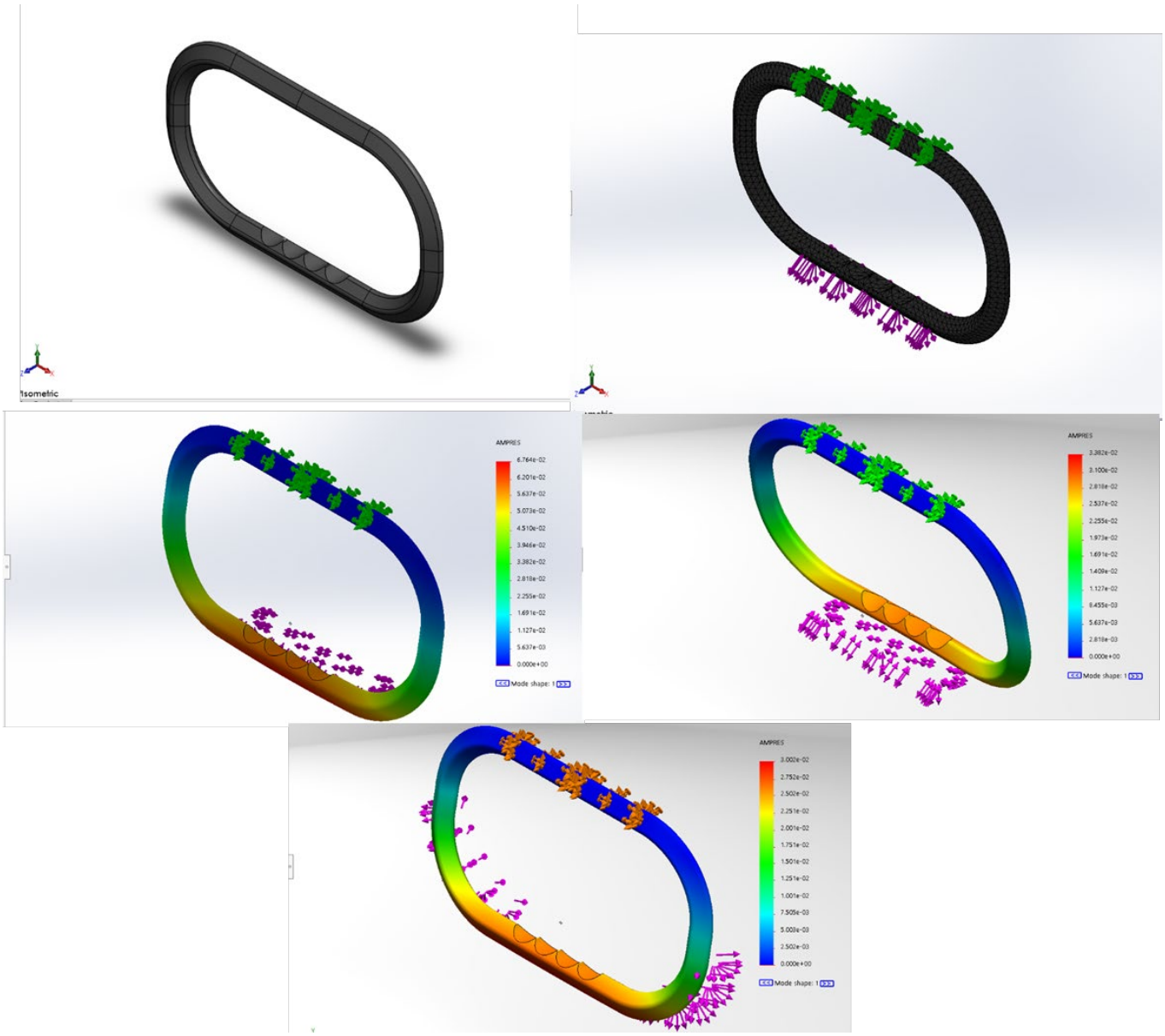

Figure 3. Simulation Samples

Figure 5 illustrates the buckling and deformation under external load. The loads act as the weight of the passengers. The three different materials used in the above experiments are PVC, silicon, and rubber. Its still inconclusive to comment but PVC shows better with the current results in hand.

5.2 Discussion

The handgrip is a fundamental component of every transport. The fact that Bangladesh does not have a similar requirement served as a driving force behind the decision to conduct this study. The optimization of the design has been finished by this point in the project, which is roughly halfway done. It has been suggested that the model be ergonomically optimized. The simulations have not yet been finished running. The fabrication process has not yet been completed. For the typical passenger who is traveling during rush hour, there is a chance that they will be unable

to make use of amenities such as seats or handgrips. Consequently, in order to achieve the required capacity, an expansion of the handgrip facility is required.

6. Conclusion

According to the findings of this study, the handgrip is one of the most important tools and components of public transportation.

In this case, our goal was to design and produce a handgrip that is ergonomically safe in order to provide the highest possible level of comfort and safety for the passengers and to prevent unintended injuries. Because we have not yet completed the project in its entirety, we are unable to comment on how the handgrip will turn out in the end. PVC, silicon, and rubber are the three primary materials that we have investigated, and our findings indicate that PVC is the material that is most suited to carrying the load of the passenger's hand. Several distinct types of simulation processes, such as strength, buckling, FOS, resilience, and durability, were carried out, and the results of these simulations are presented in the methodology section. Because the people of Bangladesh are the subject of this investigation, the simulation was carried out with that population in mind, and the results showed that PVC has the potential to offer the best holding strength to Bangladeshi people. To this point, we have determined that the grip should have dimensions of 18.626 inches in width, 10.704 inches in height, and 1.256 inches in diameter. The palm of your hand should be used for the push, and your thumb should be used to carry the stresses. This will provide the most comfort while one is holding the grip.

In order to carry out the study, a variety of considerations were made. In spite of the fact that we didn't take into account certain factors like the height of the passenger, their age, or whether or not they had a strong hand, understanding the results of such factors could provide additional insights for the implementation of the model that was designed for this study.

In order to acquire an enhanced model of the handgrip, additional research into this topic will be carried out. In the final stage of this project, after the final working procedure has been completed and the user feedback has been compiled, we will include all of the final outcomes and an analysis of them. Because the scopes and sources of this area of study are extremely limited, the findings of this study may one day be put to use in the development of mass transportation grips that are better suited to their purposes and offer greater levels of comfort.

References

Abidi, J., and Sharma, D., Poverty, disability, and employment: Global perspectives from the National Centre for Promotion of Employment for Disabled People. *Career Development and Transition for Exceptional Individuals*, vol. 37, no. 1, pp. 60-68, 2014.

Ali, H., & Abdullah, M., Exploring the perceptions about public transport and developing a mode choice model for educated disabled people in a developing country. *Case Studies on Transport Policy*, vol. 11, no. 100937, 2023.

Almada, J. F., & Renner, J. S., Public transport accessibility for wheelchair users: A perspective from macro-ergonomic design. *Work*, vol. 50, no. 4, pp. 531-541, 2015

Asadujjaman, M., Molla, M. B. A., & Al Noman, S. N., Stature estimation from hand anthropometric measurements in Bangladeshi population. *Journal of forensic and legal medicine*, vol. 65, pp. 86-91, 2019.

Ayoub, M. M., & Presti, P. L., The determination of an optimum size cylindrical handle by use of electromyography. *Ergonomics*, vol. 14, no. 4, pp. 509-518, 1971.

Bhise, V. D., *Ergonom icsin the autom otive design process*. CRC Press, Boca Raton, 2011.

Conto-Campis, J. C., Ortiz-Guzmán, J. M., Castiblanco-Jiménez, I. A., and Ortiz-Guzmán, J. E. (2019). Development of a grip and support system for public transport. *Visión electrónica*, vol. 13, no. 2, pp. 247-253, 2019.

Escalona, E., Yonusg, M., González, R., Chatigny, C., and Seifert, A., La ergonomía como herramienta para trabajadoras y trabajadores. *Ediciones Rectorado. Universidad de Carabobo. Valencia: Ed. TATUNC CA*, 2002.

Grant, K. A., Habes, D. J., & Steward, L. L., An analysis of handle designs for reducing manual effort: the influence of grip diameter. *International Journal of Industrial Ergonomics*, vol. 10, no. 3, pp. 199-206, 1992.

Harbering, M., & Schlüter, J., Determinants of transport mode choice in metropolitan areas the case of the metropolitan area of the Valley of Mexico. Journal of Transport Geography, vol. 87, no. 102766, 2020.

Indriyani, I., & Sahroni, T. R., Design analysis of an Ergonomic Handgrip Facility for Transjakarta. In *Proceedings of the International Conference on Industrial Engineering and Operations Management*, pp. 2635-2640, 2018.

Isa, H.M., Zanol, H., Alauddin, K., Nawi, M.H., Provisions of disabled facilities at the Malaysian public transport stations. In: MATEC Web of Conferences, vol. 66, EDP Sciences, pp. 00016, 2016.

Javid, M. A., Okamura, T., Nakamura, F., Tanaka, S., and Wang, R., People's behavioral intentions towards public transport in Lahore: Role of situational constraints, mobility restrictions and incentives. *KSCE Journal of Civil Engineering*, vol. 2*0*, no. 1, pp. 401-410, 2016.

Jurkauskas, A., Micevičiene, D., and Prunskienë, J., The main principles of modelling the interaction between transport infrastructure development and economy. *Transport*, vol. 20, no. 3, pp. 117-122, 2005.

Kett, M., Cole, E., & Turner, J., Disability, mobility and transport in low-and middle-income countries: a thematic review. *Sustainability*, vol. 12, no. 2, pp. 589, 2020.

Krahn, G. L., WHO World Report on Disability: a review. *Disability and health journal*, vol. 4, no. 3, pp. 141-142, 2011.

Liao, K. H., Experimental study on gender differences in hands and sequence of force application on grip and hand-grip control. *International journal of occupational safety and ergonomics*, vol. 20, no. 1, pp. 77-90, 2014.

Liao, K. H., Optimal handle grip span for maximum hand grip strength and accurate grip control strength exertion according to individual hand size. *Journal of Osteoporosis and Physical Activity*, 1-6, 2016.

Mariñas, K. A., Robielos, R. A., and Jou, Y. T. Analysis of Handgrip Strength and Anthropometric Measurements of Manufacturing Workers in the Philippines.

Márquez, M. A., Garcia, J. M., and Venezuela, S. C. T. (2004). Ergonomics of urban public passangers transportation, *9th*, *23*, 2004.

Milosevic, N. Problem of Organized Transport for Employees with Physical Disabilities in the Republic of Serbia. *Person Responsible for the Publisher..... Darko Uremović*, 29.

Njoh, A. J., Transportation infrastructure and economic development in sub-Saharan Africa. *Public Works Management & Policy*, vol. 4, no. 4, pp. 286-296, 2000.

Obelenis, V., Gedgaudienė, D., & Vasilavičius, P., Working conditions and health of the employees of public bus and trolleybus transport in Lithuania. *Medicina*, vol. 39, no. 11, pp. 1103-1109, 2003.

Pronk, C. N. A., Measuring hand-grip force, using a new application of strain gauges, 1981.

Seo, N. J., & Armstrong, T. J., Investigation of grip force, normal force, contact area, hand size, and handle size for cylindrical handles. *Human Factors*, vol. 50, no. 5, pp. 734-744, 2008.

Shamsher, R., & Abdullah, M. N., Traffic congestion in Bangladesh-causes and solutions: a study of Chittagong metropolitan city. *Asian Business Review*, vol. *2*, no. 1, pp. 13-18, 2013.

Skepper, N., Straker, L., and Pollock, C., A case study of the use of ergonomics information in a heavy engineering design process. *International Journal of Industrial Ergonomics*, vol. *26*, no. 3, pp. 425-435, 2000.

Tichauer, E. R., & Gage, H., Ergonomic principles basic to hand tool design. *American Industrial Hygiene Association Journal*, vol. *38*, no. 11, pp. 622-634, 1977.

Uetake, T., & Shimoda, M., Experimental study on the grip and hold strength for stanchions and handrails in buses. *Journal of human ergology*, vol. 35, no. 1-2, pp. 11-19, 2006.

Westgaard, R. H., & Winkel, J., Ergonomic intervention research for improved musculoskeletal health: a critical review. *International journal of industrial ergonomics*, vol. 20, no. 6, pp. 463-500, 1997.

Yulianti, F., Ravenska, K., Laurensia, J., Gozali, L., Kosasih, W., Doaly, C. O., and Tanujaya, A. P. I. H. Business Feasibility Analysis: Multifunction Bus HandGrip.

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