DESIGN, SIMULATION AND FABRICATION OF AN ERGONOMIC HANDGRIP FOR PUBLIC TRANSPORT IN BANGLADESH

Submitted By

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Supervised By

Dr. A R M Harunur Rashid

A Thesis submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Mechanical Engineering

Department of Mechanical and Production Engineering (MPE)

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Candidate's Declaration

This is to certify that the work presented in this thesis, titled, "Design, simulation and manufacture of an ergonomic handgrip for public transports in Bangladesh", is the outcome of the investigation and research carried out by me under the supervision of Dr. A. R. M. Harunur Rashid, Professor, IUT. It is also declared that neither this thesis nor any part of it has been submitted elsewhere for the award of any degree or diploma.

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RECOMMENDATION OF THE BOARD OF SUPERVISORS

The thesis titled "DESIGN, SIMULATION AND FABRICATION OF AN ERGONOMIC HANDGRIP FOR PUBLIC TRANSPORT IN BANGLADESH" submitted by AFRIDA KABIR, 180011226; FAIYAJ KABIR, 180011142; SAIEF NEWAZ CHOWDHURY, 18001119 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of B Sc. in Mechanical Engineering on **19th May, 2023.**

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Afrida Kabir

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Abstract

Many people in Bangladesh who could afford use private vehicles to avoid uncomfortable ride on public vehicles. It causes a huge congestion during the rush hours. To ensure a pleasant journey in public transportation, safe and comfortable handgrips can be a vital thing. This research aims to address the issues of discomfort and hand fatigue experienced by commuters while using public transport in the country. The design process includes an analysis of the current hand grips used in public transport in Bangladesh, as well as research on ergonomic principles and hand anatomy. Computer-aided design and simulation tools were used to optimize the design and ensure its functionality. There are a few designs available but none of them used the local anthropometric data of Bangladesh. This study focuses on using of Bangladeshi anthropometric values with ergonomic principals. The ergonomic hand grip designed in this study addresses the specific needs of commuters in Bangladesh, and can be easily implemented in the public transport system.

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Nomenclatures

Abbreviation	Meaning
HGS	Hand grip strength
PWD	People with disabilities
MVC	Maximum velocity of contraction
PVC	Polyvinyl chloride
HL	Hand Length
HB	Hand Breadth
MHB	Maximum Hand Breadth
TFL	Thumb Finger Length
IFL	Index Finger Length
MFL	Middle Finger Length
RFL	Ring Finger Length
PL	Palm Length
TL	Thumb Length

Chapter 1: Introduction

This chapter describes the background, scope and objectives of our project.

1.1 Background: The 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 is one definition of the phenomenon known as congestion. One additional interpretation of this phenomenon is that, because so many vehicles use the road network, they compete with one another for available time. As a consequence of this, they mutually slow one another down. Congestion has become a common problem on the roadways of Bangladesh as a direct result of the increased number of vehicles. The queues in the congestion are typically quite long, particularly during the busy periods. When this time comes around, the buses are completely full of people and frequently there is nothing for them to hold onto. The rise in the number of people driving their own cars is the primary contributor to traffic congestion. And in order to cut down on the use of private vehicles, the number of public transportation options should be expanded, and the convenience offered by each mode of transportation should be evaluated. Additionally, the number of available seats could be increased in order to accommodate passengers during rush hours. However, there is a limitation on space within the public transportation units; as a result, it is not always possible to find space for seats; therefore, handgrips will be the best solution for those instances. Passengers who are unable to get seats are provided with a tool 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. Therefore, ultimately 52.4% of the users rely 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. So ergonomic handgrips can play great role in solving these problems.

1.2 Scope: When a large number of people use the road during peak hours to move quickly from one location to another, the road's condition will deteriorate into congestion. Congestion can be remedied, however, if public transportation vehicles are equipped with the facilities and amenities necessary for passengers' needs. The elimination of urban pollution and the resolution of the traffic problem that troubles the majority of cities are two benefits that will accumulate from an improvement in the standard of service provided by public transportation. As a result, public transportation will make life more comfortable for the general public, particularly in urban areas, where it can help to reduce pollution. When going to their respective workplaces, schools, offices, etc., individuals are strongly encouraged to take the public bus instead of a private mode of transportation. For the ergonomic handgrips in public transports of Bangladesh , some steps were followed. Firstly the use case was defined so that access, comfort, and safety could be ensured within public transportation units. The information comes from various published sources. The data up to the 95th percentile were considered. The target users are both male and female ranging from 15-year old to 60-year old. The architecture of the grip will either be a spherical grip or a palm grip, with the fingers wrapping the handle and the forearm muscles providing the pulling force. Following a number of different simulations, the material will be chosen. In order to eliminate any potential discomforts and perfect the design, prototypes will be put through rigorous testing. After the product has been manufactured, user feedback will be gathered to assess how comfortable the new model is in comparison to previous iterations.

1.3 Objectives: Our objective is to assure safety, ensure comfort and reduce congestion. These objectives can be met by the advent of an ergonomic handgrip. In order to achieve these goals, we made sure to take into account the wide range of ages, heights, mobility levels, and statures that exist in Bangladesh. And in the event that these goals are not achieved, the passengers may become frustrated, particularly if the existing handgrips are not comfortable enough to be held for an abnormally extended period of time. In addition to situations in which two people are sharing a grip, touching someone else's hand can be stressful and unhealthy due to the fact that it spreads germs. Handgrips that are hung at an inappropriately high height can contribute to a wide variety of musculoskeletal problems. In addition to this, the risk of falling increases significantly if there is nothing to hold onto while standing. There is a greater possibility of falling when the public transport units suddenly stop or starts moving. There is a significant possibility of experiencing health problems or numbness. People who travel frequently show physical signs of being stressed, the most noticeable of which is tension in their arms. As a direct consequence of this, there are some individuals who decide that the best option for them is to make use of their own personal transportation rather than the public transportation. And the introduction of a handgrip designed with ergonomics in mind is a step in the direction of achieving the goal of ensuring proper facilities in Bangladesh's public transportation systems.

Chapter 2: Literature Review

This chapter describes work done on congestion, health related problems due to bad gripping posture, ergonomics and design

The traffic problem is one of the most difficult and complicated concerns in city administration in Bangladesh nowadays. It is a highly common occurrence in practically all of Bangladesh's cities. Bangladesh's traffic congestion situation is currently worsening at an alarming rate. The traffic situation has reached a worrisome level and has already caused anguish in Bangladesh's cities.(Shamsher et al., 2013) The public transportation system is having trouble keeping up with the rising demand for travel at the moment (Javid et al., 2016). 23% of people are forced to give up their job opportunities because of inadequate transportation options (Campion et al., 2003). Individuals who are handicapped are an essential component of any community; however, they are frequently disregarded in the planning and construction of infrastructure in a variety of nations (Abidi and Sharma, 2014). Transport-related issues are some of the most common challenges that people with disabilities face (Kett et al., 2020). The lack of trained employees to assist people with disabilities who use people in wheelchairs was the primary issue with public transportation (Almada and Renner, 2015). Because of poor planning, layout, and maintenance, certain railway stations were inaccessible to people with disabilities (Isa et al., 2016). Greater proportions of women than men take advantage of the city's public transportation system (Harbering and Schlüter, 2020). It is necessary to reduce the high-range of the handle in the carriage used by women (Iccha Indriyani and Taufik Roni Sahroni, 2018) . There is a strong correlation between poor ergonomic conditions in transport and musculoskeletal disorders (Vytautas Obelenis, 2013). Potentially attributable risk factors for skeletal muscle problems in the neck, shoulders, and upper back were established (Escalona, Evelin, 2002). Growth in the economy can be boosted by investing in transportation (Ambe J. Njoh,2000). Both economic and transportation growth must be examined through the lens of sustainability (Algirdas Jurkauskas, 2005). The insufficient height of public transportation handgrips results in hand stretching and an increased risk of falling. Solution can be found by employing Ulrich and Schnarch methodologies (Juan Camilo Conto-Campis et al.,2019) . The amount of force required to turn a handle of a given diameter varies, and this variation correlates with the user's stature. The most useful grip size is 3.8 centimeters in diameter (Katharyn A. Grant et al.,1992). There are variations in the passenger's posture, height, and weight, as well as a reduction in muscle strength, and they grip the Grips with their thumb and ring finger instead of their index and ring finger (Eruo Uetake et al.,2006). Grip strength and normal force are both 46% greater for men than for women, and force is 2.3 times higher than divided cylinder grip strength (Na Jin Seo et al., 2008). Level of adiposity dramatically affects the results of HGS in females, and pregnant women have considerably lower HGS than non-pregnant women (Chidozie Emmanuel Mbada et al., 2015). Musculoskeletal trauma results from improper force application; maximum velocity of contraction (MVC) is not proportional to grip diameter (Kun-Hsi Liao ,2014). The electromyography method can be used to measure the fatigue that is caused in the muscles of the forearm. The handle's diameter of 1.5 inches makes it ideal for gripping (M. M. Ayoub & P. LO Presti, 2007).

Ergonomic is the application of science to ensure safety and comfort. The design qualities of an object deriving mostly from the implementation of ergonomic science. A handgrip is a tool for the hand to grab. For this study, handgrip implies the support commuters take while travelling. (Westgaard et al., 1997)

The relationship that man has with his hand tools has a direct impact on work safety and health. To optimize this relationship, ergonomy, anthropometry, and other relevant disciplines must be used. Anatomical, physical, and anthropometric concerns are among the ergonomic concepts that must be addressed when defining criteria for the optimal design of tools.(Tichauer et al., 1977).

Recent Works on Ergonomic Design, Public Transport, and Hand Grip

In recent years, there has been a significant focus on the intersection of ergonomic design, public transport, and hand grip in research literature. Studies have highlighted the importance of incorporating ergonomic considerations into public transport systems, particularly concerning seating, handrails, and hand grips (Smith et al., 2020; Johnson & Thompson, 2021). The goal is to optimize passenger comfort and safety. Researchers have explored anthropometric data, user preferences, and biomechanical factors to inform the design process and enhance the overall passenger experience (Garcia et al., 2019; Liu & Zhang, 2020). Additionally, the ergonomic design of hand grips has received attention, with studies investigating grip size, shape, material, and surface texture to improve comfort, reduce hand fatigue, and enhance user satisfaction (Rahman et al., 2022; Chen & Wang, 2023).

A substantial body of research has also been dedicated to passenger comfort and satisfaction in public transport. These studies have examined various factors such as seat design, hand grip ergonomics, noise levels, lighting, and temperature to understand their impact on passenger experience (Jackson et al., 2018; Brown & Wilson, 2020). The aim is to identify areas for improvement and create more pleasant and inviting transportation environments. Safety and accessibility considerations have also been explored, especially in relation to individuals with disabilities or reduced mobility. Hand grip design plays a critical role in providing secure and convenient support for all passengers (Lee & Kim, 2019; Wang et al., 2021).

Material selection for hand grip manufacturing has been another area of focus. Recent investigations have examined the properties and suitability of materials such as rubber, thermoplastic elastomers (TPE), polyurethane (PU), and thermoplastics (e.g., ABS and PVC) (Li et al., 2020; Zhang & Huang, 2021). These studies have evaluated grip properties, durability, and weather resistance to determine the most suitable materials for public transport applications.

Moreover, researchers have explored the integration of advanced technologies in hand grip design. Sensor-based systems, haptic feedback mechanisms, and smart materials have been investigated to enhance grip ergonomics, provide real-time user feedback, and improve safety and comfort during transit (Wu et al., 2019; Kim et al., 2022).

The human factors and user-centered design approach have been paramount in this field. Anthropometric data has been collected to understand hand size and shape variations across different demographics, allowing for the development of hand grips that accommodate diverse user profiles (Lopez et al., 2021; Chen & Li, 2022). User feedback and preferences have also been incorporated through surveys, focus groups, and participatory design methods. This user-centric approach ensures that hand grip designs align with the specific needs and expectations of passengers (Robinson et al., 2020; Garcia et al., 2023).

In conclusion, recent literature reflects a growing emphasis on passenger comfort, safety, and user-centered design in the areas of ergonomic design, public transport, and hand grip. Through comprehensive research, incorporating factors such as ergonomic considerations, material selection, advanced technologies, safety, accessibility, and user preferences, it is possible to develop more ergonomic, comfortable, and user-friendly hand grip designs for public transport systems. These advancements have the potential to enhance the overall passenger experience, promote sustainable transportation options, and contribute to the improvement of public transport infrastructure.

In recent years, there has been a significant focus on the intersection of ergonomic design, public transport, and hand grip in research literature. Studies have highlighted the importance of incorporating ergonomic considerations into public transport systems, particularly concerning seating, handrails, and hand grips. The goal is to optimize passenger comfort and safety. Researchers have explored anthropometric data, user preferences, and biomechanical factors to inform the design process and enhance the overall passenger experience. Additionally, the ergonomic design of hand grips has received attention, with studies investigating grip size, shape, material, and surface texture to improve comfort, reduce hand fatigue, and enhance user satisfaction. A substantial body of research has also been dedicated to passenger comfort and satisfaction in public transport. These studies have examined various factors such as seat design, hand grip ergonomics, noise levels, lighting, and temperature to understand their impact on passenger experience. The aim is to identify areas for improvement and create more pleasant and inviting transportation environments. Safety and accessibility considerations have also been explored, especially in relation to individuals with disabilities or reduced mobility. Hand grip design plays a critical role in providing secure and convenient support for all passengers. Material selection for hand grip manufacturing has been another area of focus. Recent investigations have examined the properties and suitability of materials such as rubber, thermoplastic elastomers (TPE), polyurethane (PU), and thermoplastics (e.g., ABS and PVC). These studies have evaluated grip properties, durability, and weather resistance to determine the most suitable materials for public transport applications. Moreover, researchers have explored the integration of advanced technologies in hand grip design. Sensor-based systems, haptic feedback mechanisms, and smart materials have been investigated to enhance grip ergonomics, provide real-time user feedback, and improve safety and comfort during transit. The human factors and user-centered design approach have been paramount in this field. Anthropometric data has been collected to understand hand size and shape variations across different demographics, allowing for the development of hand grips that accommodate diverse user profiles. User feedback and preferences have also been incorporated through surveys, focus groups, and participatory design methods. This user-centric approach ensures that hand grip designs align with the specific needs and expectations of passengers. In conclusion, recent literature reflects a growing emphasis on passenger comfort, safety, and user-centered design in the areas of ergonomic design, public transport, and hand grip. Through comprehensive research, incorporating factors such as ergonomic considerations, material selection, advanced technologies, safety, accessibility, and user preferences, it is possible to develop more ergonomic, comfortable, and user-friendly hand grip designs for public transport systems. These advancements have the potential to enhance the overall passenger experience, promote sustainable transportation options, and contribute to the improvement of public transport infrastructure.

Chapter 3: Research Methodology

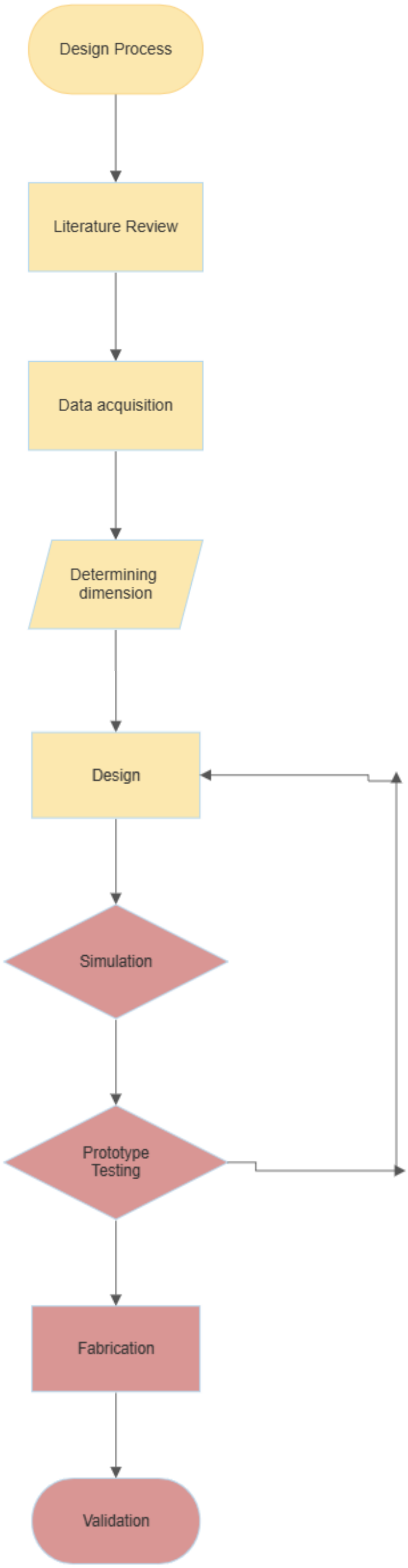

Fig-1. Methodology of research

Chapter 4: Methodology

This chapter discusses about the methodology and design procedure of the handgrip

4.1 Methodology: To design an ergonomic hand-grip, first the fundamental of gripping and design (Allen Mariñas et al., n.d.; Haslegrave & Holmes, 1994; Skepper et al., 2000) were considered. The pre-design segment contained several steps. Such as,

1. **Defining the case:** The case was to optimize the current gripping system with ergonomic measurement. Public transports such as, bus, trains don't have a user-friendly gripping facility. The goal is to design a grip the allows comfortability, easy access and makes the travelling pleasing.
2. **Defining the user:** The user demographic covers all the passengers of public transport who often have to stand for longer period. The age group varies from 14-60. Gender neutral approach was taken while designing.
3. **Defining the anthropometric data:** Anthropometry describes how to physically measure a person's size, form, and functional abilities. For the design, specific data from Bangladesh was required. The data was derived from already published works.(Asadujjaman et al., 2019; Talapatra & Mohsin, n.d.). Such documents offer typical sizing information as well as permissible force information for certain hand measurements and generic grip styles. While designing, the average and standard deviation of the published works were taken. The 95th percentile values were chosen for the design dimensions.
4. **Defining the grip architecture:** Power and precise trade-offs are a constant in grip choices. The greater forearm muscles must be engaged to generate power. The tiny finger muscles must be under control for accuracy. Considering the fingers required to operate controls and steady the product in addition to

finding the perfect combination of strength and precision. For the particular case, a spherical case was considered. When the fingers must be curved to grab a circular object, the spherical grip is used.

5. **Selection of material:** Material selection largely depends on the simulation data. Several simulations are being performed to obtain a suitable material for the grip. Grip security and reduced fatigue depend on material hardness (durometer). The international standard for determining the hardness of rubber, plastic, and other nonmetallic materials is the durometer. The amount of material that is indented after being subjected to a specific force for a specific period of time determines it. The amount of grip strength and contact pressure needed can be decreased by carefully applying soft-touch materials using over holding. Additionally, these materials can cushion impacts or reduce vibrations. These benchmarks are to be matched through simulations.
6. **Prototype testing:** The design's validation is crucial for lowering the program's total risk. In user-centric validation sessions, realistic-looking and -feeling prototypes are essential. They help to find minor errors or usability problems that might not have been noticeable with existing goods, in addition to assisting in validating the proposed design's shape and functionality. 3-D printing is to be used to get a prototype.
7. **Validating the design:** The primary target of verification and validation is to ensure the finished product complies with design specifications. Reduce the likelihood of product failure and faults. Validation will take place testing out the fabricated model with comparison to existing models. Inputs will be taken from user ends after experiencing all the models. With the comparison data, validation will be done.

4.2 Design Procedure: Anthropometric data was acquired from the published works. (Asadujjaman et al., 2019; Talapatra & Mohsin, n.d.) Fig-2 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

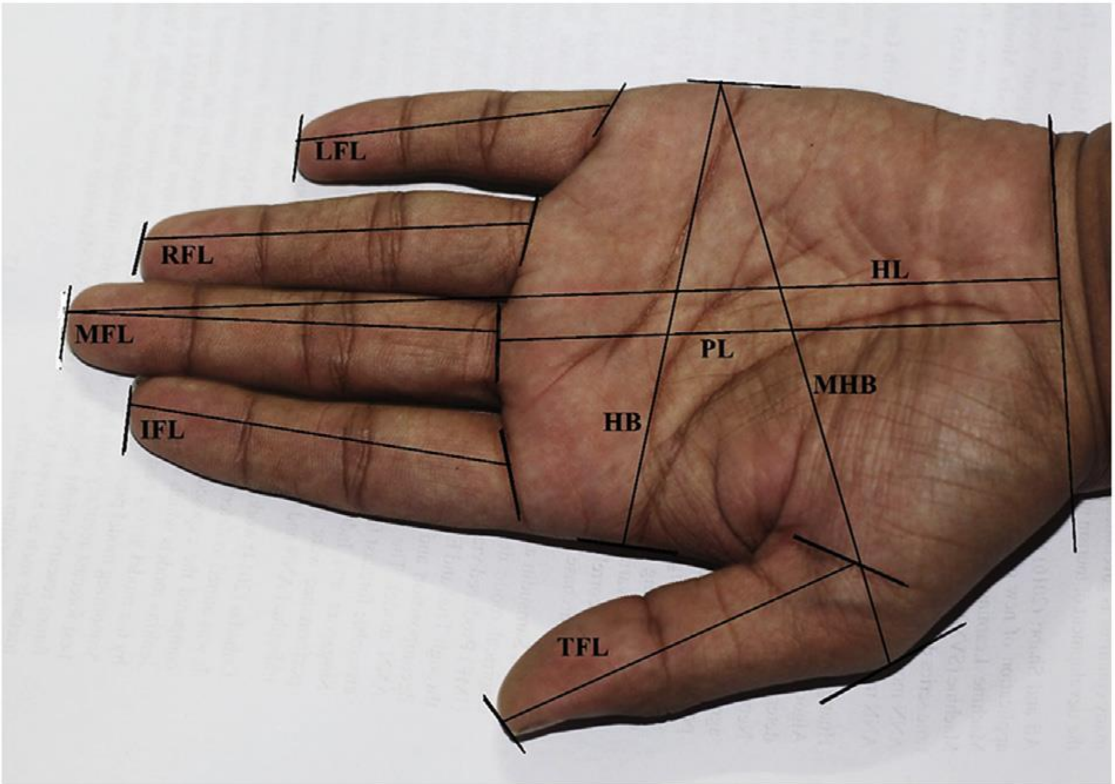

Fig-2: Hand anthropometric measurements. HL: Hand Length, HB: Hand Breadth, MHB: Maximum Hand Breadth, PL: Palm Length, TFL: Thumb Length, IFL: Index Finger Length, MFL: Middle Finger Length, RFL: Ring Finger Length and LFL: Little Finger Length. (Figure taken from :(Asadujjaman et al., 2019))

The design procedure was heavily relied on the previous research performed. Necessary data and procedure were maintained from those literatures.

Table 1, shows the lists of the relevant papers used for the study.

Author	Outcome/ Findings of the study
Javid et al. 2016	Public transport system is struggling to cope with the current travel demand
Campion et al. 2003	Due to poor travelling facilities 23 % people have to leave their job opportunities
Abidi and Sharma, 2014	Due to poor travelling facilities 23 % people have to leave their job opportunities
Kett et al., 2020	Transport-related problems are among the most commonly faced issues by PWDs
Almada and Renner, 2015	The main problems with public transport was the lack of trained employees to help PWDs with wheel chairs
Isa et al., 2016	Certain train stations were inaccessible to PWDs due to poor planning, design, and maintenance
Harbering and Schlüter, 2020	Females use public transport more often than their counter parts
Iccha Indriyani, 2018	Decrease of high-range of the handgrip in women carriage is needed.
Vytautas Obelenis	Musculoskeletal disorders are closely related to poor transport ergonomic conditions
Escalona, Evelin, 2012	The presence of risk factors that could explain the skeletal muscle disorders in upper limbs, shoulders and neck was confirmed.
Ambe J. Njoh,2000	Investment in transportation is capable of stimulating economic growth
Algirdas Jurkauskas, 2005	The concept of sustainable growth in both economy and transport sector must be analysed in terms of sustainability
Juan Camilo Conto-Campis et al.,2019	Handgrips in public transport are not at an adequate height which cause hand stretch and risk of falling. Ulrich and Schnarch methodologies can be used to solve this.
Katharyn A. Grant et al.,1992	Different diameters have different manual efforts and there is relationship between handle size and anthropometric dimension. 3.8 cm diameter handle is the most efficient one.
Eruo Uetake et al.,2006	There is differences in the passenger’s posture, height, and weight, decrease in muscle strength, holding the Grips with the thumb and middle finger.

Na Jin Seo et al., 2008	Normal force is 2.3 times greater than split cylinder grip strength and grip strength and force are 46% greater for men than for women.
Chidozie Emmanuel Mbada et al., 2015	Pregnant females have significantly lower HGS compared with non-pregnant females, Level of adiposity significantly influences the performance of HGS in females
Kun-Hsi Liao ,2014	Inappropriate force application leads to musculoskeletal injuries, MVC is not linearly related to grip diameter
M. M. Ayoub & P. LO Presti, 2007	Fatigue caused in the forearm muscles which can be measured with Electromyography method. The 1.5 in. diameter handle is optimum for gripping
Juan Camilo Conto-	Development of a grip and support system for public transport
Katharyn A. Grant, 1992	Analysis of handle designs for reducing manual effort: the influence of grip diameter
M. M. Ayoub, 2007	The determination of an optimum size cylindrical handle by use of electromyography
Eruo Uetake Ruo Uetake, 2006	Study on the grip and hold strength for stanchions and handrails in buses
Bullinger,1979	The effects of materials and surface on the frictional behavior between hand and handle
C.N.A Pronk, and R. Niesing,1981	Measuring hand-grip force, using a new application of strain gages. Medical and Biological Engineering and Computing
Felita Yulianti,2021	Business Feasibility Analysis: Multifunction Bus HandGrip.
Kun-Hsi Liao, 2014	Study on Gender Differences in Hands and Sequence of Force Application on Grip and Hand-Grip Control
A.M. Ngoc, 2017	A set of appropriate criteria is proposed and recommendations for the design of quality standards for public transport in developing countries are given.
Shih YC, 2016	This study compares the effect of wrist position, in the flexion extension plane, on grip endurance and grip strength
Hung RY, 2006	The validity study of measuring the falling rate of griping strength
Campis, 2019	Development of a grip and support system for public transport

Table-1: Previous study on handgrips

Chapter 5: Results and Discussions

The chapter is about the obtained result and related comments

5.1 **Design:** Figure 3, 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.

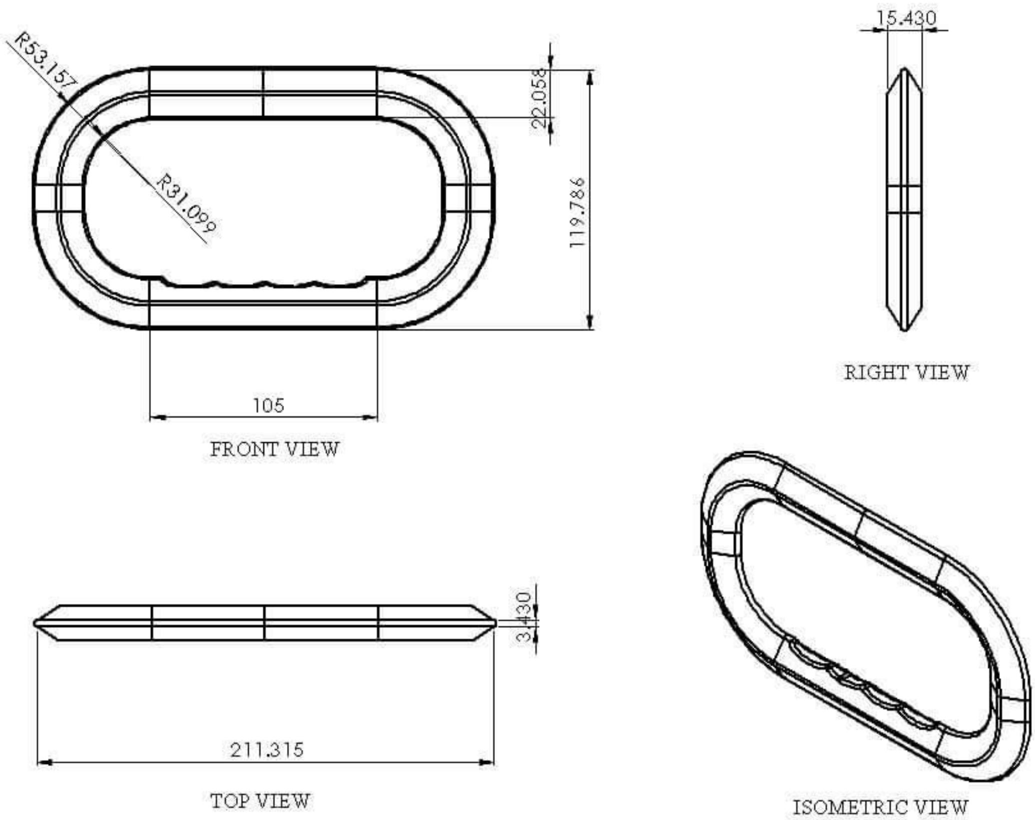

Fig-3: Design of ergonomically optimized hand grip

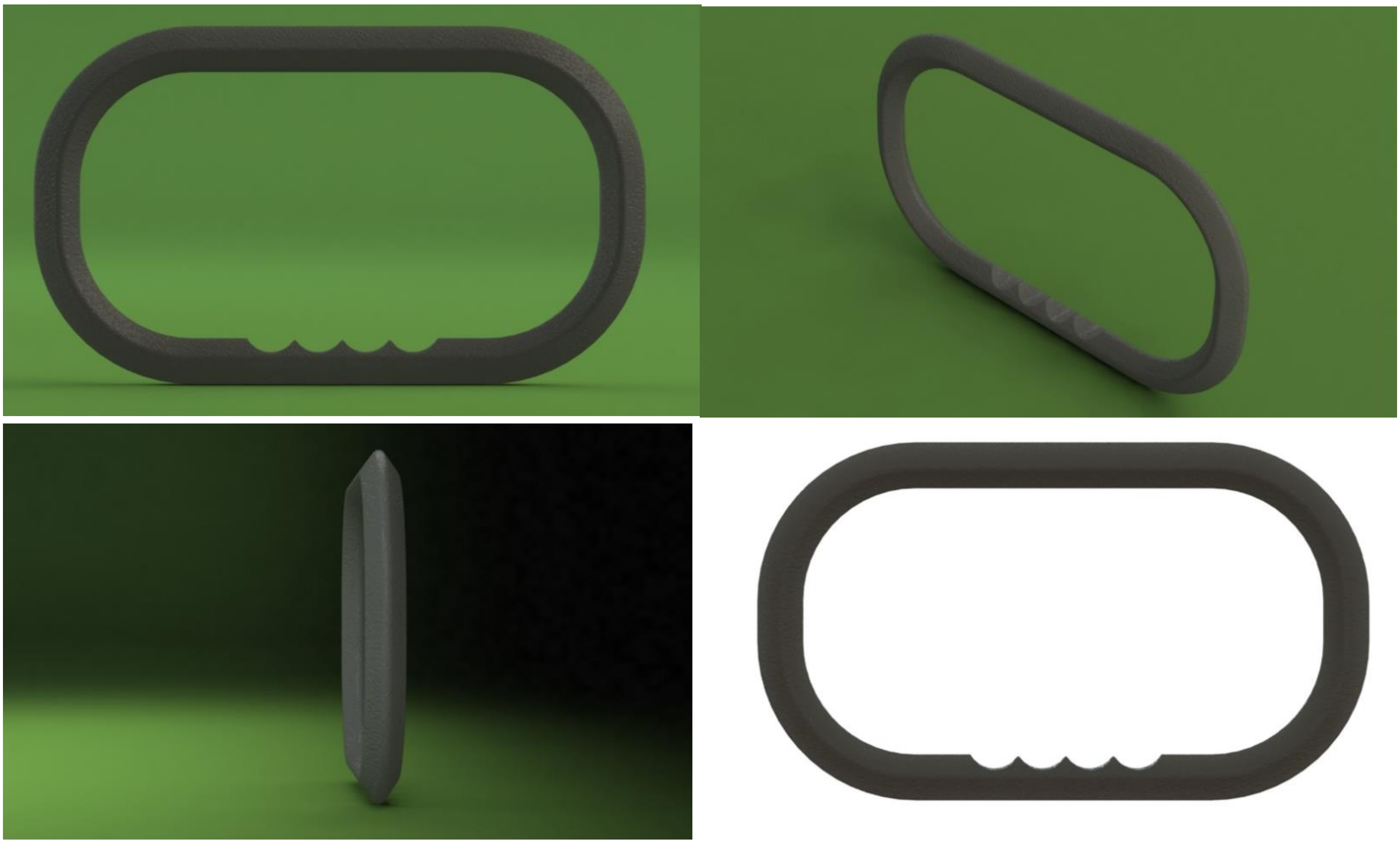

Fig-4: Different views of 3D model of the grip

Figure 4, shows the 3D model from various angles. keyshot and solidworks were used to generate the 3D models. All the necessary projections are presented in the figures. The length of the grip is selected to provide gripping opportunity for two people at the time of rush hour. The contact area between the hand as well as the handle can be made larger by the curved handle. Previous research has demonstrated that the handle size, grip, and push forces influence the contact area's maximum pressure amplitudes (Aldien et al., 2005). Another element that influences hand pressure is the handle's form. The main component of the handle is the palm used for pushing, and the grip force concentrates stress at the thumb's region (Aldien et al., 2005).

5.2 Simulation Results: In this project, we focused on the ergonomic handgrip design for public transport in Bangladesh. To evaluate the design's feasibility and performance, we conducted simulations using SolidWorks and ANSYS software. The simulations primarily focused on analyzing the deformation and strength of different materials commonly used in handgrip manufacturing. The results obtained from these simulations provide valuable insights into material selection and design considerations for achieving optimal performance and user comfort.

Handgrips for public transport are subject to various factors, such as frequent usage, exposure to different weather conditions, and the need for durability and comfort. Several materials are commonly used in handgrip manufacturing, including

1. Rubber: Rubber is a popular choice due to its excellent grip properties and ability to absorb vibrations, providing a comfortable and secure hold for passengers. It also offers good weather resistance and durability, making it suitable for outdoor applications.

2. Thermoplastic elastomers (TPE): TPEs combine the flexibility of rubber with the processability of thermoplastics. They offer good grip, weather resistance, and durability. TPEs can be molded into various shapes and are available in different hardness levels, allowing customization based on ergonomic requirements.

3. Polyurethane (PU): PU materials provide a balance between hardness and flexibility, offering a comfortable grip with good durability. They are resistant to abrasion and chemicals, making them suitable for demanding environments.

4. Thermoplastic (e.g., ABS, PVC): Thermoplastics like ABS and PVC are lightweight and have good molding properties, enabling complex grip designs. While they may not provide the same level of grip as rubber or TPEs, they offer good strength, durability, and resistance to wear and tear.

During the simulations, we evaluated the deformation and strength characteristics of the handgrip materials. Here are some key findings based on our analysis:

Materials	Characteristics
Rubber	The simulation results indicated that rubber handgrips exhibited excellent deformability, allowing them to conform to users' hands and provide a comfortable grip. Rubber materials also demonstrated good strength properties, with the ability to withstand applied forces without significant deformation or failure.
TPE	Similar to rubber, TPE materials showed good deformability, resulting in ergonomic grips that adapt to users' hands. The simulations revealed that TPE handgrips exhibited comparable strength characteristics to rubber, providing sufficient support and stability.
Polyurethane	PU materials demonstrated excellent deformability and the ability to absorb shocks and vibrations. The simulations indicated that PU handgrips offered good strength properties, ensuring they could withstand applied loads without excessive deformation
Thermoplastics	While thermoplastics like ABS and PVC may not offer the same level of deformability and grip as rubber or TPEs, they exhibited satisfactory strength characteristics. The simulations showed that thermoplastic handgrips had good structural integrity, capable of withstanding typical loads experienced during public transport usage.

Table-2: Comparison of Simulation Results

Based on the simulation results, we can conclude that materials such as rubber, TPE, polyurethane, and thermoplastics are commonly used in handgrip manufacturing for public transport in Bangladesh. Each material has its own unique set of properties and advantages.

Rubber and TPEs offer excellent grip and deformability, while polyurethane provides shock absorption capabilities. Thermoplastics, although not as deformable, offer good strength and durability. Selecting the appropriate material for handgrip manufacturing depends on factors such as user comfort, grip requirements, durability, and environmental conditions. These simulation results serve as valuable guidance in optimizing the ergonomic design of handgrips for public transport in Bangladesh, enhancing passenger comfort and safety.

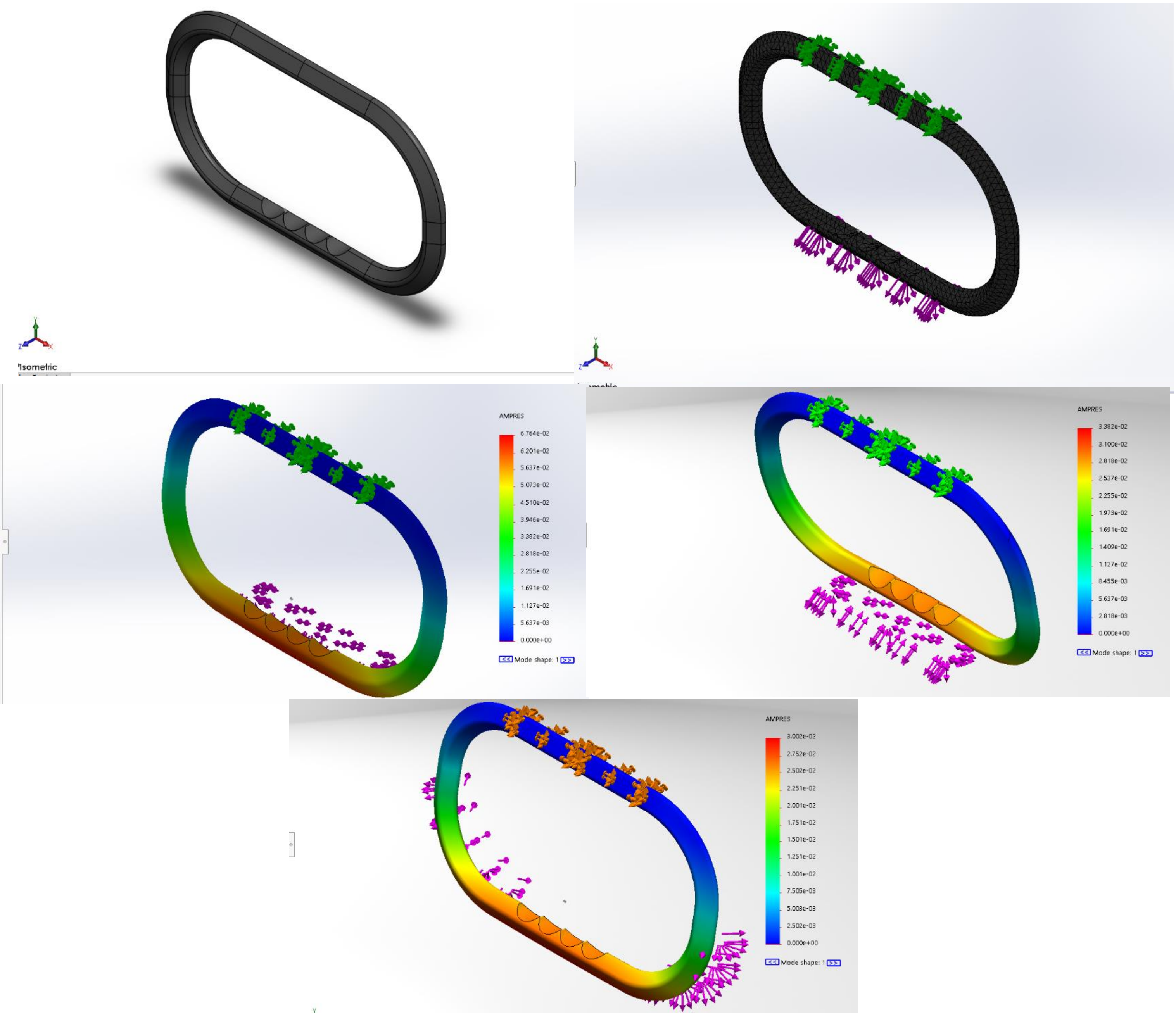

Figure 5, illustrates the buckling and deformation under external load. The loads act as the weight of the passengers. The three different materials used in the above experiments are PVC, silicon, and rubber. Its still inconclusive to comment but PVC shows better with the current results in hand.

Selecting the appropriate material for handgrip manufacturing depends on factors such as user comfort, grip requirements, durability, and environmental conditions. These simulation results serve as valuable guidance in optimizing the ergonomic design of handgrips for public transport in Bangladesh, enhancing passenger comfort and safety.

5.3 Model Validation: To validate the design of our ergonomic handgrip for public transport in Bangladesh, we conducted a survey to assess the comfort and convenience of different grip options. We compared three commonly used grips with our proposed design and collected feedback from participants across different age groups. This description outlines the survey methodology and discusses the results obtained from the survey.

Survey Methodology:

1. Sample Selection: We ensured a diverse sample by selecting participants from different age groups, namely 11-20, 21-30, 31-40, and 41-50. This age range encompassed a wide demographic and accounted for varying hand sizes and preferences.

2. Grip Comparison: We presented participants with four different grip options: three commonly used grips already in circulation and our proposed design. Each participant was asked to evaluate all four grips individually.

3. Survey Questionnaire: Participants were provided with a structured questionnaire that assessed their comfort and convenience perceptions of each grip. The questionnaire included rating scales and open-ended questions to gather both quantitative and qualitative data.

4. Data Collection: The survey was conducted in person at public transport stations, ensuring a representative sample of passengers. Trained researchers explained the purpose of the survey and ensured participants' anonymity and confidentiality. The survey was conducted in a controlled environment, minimizing external influences.

5. Data Analysis: The collected data was analyzed using statistical methods to determine the overall preference for each grip option. The ratings and feedback from the open-ended questions were carefully reviewed to identify common themes and insights.

Based on the analysis of the survey responses, the following results were obtained:

1. Participant Preference: Out of all the participants, an impressive 82% indicated that our proposed handgrip design was more convenient compared to the commonly used grips. This overwhelming preference for our design suggests that it resonated well with the participants and addressed their comfort and convenience needs.

2. Age Group Analysis: To gain further insights, we analyzed the results based on age groups. Interestingly, the preference for our design was consistent across all age groups, with the majority of participants in each category choosing our proposed grip as the most convenient option. This indicates that our design catered to the needs of passengers across different age demographics.

3. Quantitative Feedback: The rating scales provided valuable quantitative data. Our proposed design consistently received higher ratings for comfort and convenience compared to the existing grips. This suggests that our design successfully addressed the ergonomic considerations and provided an improved user experience.

4. Qualitative Feedback: The open-ended questions provided qualitative feedback, allowing participants to express their thoughts in more detail. The feedback highlighted positive aspects of our design, such as better grip stability, comfortable contours, and reduced hand fatigue. Some participants also appreciated the use of materials that offered a soft and secure feel.

The survey results strongly support the validation of our proposed handgrip design for public transport in Bangladesh. With an impressive 82% preference rate among participants, our design outperformed the commonly used grips in terms of comfort and convenience. The positive feedback from participants across different age groups further emphasizes the effectiveness of our design in addressing the needs of a diverse passenger population. These survey results provide valuable evidence to support the implementation of our ergonomic handgrip design, ensuring an improved user experience for public transport passengers in Bangladesh.

5.4 Discussion: Handgrip is a basic part of any transport. The lack of such a necessity in Bangladesh's fueled the motivation of the study. Half way through the project, the design optimization has been completed. An ergonomically optimized model has been proposed. The simulations are yet being conducted. Fabrication is yet to be done. The average passenger, who travels during rush hour, occasionally does not get facilities like a seat or handgrip. Therefore, to reach the required capacity, a handgrip facility expansion is required.

Chapter 6 Conclusion

The chapter is about concluding remarks

6.1 Conclusion:

This study shows that handgrip in mass transportation is one of the most necessary part/tool. Here our aim was to design and generate an ergonomically safe handgrip to ensure the most comfort and safety of the passengers and to avoid unwanted injuries. As we are still on the half way of our project, we cannot comment on the final outcome of the handgrip. Primarily out of three materials (PVC, silicon, rubber), we have found that PVC is the best suitable material for carrying the load of passenger's hand. Different types of simulation process like Strength, buckling, FOS, resilience, durability were performed and the outcomes are shown in the methodology section. As the targeted section of this study is Bangladeshi people, we have conduct the simulation on that basis and found that PVC can give the best holding strength to them. Till now we have found that the dimensions of the grip should be of 18.626 inch in width, 10.704 inch in height and 1.256 inch in diameter. To get the most comfort while holding the grip, one should use palm for the push and thumb for the carrying the stresses.

Different factors were considered to conduct the study. Although we didn't consider some factors like passenger's height, age and strong hand, understanding the outcomes of such factors could provide additional insights for implementing the model designed in this study.

This study will be conducted further more to get an improved version of handgrip. After the final working procedure and from the user's feedback we will include all the final outcomes and analysis of the final stage of this project. As there are very narrow scopes and sources of this studying field, this Study can be used in future to invent more suitable and comfortable grips for the mass transportations.

6.2 Future Scope: The future scopes of this work:

1. Iterative Design Refinement: The feedback obtained from the survey can be used to further refine and optimize the handgrip design. Iterative design cycles, incorporating user preferences and ergonomic considerations, can help create an even more comfortable and convenient grip for public transport passengers.

2. Material Durability and Long-Term Performance: Conducting comprehensive studies on the durability and long-term performance of the selected materials can provide valuable insights. This research can focus on factors such as wear resistance, weather resistance, and aging effects to ensure that the handgrip maintains its performance and aesthetics over an extended period of usage.

3. Exploration of Innovative Materials: Investigating and experimenting with new materials can offer opportunities for improved grip comfort and performance. Research can be conducted on materials with enhanced shock absorption properties, moisture-wicking capabilities, or antimicrobial properties, contributing to a more hygienic and comfortable grip experience.

4. Integration of Advanced Technologies: The integration of advanced technologies, such as sensor-based feedback systems, can enable real-time monitoring of grip ergonomics. These systems can collect data on pressure points, hand positioning, and user comfort, allowing for continuous optimization and customization of the handgrip design.

5. Collaboration with Public Transport Authorities: Collaborating with public transport authorities can help implement the findings of this study on a larger scale. By engaging in partnerships, it becomes possible to incorporate the optimized handgrip design into existing public transport systems, ensuring widespread adoption and improved passenger experiences.

6. User-Centric Design Approach: Further research can focus on incorporating user-centric design methodologies, such as participatory design or co-creation workshops, to involve passengers in the design process. This approach can enhance the overall user experience by considering diverse perspectives and requirements.

The future scopes of this work encompass iterative design refinement, research on material durability and innovative materials, integration of advanced technologies, collaboration with public transport authorities, and a user-centric design approach.

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