Ergonomic Design of Driver's Workstation for Modern Jeepney of ABC Transport Service and Multi-Purpose Cooperative

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Abstract

The jeepney is the most popular kind of public transportation in the Philippines for its accessibility and affordability. Over the years, the features of jeepneys have improved through modernization, yet there are still issues, particularly in the workstation design, that need to be addressed to reduce the vulnerability of jeepney drivers to work-related musculoskeletal disorders. In this study, the working condition of modern jeepney drivers at ABC Transport Service and Multi-Purpose Cooperative was assessed through observations with ten (10) drivers using the Rapid Upper Limb Assessment and Rapid Entire Body Assessment (focusing on the major processes involved such as driving, reaching, and payment), interviews with twenty (20) drivers using the Nordic Musculoskeletal Questionnaire, and the gathering of anthropometric measurements of thirty-seven (37) drivers. Results from RULA and REBA showed that medium risk was present, requiring further investigation to implement the necessary changes, while the NMQ results revealed that 46.11% of the drivers experienced discomfort in at least one body part, of which 46.99% of them had trouble during the last seven days prior to the interview. Spearman rank-order correlation analysis showed no significant relationship between the NMQ scores and the RULA and REBA scores of the three major positions involved—driving, reaching, and payment. The results of these assessments, as well as the anthropometric measurements of the drivers, served as the basis for creating an ergonomic design for the workstation that provides greater comfort and safety.

Keywords
Work-related musculoskeletal disorders, anthropometric measurements, drivers, modern jeepney, reaching

1. Introduction
Commuters' preference for affordable and accessible rides makes jeepneys the most popular mode of public transportation in the Philippines. It is a modified American automobile from World War II that allows millions of passengers to board and depart anywhere. About 270,000 franchised jeepney units are in use nationwide, with 75,000 of those in Metro Manila alone (Kecorius et al. 2017). Along with the nation's rapid development and economic growth, the government has unveiled the "Public Utility Vehicle (PUV) Modernization Program," which intends to gradually replace jeepneys, buses, and other PUVs that are at least 15 years old with more environmentally friendly, more convenient, safer, and improved features (DOTr 2018).

Though the design of a modern jeepney has improved overall, there is still much room for improvement to provide greater comfort and safety, especially to drivers. Jeepney drivers are susceptible to work-related musculoskeletal disorders (WMSDs) due to their job demands; therefore, the layout of their workstations influences how their jobs affect their health. The researchers were able to notice such scenarios through the conducted observation of the working conditions of modern jeepney drivers at ABC Transport Service and Multi-Purpose Cooperative.

ABC Transport Service and Multi-Purpose Cooperative is a company that provides public transportation services in various towns in Quezon Province. The researchers chose to perform their study at the mentioned company as they initially observed that some features of the driver's workstation were not ergonomically acceptable. The researchers noticed that the driver's seat is too high for short or medium-height drivers. According to CCOHS (2021), adjustable seat height is an important feature of ergonomically designed chairs or seats. Another observation is that light and sound controls, as well as the payment process, require reaching. Furthermore, BOSTONtec (2021) explained that reaching might cause shoulder problems as it repetitively uses soft tissues to perform such awkward postures.

The study assessed the jeepney driver's current working condition using the Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and Nordic Musculoskeletal Questionnaire (NMQ). Thus, the researchers generated an improved ergonomically designed workstation using the assessments' results and the drivers' anthropometric measurements.

1.1 Objectives

This study aimed to provide ergonomic improvements to the current design of the driver's workstation. The current working condition was evaluated using the left-hand-right-hand chart and further assessed through observation using ergonomic assessment tools such as Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA). The physical discomfort of the drivers was recorded through interviews using the Nordic Musculoskeletal Questionnaire. The researchers determined the relationship between the ergonomic assessment and the driver's physical discomfort. Furthermore, the anthropometric measurements of the drivers were gathered, such as height, upper and lower arm length, upper and lower leg length, and reach. These measurements, together with the results of the data gathered from observations and interviews, served as the basis for proposing an ergonomically designed driver's workstation.

2. Literature Review

Health hazards such as neck and back discomfort, muscle exhaustion, tension, headaches, and other work-related musculoskeletal disorders (WMSDs) are very common in workplaces. This usually results from poor and awkward posture, static work positions, uncomfortable repetitive movements, manual material handling, and other poor body movements at work. Furthermore, the design of the equipment used in the workplace and the design of the workstation itself can also be a huge factor in musculoskeletal disorders, as they may cause additional strain on muscles, ligaments, and other soft tissues. At first, symptoms may not be disturbing enough to catch management's attention for necessary countermeasures. However, continuous exposure to activities that cause MSDs may lead to more serious and long-term consequences.

Professional drivers of public transportation are at risk for developing musculoskeletal disorders (MSDs). Numerous researchers have already investigated how particular workplace conditions can result in MSDs in professional drivers (Pandarinath et al. 2023). Das (2021) added that professional drivers are more likely than the general public to experience the harmful effects of diagnosable back conditions, including prolapsed intervertebral plates. According to Sharma et al. (2022), professional driving requires long hours at work, uncomfortable seating, negotiating rough terrain and highways, and perhaps performing minor repairs and other auxiliary transportation duties. Thus, these activities increase the possibility that drivers will experience a variety of musculoskeletal disorders (MSDs).

In order to stop an injury from getting worse, Brown (2019) asserted that it is important to pay attention and respond immediately to the early indications of WMSDs. Common symptoms include soreness, pain, discomfort, redness and swelling, restricted range of motion, joint stiffness, weakness and clumsiness, numbness or tingling sensations, popping or crackling sounds in the joints, and burning feelings in the muscles. In repetitive jobs, cumulative trauma injuries can develop over time. In the study of Hashim and Taha (2016), factors such as the driver's seat's adjustability, forward and backward visibility, in-cabin temperature, noise and vibration exposure, environmental factors, baggage handling, driving hours per shift, driving hours per week, and demographic factors were evaluated as affecting driving conditions.

In providing the necessary countermeasures to address WMSDs, it is important to consider the anthropometric measurements of the employees involved and the concept of ergonomics to provide effective solutions. The basic anthropometric measurements, according to Casadei and Kiel (2022), include height, weight, head circumference, body mass index (BMI), waist, hip, and limb circumferences, and skinfold thickness. Furthermore, as stated by Magee and Manske (2021), anthropometry can be used to determine a person's body type and whether they are fit for a given activity. On the other hand, ergonomics concerns how humans interact with systems, processes, equipment, tools, and other factors in their working environment. As stated by Choobineh et al. (2021), ergonomics increases workers' comfort while also increasing their productivity and efficiency. Kasemsan et al. (2021) added that ergonomics has been utilized to boost productivity, minimize musculoskeletal problems, and enhance the occupational quality of life. It is backed up by Rostami et al. (2022), who assert that ergonomic intervention programs (EIPs) will help companies prevent workers from developing WMSDs. It is best to incorporate ergonomics from the beginning of the development of new tools, workstations, and processes, as well as the planning, design, and validation phases of the product life cycle. This is why more and more industries are seeing the value of putting ergonomics into practice in the workplace.

With the exposure of drivers to WMSDs, prevention from the cause of physical discomfort should be given to them; if not, countermeasures to decrease the exposure to risks should be at least provided. However, Syah (2020) warned that for an ergonomic improvement approach to be effective, there must be a systematic way to do ergonomic risk assessments for each job in the workplace.

3. Methods

3.1 Research Design

This study is an applied type of research. The research focuses on implementing improvements and changes at a workstation. The researchers provided a possible solution to the existing work-related musculoskeletal disorder encountered by the modern jeepney drivers of ABC Transport Service and Multipurpose Cooperative. Hence, they utilized the data gathered from the assessments and the anthropometric measurements of the drivers, together with their knowledge of ergonomics, to provide an ergonomic design improvement.

3.2 Research Environment

The researchers partnered with ABC Transport Service and Multipurpose Cooperative, the sole provider of modern jeepney transportation in various towns in Quezon Province. ABC Transport Service and MPC has two modern jeepney models: Isuzu and Hino, and travel on three different routes; thus, both models and all the routes were taken into consideration to gather more holistic data.

3.3 Data Gathering Procedures

The researchers conducted a primary observation to determine problems associated with the current workstations of the drivers. Furthermore, the working conditions were assessed using the Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and Nordic Musculoskeletal Questionnaire (NMQ). Additionally, the anthropometric measurements of the drivers were gathered, which served as the basis for the improved design of the workstation.

3.4 Design of the Improved Driver's Workstation

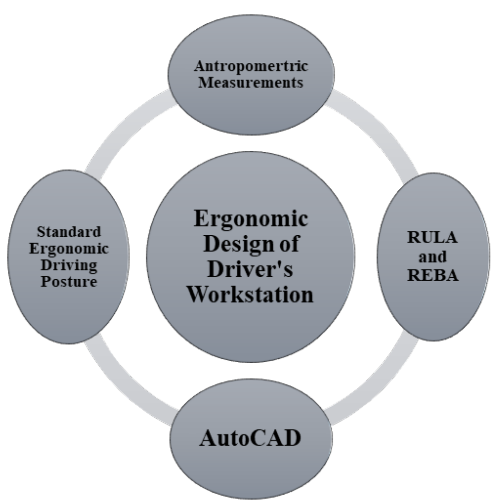

Figure 1. Block Diagram of the Ergonomic Design of the Driver's Workstation

Figure 1 illustrates the concepts and tools utilized in producing an improved ergonomically designed workstation. The anthropometric measurements of the drivers were mainly used as a basis for generating the design. Furthermore, the researchers identified which part of the workstation contributes to unsafe postures through the results from RULA and REBA. Lastly, the standard ergonomic driving posture was utilized to create the design that was generated using AutoCAD.

4. Results and Discussion

4.1 Existing Working Conditions

Figure 2. Existing Driver's Working Condition for Hino

Figure 2 shows the three major positions involved during driving, such as the standard driving position, the reaching position, and the payment position, respectively. These figures represent the existing working conditions for Hino.

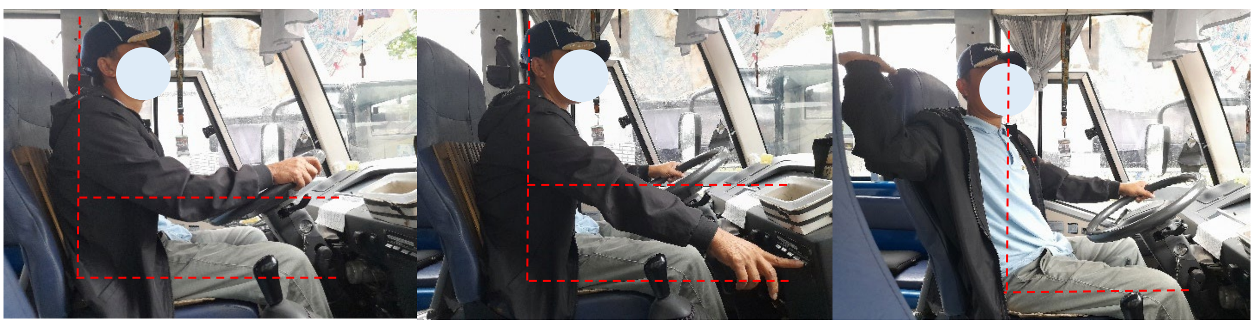

Figure 3. Existing Driver's Working Condition for Isuzu

Figure 3 also shows the three major positions in parallel to Figure 2. Meanwhile, these figures represent the existing working conditions for Isuzu.

Table 1. Mean of RULA and REBA of the Existing Driver's Working Condition

Assessment	Position	Mean Score	Remarks
RULA	Standard Driving	5	further investigation, change soon
	Reaching	6	
	Payment	5	
REBA	Standard Driving	4	medium risk, further investigation, change soon
	Reaching	6	
	Payment	6	

The ten (10) drivers' mean RULA and REBA scores for the three primary driving positions are shown in Table 1. The three RULA scores indicate that further investigation and immediate change are needed. Moreover, three REBA scores denote that medium risk is present and that further investigation and immediate change should be implemented. Risk factors for driving include a wide variety of drivers' anthropometric measurements, long labor and sitting periods, reaching, and repetitive manual processes of payment.

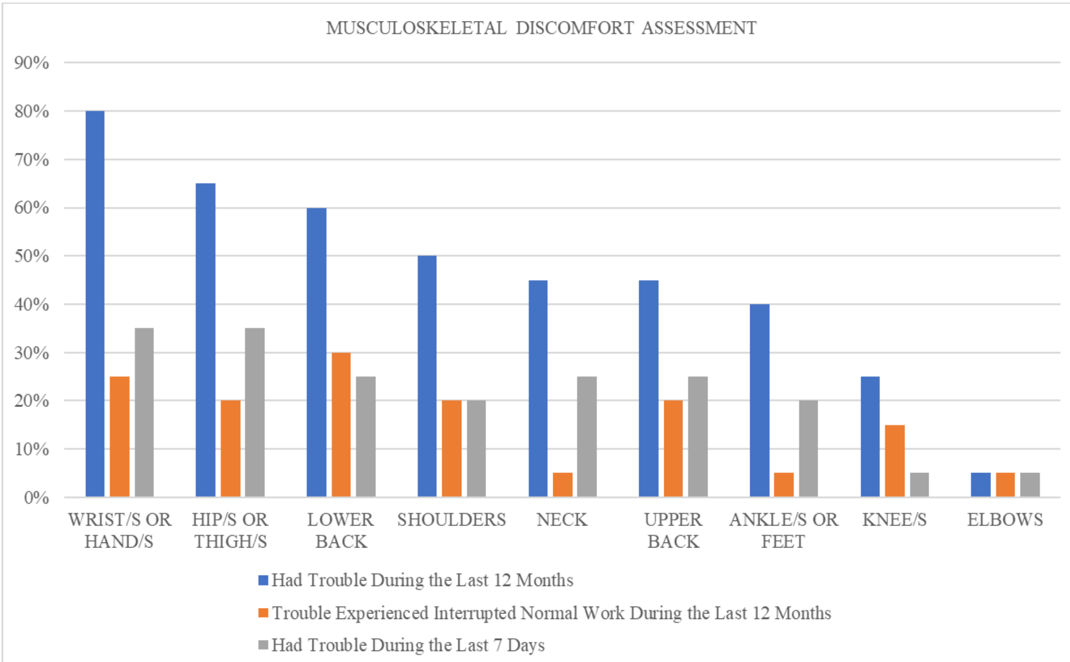

Figure 4. Nordic Musculoskeletal Questionnaire Results

Figure 4 illustrates the results of the physical discomfort assessment with the drivers. 80% of the respondents, or sixteen (16) out of twenty (20) respondents, claimed to have experienced trouble with their wrist/s or hand/s during the last 12 months, making these body parts the most affected part during the discomfort. Meanwhile, the elbow, with 1% of the respondents, or one (1) out of twenty (20), claimed to experience trouble with it, being the least affected body part during the last 12 months. Furthermore, results using the NMQ revealed that on average, 46.11% of the total number of respondents, or approximately nine (9) out of twenty (20) drivers, are experiencing trouble with at least one body part. Among those drivers that are experiencing trouble, 46.99%, or approximately four (4) out of nine (9) drivers, had trouble with at least one of the aforementioned body parts at any time during the last seven (7) days prior to the time of the interview. According to most of the respondents, they usually ignore most of the trouble that they experience because they are already used to it.

4.2 Spearman Rank-order Correlation Analysis

Table 2. Results of Spearman Rank-order Correlation Analysis

			Nordic	RULA. StandardDrivingPosition
Spearman's rho	Nordic	Correlation Coefficient	1.000	.000
		Sig. (2-tailed)	.	1.000
		N	10	10
	RULA. StandardDrivingPosition	Correlation Coefficient	.000	1.000
		Sig. (2-tailed)	1.000	.
		N	10	10

		Nordic	REBA. StandardDrivingPosition
Nordic	Correlation Coefficient	1.000	.082
	Sig. (2-tailed)	.	.821
	N	10	10
REBA. StandardDrivingPosition	Correlation Coefficient	.082	1.000
	Sig. (2-tailed)	.821	.
	N	10	10

			Nordic	RULA. Reaching
Spearman's rho	Nordic	Correlation Coefficient	1.000	-.256
		Sig. (2-tailed)	.	.475
		N	10	10
	RULA.Reaching	Correlation Coefficient	-.256	1.000
		Sig. (2-tailed)	.475	.
		N	10	10

		Nordic	REBA. Reaching
Nordic	Correlation Coefficient	1.000	-.489
	Sig. (2-tailed)	.	.151
	N	10	10
REBA.Reaching	Correlation Coefficient	-.489	1.000
	Sig. (2-tailed)	.151	.
	N	10	10

			Nordic	RULA. PaymentPosition
Spearman's rho	Nordic	Correlation Coefficient	1.000	-.171
		Sig. (2-tailed)	.	.637
		N	10	10
	RULA.PaymentPosition	Correlation Coefficient	-.171	1.000
		Sig. (2-tailed)	.637	.
		N	10	10

		Nordic	REBA. PaymentPosition
Nordic	Correlation Coefficient	1.000	.148
	Sig. (2-tailed)	.	.683
	N	10	10
REBA.PaymentPosition	Correlation Coefficient	.148	1.000
	Sig. (2-tailed)	.683	.
	N	10	10

Table 2 indicates the correlational analysis of the ergonomic assessment and drivers' physical discomfort. Through Spearman Rank Order correlation analysis, it was found that NMQ scores have a negligible correlation with RULA-Standard Driving Position scores (r_s=0.000;p=1.000), weak negative correlation with RULA-Reaching scores (r_s= -0.256;p=0.475), negligible negative correlation with RULA-Payment Position scores (r_s=-0.171;p=0.637), negligible positive correlation with REBA-Standard Driving Position scores (r_s=0.082;p=0.637), moderate negative correlation with REBA-Reaching scores (r_s=-0.489;p=0.151), and a weak positive correlation with REBA-Payment Position (r_s=0.148;p =0.683). The assessments of the three positions do not show any significant relationship with the physical discomfort experienced by the drivers.

The researchers speculated that the existence of other factors, such as fear of speaking out and a feeling of contentment, may contribute to the result of the correlation analysis. In the research that was published in the National Safety Council's Journal of Safety Research (Vol. 45), young employees said that they were unable to discuss safety concerns with their boss because they felt powerless (Johnson 2013). Furthermore, Hurt and Dye (2020) stated in their book that employees are silent because they do not believe that leaders are interested in their ideas, they lack the courage to speak up, and they believe nothing will happen. Drivers who took part in the research by Coz et al. (2015) stated that they are all satisfied with the current state of their workstations. However, the respondents all agreed that body aches and other discomforts are common after each working day. Similarly, in the study of Sekkay et al. (2021), 43.1% of drivers who took part in their research claimed to have had musculoskeletal pain in at least one body area over the previous 12 months. Drivers may assert that they are content with their present workstation, whereas data indicates that they are experiencing WMSDs.

In addition, similar to the research from the Journal of Cornea and External Disease, the results from the partial Spearman correlation analysis by Nichols et al. (2004) found that there is no significant relationship between the tests performed on their patients and the symptoms that those patients experience.

4.3 Design of the Improved Driver's Workstation

Table 3. Summary of the Drivers' Anthropometric Measurements

Dimension (cm)	Percentile			Standard Deviation
	5th	50th (Median)	95th	
Height	156.10	165.00	172.76	5.06
Upper Arm Length	27.06	33.00	39.75	3.85
Lower Arm Length	38.79	43.00	47.42	2.62

Upper Leg Length	46.42	51.00	57.31	3.31
Lower Leg Length	46.23	51.00	57.01	3.28
Reach	76.15	90.00	105.47	8.91

Table 3 provides a summary of the thirty-seven (37) drivers' anthropometric measurements. This was used as a basis for the improved workstation design. The 5th, 50th, and 95th percentiles were incorporated to determine the drivers' minimum and maximum dimensions. The data assisted the researchers in determining what needed to be changed and maintained based on the measurements of the existing drivers' workstations (Figure 5, 6).

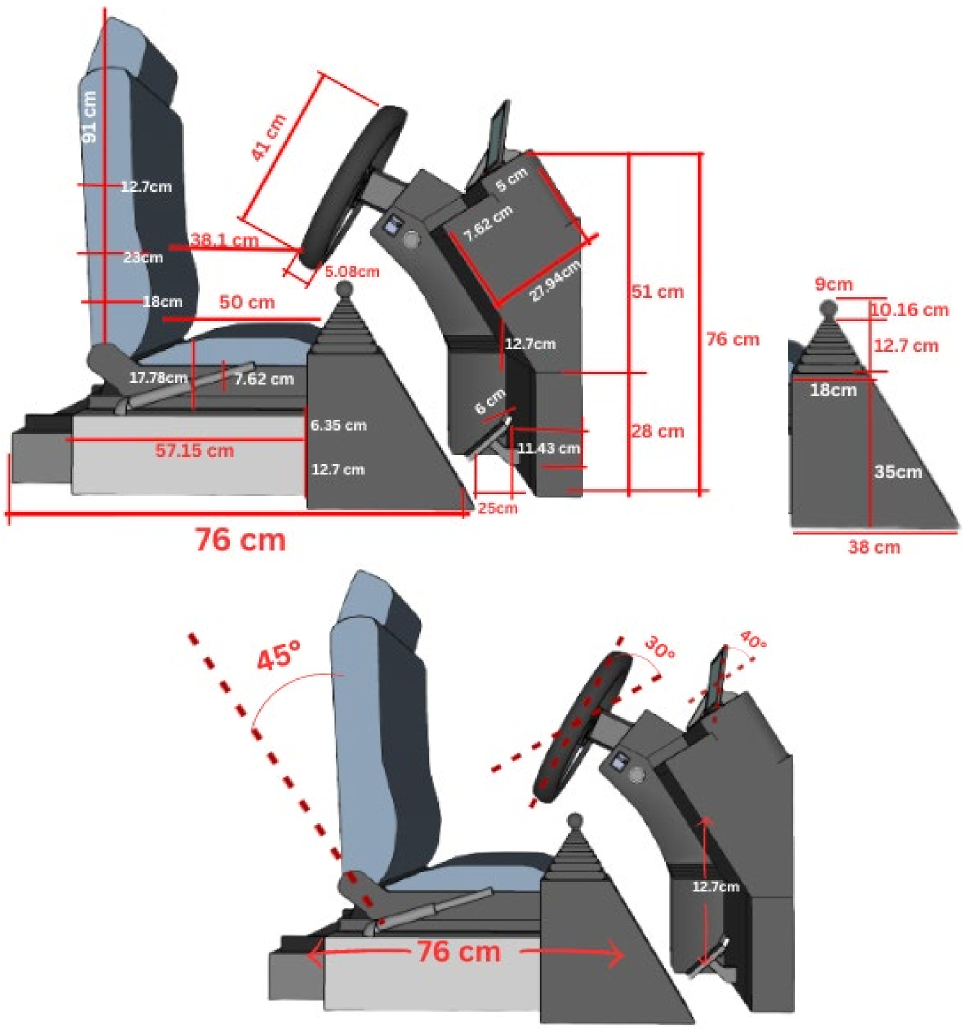

Figure 5. Workstation's Left Side View

Table 4. Dimensions of the Workstation

Components	Measurements (cm)	Characteristics

Driver's Seat	Backrest Height	91.00	Adjustable at 45 degrees	Horizontally adjustable by 76.0 cm; vertically adjustable by 12.7 cm
	Lumbar Support	18.00	Adjustable up to 23 cm	
	Seat Pan Length	50.00	Fixed	
Steering Wheel	Diameter	41.00	Adjustable at 30 degrees	Vertically adjustable by 12.7 cm
	Diameter of the grip	5.08	Fixed	
	Circumference of the grip	10.00	Fixed	
Gear Stick	Height	57.86	Fixed	
	Base	38.00	Fixed	
Dashboard	Height	76.00	Fixed	
Foot Controls	Acceleration control length	25.00	Elevated 11.43 cm from the ground	
	Clutch and brake control length	6.00	Elevated 12.7 cm from the ground	

Table 4 shows the dimensions of each component from the left-side view of the proposed design of the workstation. The researchers based the dimension on the anthropometric measurements of the drivers as well as the standard driving posture. As stated in Physio Med (n.d.), the driver's hips should be at least as high as his knees after adjusting the seat height. It's critical to confirm that the driver can still see the road, the devices, and the dashboard. Additionally, the seat should be positioned so that the driver can reach and fully depress the foot pedals without releasing the backrest. Throughout this process, the knees should ideally be slightly bent (Jen et al. 2015).

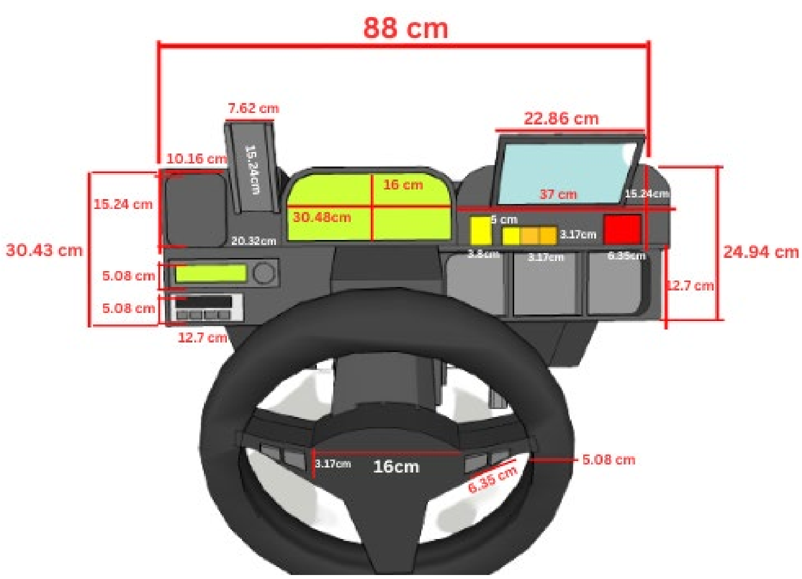

Figure 6. Dashboard

Table 5. Dashboard Dimensions

<table>
<tr><th colspan="2">Components</th><th>Measurements (cm)</th><th colspan="2">Characteristics</th></tr>
<tr><td rowspan="2">Phone Holder</td><td>Height</td><td>15.24</td><td colspan="2">Fixed</td></tr>
<tr><td>Width</td><td>7.62</td><td colspan="2">Fixed</td></tr>
<tr><td rowspan="2">Dashboard</td><td>Height</td><td>16.00</td><td colspan="2">Fixed</td></tr>
<tr><td>Width</td><td>30.48</td><td colspan="2">Fixed</td></tr>
<tr><td rowspan="2">CCTV Monitor</td><td>Height</td><td>15.24</td><td>Fixed</td><td rowspan="2">Adjustable at 40 degrees</td></tr>
<tr><td>Width</td><td>22.86</td><td>Fixed</td></tr>
<tr><td rowspan="2">Outdoor Light Switch</td><td>Height</td><td>5.08</td><td colspan="2">Fixed</td></tr>
<tr><td>Width</td><td>3.81</td><td colspan="2">Fixed</td></tr>
<tr><td rowspan="2">Indoor Light Switches</td><td>Height</td><td>3.175</td><td colspan="2">Fixed</td></tr>
<tr><td>Width</td><td>3.175</td><td colspan="2">Fixed</td></tr>
<tr><td rowspan="2">Warning Screen for overloading</td><td>Height</td><td>5.08</td><td colspan="2">Fixed</td></tr>
<tr><td>Width</td><td>6.35</td><td colspan="2">Fixed</td></tr>
<tr><td rowspan="2">Radio Controls</td><td>Height</td><td>5.08</td><td colspan="2">Fixed</td></tr>
<tr><td>Length</td><td>19.05</td><td colspan="2">Fixed</td></tr>
<tr><td rowspan="2">Aircon Controls</td><td>Height</td><td>5.08</td><td colspan="2">Fixed</td></tr>
<tr><td>Length</td><td>12.7</td><td colspan="2">Fixed</td></tr>
</table>

Table 5 provides the dimensions of the components that can be found on the dashboard. These are the controls that the driver's hands tend to use as they drive. The researchers arranged the components of the dashboard in a way that would prevent drivers from reaching them. UC San Diego (2021) stated that reaching could cause or result in increased WMSDs.

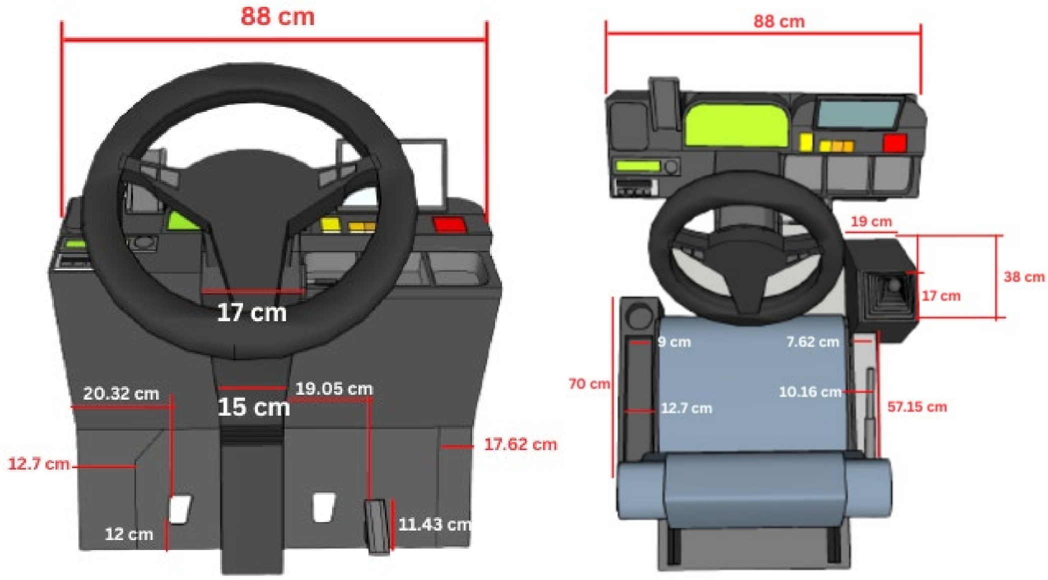

Figure 7. Workstation's Front and Top View

Figure 7 adds a more holistic perspective to the proposed ergonomically designed driver's workstation.

5. Conclusion

ABC Transport Service and Multipurpose Cooperative has two types of models for modern jeepneys. The movement of the driver slightly varies with the model of the unit the driver is using since the location of some controls differs from one model to the other. However, the researchers identified that with both models, reaching some controls is one of the problems encountered by the drivers during their work. The analysis found that one of the main reasons why the drivers experience work-related musculoskeletal pain and perform unsafe postures such as reaching is due to the existing design of the workstation, which is not based on the wide range of anthropometric measurements of the drivers.

From the scores of the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA), the result shows that further investigation and changes are needed to be implemented. Meanwhile, the Nordic Musculoskeletal Questionnaire results revealed that 46.11% of respondents experienced trouble with at least one body part, while 46.99% of that number had trouble during the last seven (7) days prior to the interview. The researchers determined that there is no significant relationship between the result of the assessment using RULA and REBA and the physical discomfort experienced by the drivers using the NMQ when correlated.

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Biographies

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Justine R. Modomo is a 4th-year graduating Industrial Engineering student at Manuel S. Enverga University Foundation, Philippines. During high school, he participated in a Filipino Action Research competition, became the Editor in Chief of the school publication, and represented the school as a candidate for the Honor Society of the Lambda Kappa Phi: Search for Benjamin V. Tan, Most Outstanding Male Student in Lucena City 2017. Recently in college, he represented the school as one of the participants in the group for the Inter-University Quiz Contest of the 13th Philippine Institute of Industrial Engineers—Calabarzon Student Chapter Regional Congress. Currently, he is a member of the Philippine Institute of Industrial Engineers—Manuel S. Enverga University Foundation Student Chapter.

Karl Justin N. Bariga is a 4th-year graduating Industrial Engineering student at Manuel S. Enverga University Foundation, Philippines. In his freshman year, he is one of the 12 students who were chosen to represent the College of Engineering Department in a basketball tournament held at the Manuel S. Enverga University Foundation, Philippines. Currently, he is a member of the Philippine Institute of Industrial Engineers—Manuel S. Enverga University Foundation Student Chapter.

Dr. James Louie Meneses is an experienced professor, consultant, industrial engineer, and researcher. As a professor, he teaches industrial engineering courses, including research, operations management, operations research, feasibility studies, and ergonomics. As a consultant, he works in industrial engineering designs, management, quality management systems, and data analysis. In his early professional life, he worked as a quality control engineer and management trainee in a manufacturing company. Currently, he is working as a full-time professor and a research coordinator at the Manuel S. Enverga University Foundation, Philippines. His role as a consultant is mainly related to the quality management system, quality, and system improvement. He works closely with researchers in data analysis, applying 1st- and 2nd-generation statistics (Structural Equation Modeling). His work as a researcher is mainly associated with using the lean six-sigma methodology, ergonomic design, and Partial Least Square Structural Equation Modeling (PLS-SEM). He holds a Doctor of Philosophy in Management from the Lyceum of the Philippines, Laguna, and earned his Master of Engineering, majoring in Industrial Engineering, at Adamson University. He presented his work in several research fora, where he was awarded best presenter and best research paper.

Engr. Jerico R. Amago is a certified industrial engineer who holds a bachelor's degree in industrial engineering. He is an experienced production engineer and quality control engineer with a demonstrated history of working in the manufacturing industry. In addition to his industry experience, he is also a lecturer at the Manuel S. Enverga University Foundation, Philippines, where he shares his knowledge and experience with the next generation of industrial engineers.