Case study

Workplace Efficiency Improvement for Jeepney Drivers in Metro Manila

Rosemary R. Seva, Jeric Daniel M. Axalan and Anne Rhea P. Landicho
Human Factors and Ergonomics Center, Industrial Engineering Department, De La Salle University, Manila, Philippines

Abstract

Background: The jeepney is the most popular means of transportation in the Philippines. A jeepney is a long utility vehicle, like a mini-bus, manufactured by local companies, that can accommodate from 13 to 23 passengers. The current design of jeepneys, however, exposes its drivers to musculoskeletal discomfort and unnecessary motion. **Aims:** The study aims to identify any physical ergonomic hazards in the jeepney driver's workspace and to develop an analytical model of the workspace that will address any identified hazards and improve driver comfort. The re-design aims to improve the awkward postures and eliminate the unnecessary tasks that are currently performed by jeepney drivers. **Method:** The dimensions of the jeepney were evaluated against anthropometric measurements previously collected from 100 drivers. Postures assumed by the drivers were evaluated using Rapid Upper Limb Assessment (RULA). An analytical prototype of the driver's workspace was developed using Computer Aided Three-dimensional Interactive Application (CATIA) software. A number of design considerations were included in two alternative options for the workspace re-design for the fare collection component of the driver's tasks and two alternative options were identified for the design of the money holder in the analytical prototype. **Results:** Based on the analysis conducted, the dimensions of the driver's workspace were not fitted to 95th percentile of the population. The workstation resulted in awkward driving postures which were identified using the RULA with scores of 3 and 4 for hands on steering wheel and hand on shifting gear, respectively. The action of reaching backward to provide passengers with change, as evaluated from the task analysis, was proven to be unnecessary. The proposed re-design of the jeepney driver's workspace was able to incorporate appropriate dimensions that enabled the proper location of vehicle controls, considering anthropometric constraints of reach, height, strength, and posture. RULA scores obtained from an analytical simulation showed a decrease in awkward postures. Responses by jeepney drivers were also favourable for the re-design of the fare collection system. **Conclusion:** The proposed re-design of the jeepney driver's workspace was able to address the problems encountered by drivers. However, there is a need to make a full-scale prototype in order to test its overall acceptability. This study may be used by future researchers to further improve the design of the jeepney. Manufacturers could also tackle issues of vibration and force exerted on the steering wheel, pedals, and while shifting gear, which can also influence driver discomfort.

Background

The jeepney is the second most popular means of transportation in the Philippines, comprising 30% of all registered vehicles in 2007 (1). The jeepney is a utility vehicle that is manufactured by local companies and is uniquely Filipino in its aesthetic design. Some jeepneys are bought newly manufactured, but approximately half of those plying the streets are reconditioned old units or manufactured from scrap materials and surplus parts. The design is usually customized by the owner in terms of body design and capacity. As such, jeepneys can accommodate from 13 to 23 passengers, depending on the length of the body. Jeepney drivers often work long shifts that can extend up to 18 hours, if the need arises. The length of the working hours is usually dictated by the owner of the unit and the earnings of the driver. Some drivers share the jeepney with other drivers, so may only work every other day. Often with shared jeepney arrangements, drivers may extend their driving hours to 18 and then rest the next day. One reason for the popularity of the jeepney is its low acquisition cost, durability, and large passenger capacity. The jeepney was designed for short distance travelling of about 1 to 1.5 hours. The passenger seats are not very comfortable, and the vehicle is usually cramped, when at full passenger capacity. Drivers have a tendency to overload the vehicle, especially during rush hours, in order to earn more. Within the jeepney, the driver's workspace was not designed with comfort in mind, so drivers can assume various positions in order to ease discomfort from static postures.

Since passengers often only spend a few minutes inside a jeepney, the focus of this study was on the comfort of the driver in the context of the tasks performed and their working environment. In Metro Manila, where there are many jeepneys, the driver also performs the task of a conductor. The driver collects the fare from each passenger, calculates the change required, if there is any, gets the correct change

Corresponding author: Rosemary R. Seva. Email – coers2000@gmail.com

from the money holder, and then reaches behind his head and hands any change to the passenger. The driver performs these activities countless times throughout the day, which is both physically and mentally exhausting. In a related study, Barayuga et al. (2) designed a seat for the jeepney driver aimed at easing the pain from the awkward postures they experience throughout the day. The authors attributed these pains to the poor design of the seat, which lacks adjustability, has no headrest, and is not often fitted to the driver's body dimensions. The current study, however, only focused on the driver's immediate workspace, seat design, and their physical comfort. The mental workload in collecting fares and returning change was not considered. Some ergonomics issues immediately apparent from the driver's work tasks were non-conformance of the workspace design to Filipino anthropometric dimensions; arm extension brought about by taking and giving change towards the back of the vehicle; and awkward driving postures, due to the location of the controls (Figure 1). This study aims to identify physical ergonomic hazards in the jeepney driver's workspace and to develop an analytical model of the workspace that would address any identified hazards and improve driver comfort. The final design should be able to reduce the impact of any ergonomic hazards brought by the workspace, in terms of driving posture, reaching for and changing gears, reaching backwards to provide change, and reaching the money holder.

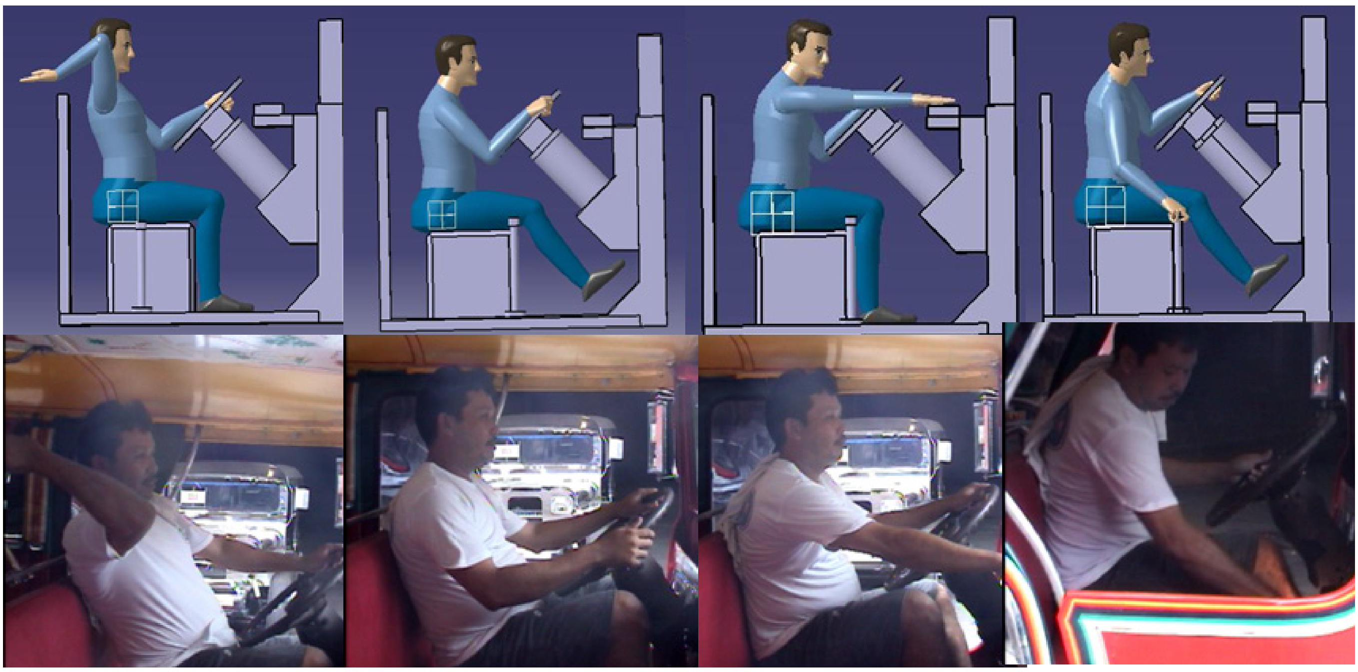
Method

Postural analysis

The first phase of the study involved understanding the problems encountered by drivers while driving and collecting fares. Postures of the drivers were observed and documented for further analysis using the Rapid Upper Limb Assessment (RULA). RULA is a survey method that is applicable in investigating seated workers (3). The method assesses biomechanical and postural loading on the body, with particular attention to the neck, trunk and upper limbs. It considers the angles formed by the limbs and rates them according to a coding system. The final score obtained from using the method determines the kind of intervention that needs to be conducted. Four likely postures of the drivers were analysed: (i) both arms on the steering wheel; (ii) right arm to the gear; (iii) taking payment from a passenger; and (iv) taking money from the money holder. These postures were chosen because they were awkward and could potentially be improved by changing the design of the workspace. Each posture was analysed using RULA and the average scores are shown in Table 1.

Table 1. *Posture scores*

Posture	Average RULA Score
Driving	3
Reaching gear	4
Reaching backward	6
Reaching money holder	5



Reaching Backwards   Driving Posture   Reaching Money Holder   Reaching Shifting Gear

Figure 1. *Driving Postures*

Anthropometric analysis

The workspace dimensions of the drivers were compared to anthropometric data of jeepney drivers gathered by Barayuga et al. (2). In their study, the authors gathered the anthropometric data shown in Table 2 from 100 jeepney drivers, who were all Filipino males aged 31 to 40 years old, and with 5 to 10 years of driving experience.

Table 2. *Anthropometric Data of 100 Jeepney Drivers*

Body Dimension	Mean (inches)	SD (inches)
Arm reach	30.7	2.1
Head circumference	22.3	1.8
Foot length	10.1	1.1
Foot width	4.1	0.7
Head to seat height	34.0	1.4
Eye height, sitting	30.1	1.8
Shoulder breadth	16.3	1.3
Hip breadth	16.1	1.1
Hand length	7.4	0.6
Hand width	4.3	0.5
Knee height	20.8	1.5
Popliteal height	18.7	2.2
Buttock to popliteal length	18.6	1.9
Buttock to knee length	21.9	1.6
Elbow to wrist length	10.8	1.0
Thigh clearance	6.1	1.3
Shoulder to elbow distance	12.6	1.2
Elbow rest height	9.7	1.7
Shoulder to seat height	22.4	1.7

Source: Barayuga EB, Castillo MA, Martinez MT. A Study on an Ergonomically Designed Jeepney Driver Seat. Manila: De La Salle University; 1997.

The anthropometric data from Barayuga et al. (2) was then evaluated with respect to the measurements of the current jeepney driver's workspace, according to static and dynamic dimensions. This was done because both static and dynamic dimensions required different analyses, such as placement of components and clearances for static dimensions, and the driver's fit during operations in the workspace. Eleven workspace dimensions were compared to the anthropometric data, but only five dimensions did not conform to either the 5th or 95th percentile dimensions as shown in Table 3. The 5th and 95th percentiles were used as a reference as these percentiles are commonly used in designing products for the majority of the population.

The clearance between the knee and the steering wheel was 5.5 inches. This amount of knee clearance is relatively small, wherein ease of access and exit of the jeepney driver is minimal because of the junction of the steering wheel. The minimum distance from the backrest to the steering wheel was taken from the lowest edge of the steering wheel. The lowest edge of the steering wheel may not have touched the knee by 2.1 inches, but the clearance between the chest and waist to the steering wheel was obstructed the jeepney driver. The reach of the steering wheel was attainable, but the distance was identified as too close to the driver. This distance was about the same as the knee clearance that tended the driver to bend his forearms and to be supported by the whole steering wheel (Figure 2). The lack of adjustability of driver's seat made the closeness of the steering wheel to the driver an obstruction in body clearance upon entering or leaving the vehicle.

Figure 2. *Jeepney Driver's Posture*

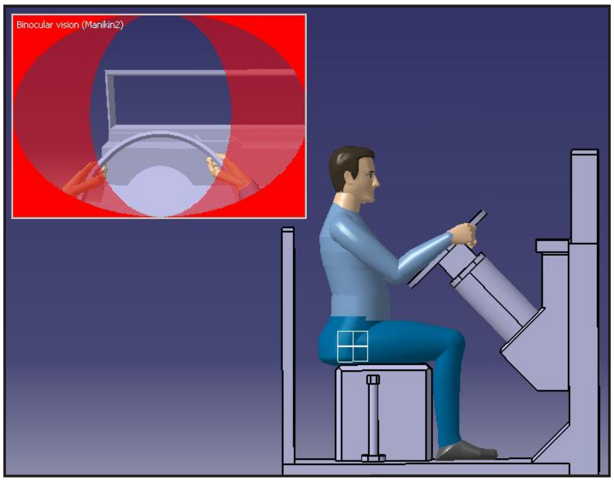


Figure 3. *Jeepney Driver Modeled Using CATIA*

Table 3. *Comparison of the Jeepney Driver's Workplace Dimensions to Anthropometric Data*

Workstation	Actual dimension (inches)	Body Part	Percentile	Required dimension (inches)	Gap (inches)
Distance from floor to steering wheel	29.0	Knee height	95th	23.5	5.5
Vertical distance from pedal to steering wheel	20.0	Knee height	95th	23.5	3.5
Minimum distance from backrest to steering wheel	15.7	Arm reach	5th	27.1	11.4
Seat breadth	17.5	Hip breadth	95th	18.0	0.5
Upper backrest width	17.0	Shoulder breadth	95th	18.0	1.0

The seat breadth was less than the hip breadth of the 95th percentile by half an inch. The seat breadth should be greater than the hip breadth in order to accommodate the driver's sitting comfort. The minimum seat breadth should accommodate the 95th percentile; this would allow the 5th percentile to also be considered.

Dynamic dimensions included functional arm reach and clearance. The dynamic dimensions were difficult to obtain, due to changes in body position, so the Computer Aided Three-dimensional Interactive Application (CATIA) software was used to simulate the movement of the driver in a modelled workspace. The 95th and 5th percentile measurements were used for the anthropometric measurements of the virtual, manikin driver. To analyse the functional arm reach of the jeepney driver, the 95th and 5th percentile were inserted into the modelled workspace with their corresponding reach envelope. The manikin driver was presented as sitting erect, looking straight ahead, and with both knees and ankles forming right angles as in Figure 3. This allowed a neutral sitting posture for the driver, without considering the inclination of the backrest. All reach zones were taken from the right hand as the minimum reach and middle finger for maximum reach.

Design process

The design process proposed by Hitchcock et al. (4) was followed in creating the analytical model of the jeepney using the CATIA software. This process involved seven stages:

1. Determine the body dimensions important in the design. These dimensions served as the basis for designing the layout of the workspace.
2. Define the population who will use the equipment or facilities. The users were the Filipino jeepney drivers in Metro Manila, who were male and of working age.
3. Determine what principle should be applied: design for extreme individuals and design for an adjustable range. The design for extreme individuals was deemed important both, in the placement of the components, as well as the measurement in height from floor to roof. Adjustable ranges were taken into account for the driver's seat when adjusting away from the steering wheel, and in the inclination of the back rest.
4. When relevant, select the percentage of the population to be accommodated. One of the objectives of the study was to provide a workspace that would fit for the 5th and 95th percentile of the Filipino drivers. Hence, these proportions were added in the design process.
5. Locate anthropometric tables appropriate for the population and extract relevant values. The anthropometric table used for jeepney drivers was obtained from Barayuga et al. (2).
6. If special clothing is to be worn, add appropriate allowances. The clothing or apparel worn by the drivers was negligible, hence clothing was assumed to be a non-hindrance to the driver in the workspace.
7. Build a full-scale mock-up of the equipment, or facility, being designed and have it tested by the intended users. Several analytical prototypes were generated based on suggestions obtained from observations and interviews with users. Each design was shown to a sample of drivers to determine its acceptability and practicality. All the necessary anthropometric data cannot substitute for a full-scale mock-up. However, in the early design phase, it is often the practice to use small-scale, virtual or physical models, such as an articulated model. The CATIA modelling software that assesses the adequacy of preliminary workspace designs, in terms of anthropometric considerations, was used to test the jeepney driver's workspace design for the intended user.

Various information sources were used to guide the factors that went into the final workspace re-design for jeepney drivers. These sources contained information on clearance, reach, vision, and posture. Functional requirements of the work tasks were also considered in the re-design, such as the ability to manipulate the gear shift, steering wheel, and pedals, which are the basic actions of the driver. Drivers must be able to manipulate these components, without exerting much effort or creating stress on their body parts. The visual workspace of the driver was also considered, as it is essential to driver and passenger safety. Aside from looking at the road (as their primary viewing direction), drivers need to look at the side view mirrors, rear view mirror, and at the money holder.

Results

Jeepney workspace design

Several alternatives were evaluated before arriving at the final analytical prototype of the driver's workspace, including the fare collection system. The final design is shown in Figure 4 which features a seat that conforms to the anthropometric dimensions of the Filipino drivers as computed in Table 4. The seat used for the model was designed in accordance to seat standards common in the automotive industry. The ergonomics of the seat for jeepney drivers has already been studied previously [2]. The seat design provides the driver with a comfortable driving position, and is able to be adjusted for comfort and to reach the controls with ease.

Table 4. *Seat Dimensions of the Jeepney*

Driver's Seat Dimension	Percentile to Consider	Body Dimension to Consider	Value (inches)
Seat height	5th percentile	Popliteal height	14.90
Seat length	5th percentile	Popliteal length	16.25
Seat Width	95th percentile	Hip breadth	18.00
Backrest height	95th percentile	Shoulder height	25.00
Backrest width	95th percentile	Shoulder breadth	18.00

The gear shift was designed as a component of the workspace that must be readily distinguishable by sight, or touch, and that would allow drivers to keep their control movements as short as possible. To determine the ideal location of the gear shift, the forward distance was measured horizontally from the seat reference point (SRP), where the back of the seat surface intersects the backrest in the midline. Since the backrest angle and the amount of permitted body movement both influence reach distance, Damon et al. (5) recommended

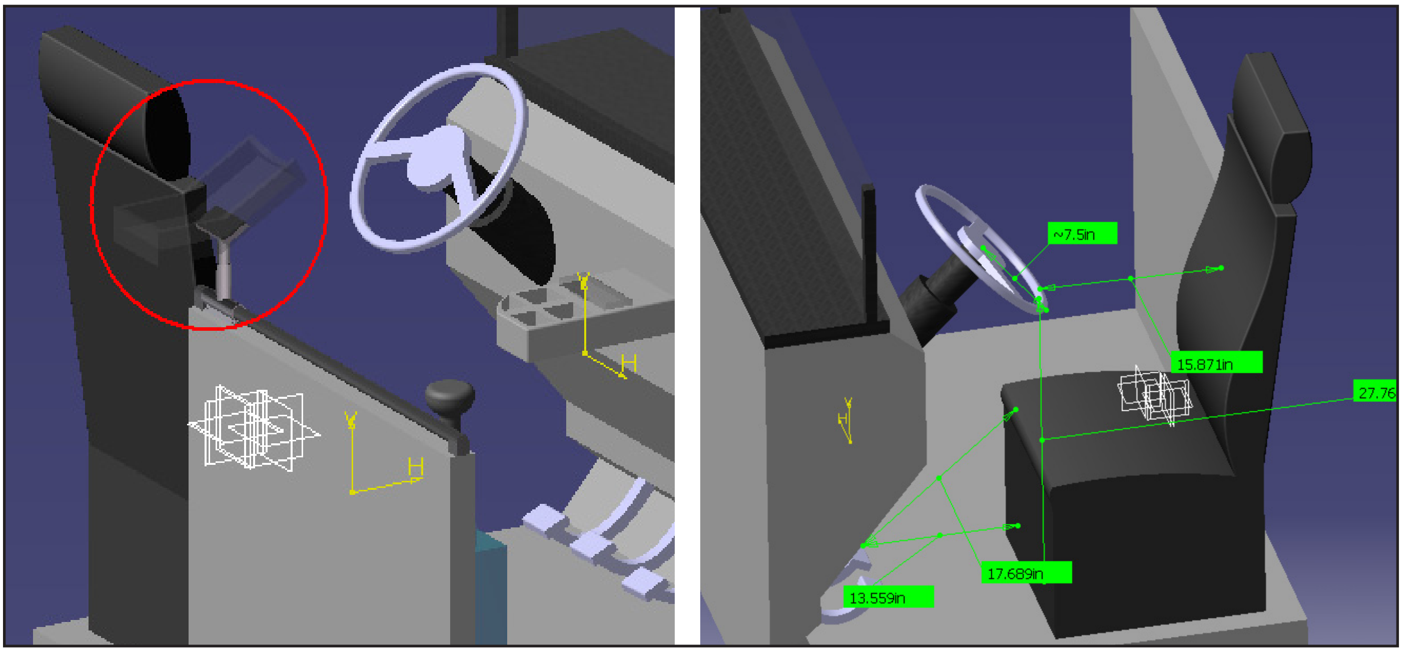


Figure 4. *Final analytical prototype of the jeepney workstation*

that measurements should be taken from the plane of the backrest, immediately behind the shoulder. Using these measurement reference points, the 5th percentile for arm reach for fore-and-aft locations was conducted, resulting in the gear shift location being ideally placed at no more than 27.10 inches from the SRP. Considering the 5th percentile hand breadth at thumb and based on the anthropometric data gathered by Barayuga et al. (2), the length of the hand grip should be at least 3.40 inches. However, Damon et al. (5) recommended that the minimum diameter should depend on the force exerted. Since users do not have to exert much force in the hand grip, the minimum diameter of 1.75 inches was used as recommended by Woodson et al. (6).

For the location of the steering wheel, the maximum reach of the 5th percentile functional arm reach was used, which was 27.10 inches. This was the location of the steering wheel from the shoulder of the driver to the centre point of the wheel. The distance measured from the tip of the steering wheel to the floor was 27.76 inches, which was based on a knee clearance of the 95th percentile, modelled in the CATIA software. However, it should be noted that the diameter and inclination of the wheel would depend on the vehicle type and force exerted on the steering wheel.

For the design of the vehicle foot pedals, Damon et al. (6) indicated that fore-and-aft SRP-pedal distance bears a definite relationship to leg length and consequently to stature. If maximum pressure is desired, then the distance should be about 47.5% of stature, when the pedal is 2.5 inches above the SRP. However, when greater force is not needed, the distance should be 55% of stature for comfort. In the design of the jeepney, it was assumed that maximum force was needed. This assumption was made due to the fact that the pedals of the jeepney are more difficult to press than those of automobiles. The dimensions of pedals are shown in Figure 5.

For the money holder, the design concept was to have a dashboard shaped like an 'L', so that the money holder was both easier to reach and was more visible to the driver. It was assumed that the driver would not to lean forward, but would maintain his driving posture when he was required to access the money holder. Figure 4 shows the 'L' shape modification of the dashboard and the money holder, placed to the right of the steering wheel.

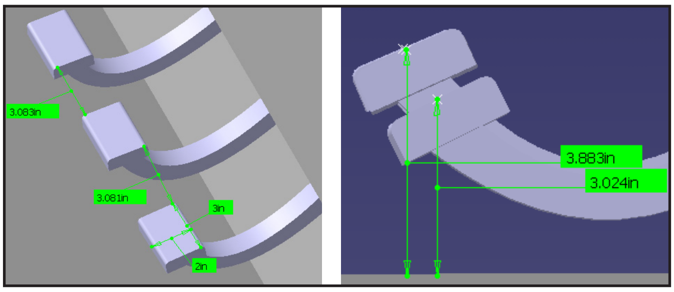


Figure 5. *Pedal Design*

Fare collection design

After considering several alternatives for re-designing the fare collection and change provision component of the driver's tasks, a back slide design was chosen to provide any required change to passengers, due to its simplicity, cost-effectiveness, and safety. In this design, the driver was provided with a change box, where passengers could place their fare, and the driver could retrieve money, without extending his arm. Since the change box was placed within the direct visual field of the driver, his peripheral view was still able to be focused on the road. The change box was elevated to a height that would be easily reached by the driver. The change box attachment could be clamped to the divider of the jeepney, as shown in Figure 6.

Design evaluation

Driver manikins were simulated while they rested on a backrest, which was inclined at 103 degrees. Since the re-designed workspace components had already been fitted with the body dimensions of the 5th and 95th percentile manikin, the static fit was achieved. Final workspace design was differentiated with the current workplace through calculating the workspace dimensions in relation to the anthropometric data. With the objective of closing the gap between the workspace dimensions and the different body measurements, the analytical prototype has attained the accommodation of the driver manikin in any body dimensions. Compared to the current workplace, the functional reach to all of the driver's task components was achieved, especially the placement of the money holder. Although all components were located closer to driver, this does not mean clearance was severely affected, because the components do not obstruct the functional movements of the driver in the workplace.

The postures of the virtual driver manikins were evaluated using RULA and the scores ranged from 2 to 3, depending on which part of the steering wheel was grasped. The RULA score of reaching for the gear shift improved, reducing from 4 to 2. Initial comments and suggestions from both the jeepney drivers and passengers were solicited to evaluate the fare collection component re-design. Drivers reported difficulty in adjusting the component to fit their seat height. However, upon accomplishment of set-up, drivers report that the task of receiving payment from the passengers was more convenient, since they did not have to extend their arm reach all the way back. On the other hand, passengers had some difficulty in receiving their change. This can be attributed to the fact that the surface of the prototype was flat and closed, which may require more effort when retrieving coins. There was also evidence of adjustment from the drivers in utilising the model. Two out of the five drivers tended to still wait for the passengers to retrieve their money, thus causing some delay, though only minimal.

Figure 6. *Final prototype of the proposed fare collection system*

Conclusions

Jeepney drivers in Metro Manila were likely to suffer from musculoskeletal discomfort, due to the poor design of their workspace and the system used for fare collection. Their current workspace did not conform to Filipino drivers' anthropometric measurements and the drivers were subjected to awkward driving postures, due to location of the controls and the task of collecting fares. The proposed re-design of the jeepney driver's workspace presented in this study was able to incorporate appropriate dimensions that enabled the proper location of controls considering anthropometric constraints of reach, height, strength, and posture. RULA scores obtained from analytical simulation showed a decrease in awkward postures. The re-designed fare collection component also earned positive feedback from drivers.

The results of this study may be used by future researchers to further improve the design of the jeepney. Other ergonomic-related issues still to be tackled are the vibration and force exerted on the steering wheel, pedals, and gear shift, which can also influence driver discomfort. Vibration is directly felt not only by the jeepney drivers, but also by the passengers. The jeepney drivers exert more effort in controlling the steering wheel, pedals, and in shifting gear, not only because of the materials used, but also because of their location inside the workspace. In relation to the fare collection re-design, further improvement can be made by improving the design of the exchange case, so that passengers would find it easier to take their change. Jeepney manufacturers could use the results of this study to enhance the design of the jeepney or may use the current findings to build life-size prototypes that could be tested further. It is expected that a life-size prototype would reveal unique findings that were possibly not obtained using the manikin simulation.

References

1. National Statistical Coordination Board. *Transport and communication*. 2009 [cited 2010 June 15]; Available from: http://www.nscb.gov.ph/secstat/d_trans.asp.
2. Barayuga EB, Castillo MA, Martinez MT. *A Study on an Ergonomically Designed Jeepney Driver Seat*. Manila: De La Salle University; 1997.
3. McAttamney L, Corlett EN. RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics*. 1993;24(2):91-9.
4. Hitchcock D, Haines V, Elton E. Integrating ergonomics: a practical case study. *Design Journal*. 2004;7(3):32-40.
5. Damon A, Stoudt H, Mc Farland R. *The Human Body In Equipment Design*. Cambridge Massachusets: Harvard University Press; 1966.
6. Woodson W, Tillman B, Tillman P. *Human Factors Design Handbook*. New York: McGraw Hill, Inc; 1992.