# Ergonomic Analysis of Tricycle Sidecar Seats: Basis for Proposed Standard Design

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**Asia Pacific Journal of Multidisciplinary Research**
Vol. 3 No.5, 58-67
December 2015 Part I
P-ISSN 2350-7756
E-ISSN 2350-8442
www.apjmr.com

*Date Received: October 31, 2015; Date Revised: December 10, 2015*

**Abstract –***Ergonomics (also called human factors engineering) is the study of human characteristics for the appropriate design of the living and work environment. It is applied in various industrial areas which includes transportation.Tricycle being one of the most common means of public transportation in Lipa City has various adaptations to suit the culture, and environment. The purpose of this study is to analyze the variability in design of the tricycles in Lipa City, Philippines and propose a standard ergonomically designed tricycle sidecar seat for a greater population.*

*The study was conducted at 26 tricycle terminals with 232 tricycle samples within Lipa City proper including the public market area where 400 commuters were given questionnaires to determine the risk factors associated with the existing tricycle sidecar seat design. Anthropometric measurements of 100 males and 100 female commuters were obtained together with the sidecar dimensions of 232 tricycles to substantiate the observed variations in design.*

*Using the design for the average and design for the extremes, it was found out that most of the tricycles in Lipa City, Philippines have inappropriate inclined seat and lowered sidecar seat pan height which can result to leg and abdominal pain; narrowed seat pan depth which caused pressure on buttocks and legs; narrowed backrest width which can cause upper and low back pain; low backrest height that can pose upper back pain; which can also result to abdominal pain; inclined backrest and limited vertical clearance which can cause upper back pain and neck pain. The researcher proposed a sidecar seat design standard which can be used by the Land Transportation Office, and Land Transportation Franchising and Regulatory Board to provide ease, comfort, and convenience to the passengers.*

**Keywords –** *Ergonomics, Anthropometry*

## INTRODUCTION

Ergonomics (also called human factors engineering) is the study of human characteristics for the appropriate design of the living and work environment [1]. Its fundamental aim is that all human-made tools, devices, equipment, machines, and environment should advance, directly and indirectly, the safety, well-being, and performance of human beings. This includes anthropometry, an applied discipline which is one of the cores of ergonomics.It commands ergonomic analysis which intends to design things to "fit" the human body, and therefore achieve its ultimate goal of generating "optimal" conditions which are so well adapted to human characteristics, capabilities, and desires, that physical, mental, and social well-being is achieved.

Human Factors Engineering or Ergonomics is applied in various industrial areas which includes transportation.It is evident that some of the vital artefacts of our daily lives are used to assist human activity and mobility. Design of cars, trains, ships, boats, planes, etc. is exhibited to enable the users an efficient, effective, and safe transportation [2].

The local three-wheelers also known as tricycle plays a vital role in the existing public transportation hierarchy in provinces and municipalities. In most cases, tricycles may be one of the first things that come to mind when one thinks about convenient mode of transportation in the Philippines. Tricycle is one of the most common modes of public transportation in Lipa City, Philippines but it was observed that tricycles in the City differ in forms, style, color, and/or design. There is an increasing number of tricycle franchises making the tricycles the most visible vehicles in the streets. Based on the Local Government Code, franchises are granted by

the Local Government Unit (LGU) which in turn is also responsible in supervising the operations [3]. However, the absence of a comprehensive policy that will address the problems faced by the local tricycles has been a perennial problem in Lipa City.

In response to this concern, the proponent became interested in analyzing the varying designs which spell out the lack of policies and guidelines, and implementation of engineering principles. This study aimed to evaluate the variations in dimensions of the existing tricycle sidecar seats within Lipa City and propose a standard design using risk factors determination associated with the existing design, and the anthropometric measurements of sample passengers as important inputs.

The results of the study would help the Land Transportation Franchising and Regulatory Board (LTFRB) and Lipa City MOTORPOOL department to set necessary guidelines to implement a standard design for tricycle sidecar passengers' seat. This would also provide necessary insights and information for planning and implementation of the proposed standard design.

The study would serve as a guide in analyzing the effectiveness of the design and provide ideas and information that will be useful in decision making regarding the existence of varying designs of tricycles, or the emergent need for redesign.Also, the findings of the study will create awareness on the risk factors experienced in riding a tricycle. Moreover, the output of the study will be a basis to help prevent such risk factors by providing a design that will provide commuters a convenient and safe ride.

## STATEMENT OF THE PROBLEM

This study aimed to deliver a proposed standard tricycle side car seat design. Further, the study sought to answer the following questions:

1. What specific guidelines do LTFRB and MOTORPOOL use for public utility vehicles, specifically for tricycle franchising?
2. What problems do commuters encounter while riding on a tricycle?
3. What are the variations of the existing tricycle sidecars' seat design in terms of Seat pan height, Seat pan depth, Seat back height, Seat back width, Sidecar's vertical clearance, and Seat cushion and upholstery?
4. What are the anthropometric measures of the commuter samples in terms of Popliteal height, Buttock-to-popliteal length, Sitting shoulder height, Shoulder breadth, and Sitting height?
5. What standard design of tricycle sidecar seat may be proposed to LTFRB and MOTORPOOL for franchising?

## METHODS

This research focused on establishing an ergonomically designed tricycle passenger's seat which will provide convenience and comfort to commuters by reducing the risks of improper or awkward sitting posture.

The researcher used case study and developmental type of research which involved gathering primary data by determining the passengers' observations on the varying designs of tricycle and their personal tricycle ride experiences.

This study was conducted at Lipa City Public Market particularly on the 26 tricycle terminals and some other areas within the vicinity with a total of 232 tricycle samples. Four hundred (400) commuters were given questionnaires adapted from the Nordic Musculoskeletal Questionnaireto screen risk factors, discomfort, and symptoms on some body parts relative to the existing design.[4]To gather the essential data, the researcher conducted interviews with the person-in-charge at the Lipa City Franchising Division for the total number of registered tricycle franchise as well as the number of tricycle terminals in the public market.

The researcher has also interviewed personnel from the engineering department with regard to the guidelines for tricycle inspection.Survey was conducted using the self-constructed survey forms. In addition, the proponent measured the passenger's seats to determine whether the dimensions are within the acceptable design.

The ergonomic analysis necessitates the researcher to use anthropometric data. The main purpose of measurement and estimation of anthropometric data is to design "machines" which enhance the fit with the intended users. By enhancing, it is meant that the design improves the operator or user's comfort, thus, reduces the strain experienced by the body while working in the environment.[5]The researcher obtained the anthropometric data of the two hundred commuters, (100 females and 100 males). Anthropometric measurements obtained are thepopliteal height,buttock-to-popliteal length, sitting shoulder height, shoulder breadth, and sitting height. These measurements are used as basis in the

ergonomic intervention on the existing tricycle sidecar seat design [6].

The following figures represent the anthropometric measurements taken from the research participants.

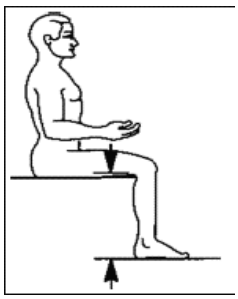

Figure 1. Popliteal Height

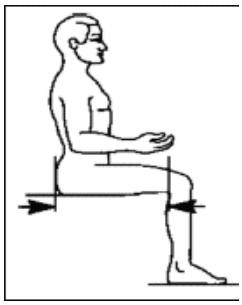

Figure 2.Buttock-to-popliteal length

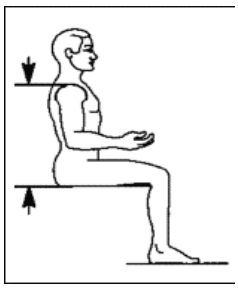

Figure3. Sitting Shoulder Height

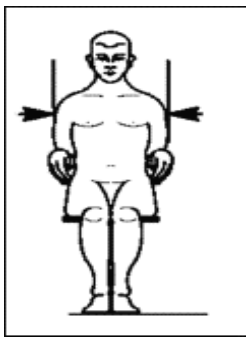

Figure 4. Shoulder Breadth

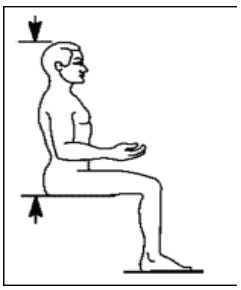

Figure 5. Sitting Height

The researcher determined the existing measurements of the design of tricycle's passenger seats with respect to the backrest width, backrest angle, seat pan depth, seat height, sidecars' vertical clearance(sitting height), and horizontal clearance from the seat edge to the sidecar front edge.A survey to the commuters in different areas of Lipa City was conducted. The researcher obtained the anthropometric measurements of the commuters which were used as basis to evaluate the existing design of the sidecar seats, and basis for ergonomic design intervention.

The mean *m* (commonly called the average) and the standard deviation were computed to come up with a design that will fit the commuters.

A normally distributed set of *n* data is described by two simple statistics: The 50$^{th}$ percentile is, by definition, the same as the mean m. Mathematically,

$$m = \frac{\sum x}{n'} \qquad (1)$$

Where $\sum x$ is the sum of the individual measurements. The standard deviation *SD* describes the distribution of the data:

$$SD = \sqrt{\frac{\sum(x-\overline{x})^2}{(n-1)}} \qquad (2)$$

To calculate a percentile value *p* of a normal distribution, the standard deviation is multiplied by a factor *k* selected from the Probability Distribution and Percentile Table from Mean and Standard Deviation.[7]Then the product is subtracted from the mean if *p* is below the average value:

$$p = m - kSD \qquad (3)$$

If *p* is above the average, add the product to the mean:

$$p = m + kSD \qquad (4)$$



P-ISSN 2350-7756 | E-ISSN 2350-8442 | www.apjmr.com
Asia Pacific Journal of Multidisciplinary Research, Vol. 3, No. 5, December 2015

Table 1- Factor *k* For Computing Percentiles From Mean X and Standard Deviation S

| | Percentile *p* associated with X | |
|---|---|---|
| *K* | X = X - *k*S | X = X + *k*S |
| 2.576 | 0.5 | 99.5 |
| 2.326 | 1 | 99 |
| 2.06 | 2 | 98 |
| 1.96 | 2.5 | 97.5 |
| 1.88 | 3 | 97 |
| 1.65 | 5 | 95 |
| 1.28 | 10 | 90 |
| 1.04 | 15 | 85 |
| 1 | 16.5 | 83.5 |
| 0.84 | 20 | 80 |
| 0.67 | 25 | 75 |
| 0 | 50 | 50 |

The researcher used the Design for the Extreme and Design for a Range. The fifth percentile was used to determine the dimension that will fit to the shortest person taken from the sample. On the other hand, 50$^{th}$ percentile was used in designing for the average person and 95$^{th}$ percentile was used in designing for the tallest person represented in the sample. Design for the extreme individual is used based on the extreme size of an anthropometric variable(s) that the potential current user population possess while design for a range depends on the component or item being designed where researcher may decide to use another suitable range [5].

## RESULTS AND DISCUSSION

### LTFRB and MOTORPOOL Guidelines

Based on the specified requirements listed in the form securedfrom the LTFRB, tricycle operators/owners may acquire franchise provided that they furnished all the major requirements needed including Certificate of Registration and Official Receipt.

The MOTORPOOL department at the City Engineering Office conducts the tricycle inspection. However,it was found out that tricycle design specifically the dimensions of the sidecar passenger's seat is not included in the checklist of items inspected.Instead, the chassis, electrical wirings of the tricycle and sidecar color are inspected. This only proves that LTFRB has notthedimensions of tricycle sidecar seatsin their guidelines which could be a basis for granting franchise to the applicants, hence, resulting to variations in design.

### Risk Factors

The researcher also performed a survey in order to gather information about the risk factors associated with the existing design of tricycle sidecar seats. The respondents of the survey were the tricycle commuters at different areas in Lipa City.

Based on results of the survey,31% of the respondents had a tricycle ride on a daily basis. This indicates that tricycle is typically used as means of transportation in Lipa City.It was also found out that 63.75% of the respondents' trip last for 10-15 minutes. This shows that most of the tricycle commuters are exposed to prolonged sitting.Most of them have observed and experienceda lowered seat which is identified as a design problem reported to be 43%. This signifies that there is a need for improvement of the existing design of sidecar's seat primarily with the seat height.

The study has identified a high percentage of design problemsamong lowered seat tricycle which is the primary cause of leg pain and lower back pain experienced by the commuters. The second most observed design problem with a score of 28% is associated with the awkward sitting position. Some other design concerns are the neck and upper back pain experienced by the commuters.In line with this, most of the commuters experienced pain on the lower-back with a percentage of 33.38%. Next is leg-pain experienced by 24.20% of the commuters. Third is the neck area where the pain was felt. The fourth is the upper-back area and the least pained part of the body is the abdomen. This indicates that the commuters are exposed to risk factors by sitting on a "lowered" passenger seat.It was also found out that 86% of the respondents experienced moderate pain, while 8.5% expressed very painful suffering and 5.5% did not feel pain at all. It can be interpreted that passengers experience pain and discomfort by regularly riding on tricycles with design issues.

This study was conducted in order to address the experienced discomfort and inconvenience, and to lessen the exposure to risk factors by proposingergonomic design interventions.The survey results convey that 57.5% of the respondents expressed the pain experienced to be very risky. Also, 28.50% of the respondents have expressed a moderate risky on the pain felt. This only manifests the riskexposures due to design problems in the tricycle sidecar passengers' seat, thus improvement is needed.

Moreover, 85% of the respondentshave expressed the need to modify the existing design of tricycle. This

further justifies that commuters are not satisfied on the existing design.

1. Tricycle Sidecar Seat Design vs.
2. Anthropometric Measurements

In order to come up with an ergonomically designed tricycle sidecar seat, the researcher used the data gathered from tricycles and commuters. Based on the evaluation done by the researcher, the present design of tricycle sidecars do not fit into the anthropometric measurements obtained from the commuters.An interview is conducted with thesupervisor of a known tricycle sidecar fabrication shop in Lipa City, Philippines. It was found out that tricycle sidecar design was based on the owner's/operator's desired dimensions.

The seat pan depth that the proponent used is 18.35 inches based on the 50$^{th}$ percentile value of female commuters. Thus, based on the 232 tricycle samples no existing design on the seat pan depth fits the commuters based on the commuters' buttock-popliteal-length.The seat back width which is 33.40 inches based on the 50$^{th}$ percentile of female commuters does not fit to the existing design of tricycle seat back width in Lipa City with respect to the shoulder breadth.

The proponent used 36.80 inchesfor the sidecar's vertical clearance based on the 95$^{th}$ percentile values. Based on the calculated score, it was found out that no existing tricycle sidecar sitting height fits the commuters' anthropometric sitting height.

Tricycle sidecar seat back height should accommodate the 95$^{th}$ percentile of male commuters with respect to their sitting shoulder height. The proponentused 25.99 inches based on the 95$^{th}$ percentile. Therefore, no existing tricycle sidecar seat back height fits the commuters.

**Ergonomic Intervention - Proposed Design**

Based on the results of the survey, 13% is accounted to inclined tricycle sidecar passenger's seat design problem while 28% is accounted to awkward sitting position.

The Figure 6a shows a passenger seated on an inclined, and limited vertical clearance tricycle sidecar's sitting height. These problems on the existing design of tricycles in Lipa City causes neck pain due to awkward sitting position and upper back pain because of too much inclination of seat that could not support the backrest while having a sitting position as shown in the figure.

Figure 6a. Passenger experiencing a limited vertical clearance and backrest

To come up with an ergonomically designed tricycle sidecar vertical clearance, the researcher measured the commuters' sitting height. To prevent such risk factors, the proposed sidecar's sitting height should be 36.80 inches to accommodate the 95$^{th}$ percentile commuters with respect to their sitting height illustrated in the following Figure 6b. The proponentused this to ensure that most of the commuters will not experience awkward sitting position with associated neck and upper back pain.

Figure 6b. Proposed design

Based on the result of the survey, problem on narrowed seat tricycle sidecar passenger's seat design accounted to 16%.

The following Figure 7a shows two commuters seated on a narrow sidecar seat. As shown in the figure, both passengers donot have a good sitting position. The commuters could not use the seat backrest for support which can cause upper and lower

back pains.In relation to this, the researcher measured the commuters' shoulder breadth to come up with an ergonomically designed seat back support width.

Figure 7a. Narrow passengers' seat for two passengers

The result of the analysis necessitates the modification on the tricycle's "basic shell". The basic shell defines the minimum space where two normal sized adult commuters could be accommodated comfortably while seated inside the tricycle [8]. Therefore, the proposed seat back width is 33.4 inches based on the 50$^{th}$ percentile for female with respect to their shoulder breadth as shown in the following Figure 7b . The proponent's design is not based on the 5$^{th}$ and 95$^{th}$ percentiles because it will be too narrow for two passengers to sit if the design is based on the 5$^{th}$ percentile. On the other hand, it will be too wide for a tricycle sidecar passenger's seat if design is based on the 95$^{th}$ percentile.

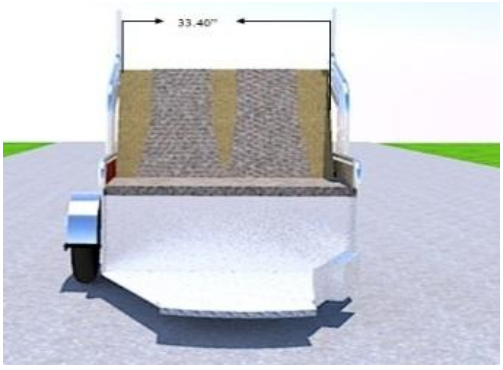


Figure 7b. Proposed passengers' back support width

Based on the result of the survey, lowered seat tricycle sidecar passenger's seat designwhich is the topmost design problemwith 43% share based on the responses of the research participants.

The next figure 8a shows a commuter seated on a lowered sidecar seat. Sitting on a lowered seat caused leg pain especially to female commuters. Being a conservative Filipino woman, sitting on a lowered seat has tendency to keep the legs inclined sideward through the entire trip which is a painful position. Associated pain such as abdominal pain occurs with this kind of position. In this case the "large knee and hip angles became uncomfortable and the spine is flexed as the pelvis rotates backward when a seat is too low. Also, abdominal organs are compressed when sitting in a too low seat because the commuters have the tendency to lean forward [9].

Figure 8a. Commuter seated on a lowered side car

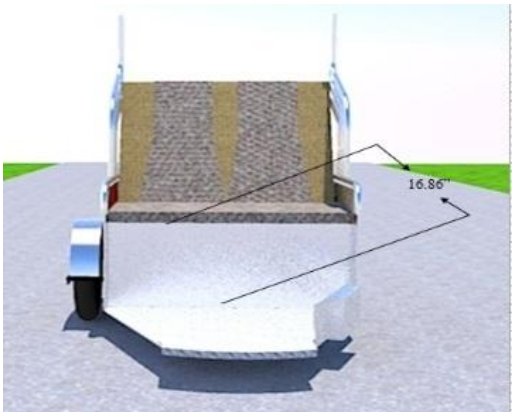


Figure 8b. Proposed Seat pan height

Thus, researcher measured commuters' popliteal height to come up with an ergonomically designed sidecar seat pan height shown in Figure 8b. The proposed seat pan height based on the evaluated data is 16.86 inches derived from the 50$^{th}$ percentile for female with respect to commuters' popliteal height. The proponent did not consider the design for the extremes because if the 5$^{th}$ percentile will be used, it will be too low for the 95$^{th}$ percentile woman and man. On the other hand, if the 95$^{th}$ percentile will be

used, it will be too high for the 5th percentile woman and man commuters, thus, having a sitting position with feet off the sidecar's floor.

Based on the result of the survey, 13% is accounted to inclined seat design problem of the existing tricycle design. The next figure 9a shows a commuter seated on an inclined sidecar seat. This kind of sitting position causes abdominal pain due to compression between the body trunk and the inclined buttock-knee.

Figure 9a. Passenger on an inclined seat

Figure 9b. Typical seat design

The proponent suggested a seat and backrest cushion with a thickness of 1.5 inches with leather upholstery to make the sitting comfortable since most of the seats and backrest are made of plank making it uncomfortable because the passengers usually feel that they are seated on a plain plank only [10]. This improvement will ensure the "feel"; a comfortable physical contact between the sitter and the seat while supporting the pressure distribution. The cushion should be deflected evenly across a lateral section at the hips [11]. Also, the proponent used an angle of five degrees for seat pan inclination for better backrest contact based on the seat design criteria recommending 5 – 10 degrees inclination [12].

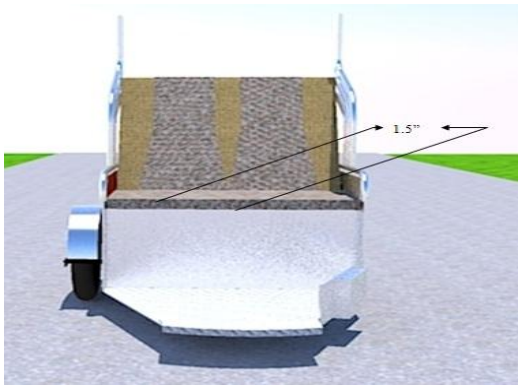


Figure 9c. Proposed seat design

Upon observation, the proponent has also identifiedsome other concerns on thesidecar seat pan which is considered not ergonomically designed for the commuters.The following figure 10a shows a tricycle sidecar seat with short seat pan depth. The seat pan is the portion of the seat which supports the weight of the buttocks. Thus, a short seat pan does not fully support the weight of the buttocks of the commuters which gives pressure on the legs [9]

Figure 10a. Short seat pan depth

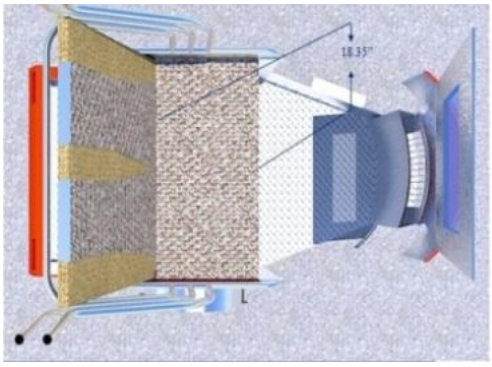


Figure 10b. Proposed dimension for seat pan depth

To establish an ergonomically designed tricycle sidecar seat pan depth, the researcher measured the


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commuters' buttock-popliteal-length. The proposed seat pan depth is 18.35 inches based on the 50th percentile for female.The proponent considered the designed for the average and not on the extremes 5th and 95th percentiles because upon analysis, designing seat pan depth based on the 5th percentile of woman will be too narrow for the 95th percentile male and female commuters. On the other hand, designing for the extreme will not accommodate the 5th percentile woman and man, thus it will be difficult for them to use the backrest. The seat pan depth is taken into account in such a way that commuters can properly sit and reach the backrest for support.

The following Figure 11 shows the backrest which is 25.99 inches in height to accommodate the 95th percentile commuters based on their sitting-shoulder height. With this, 5th and 50th percentile commuters will experience a full back support which is based on seat design criteria; the higher backrest gives better trunk weight support.

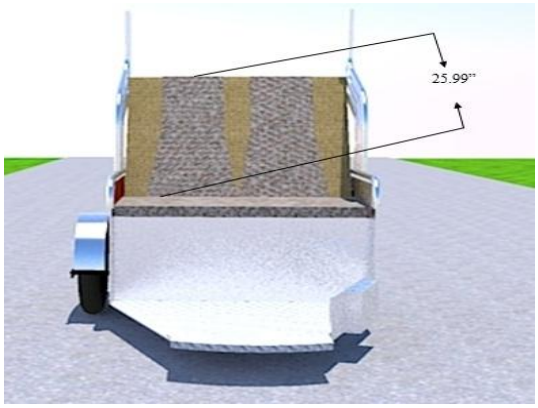


Figure 11. Proposed back rest height

On the other hand, for the 95th percentile commuters it will be a medium level back support which is based on the seat design criteria which is about 26 inches high. Also, the proposed seat back angle is 100 degrees based on the recommended seat back inclination of 90 to 110 degrees.Proper seat back inclination helps stimulate blood flow and relieve the pressure on the spine. Approximately 40% of the stress on the spinal disc may be reduced.[13]

Upon evaluation of the data gathered from the existing design of tricycle sidecars' seat in Lipa City, the researcher came up with an ergonomic intervention which is a proposed sidecar seat design for ease and convenience of the commuters.

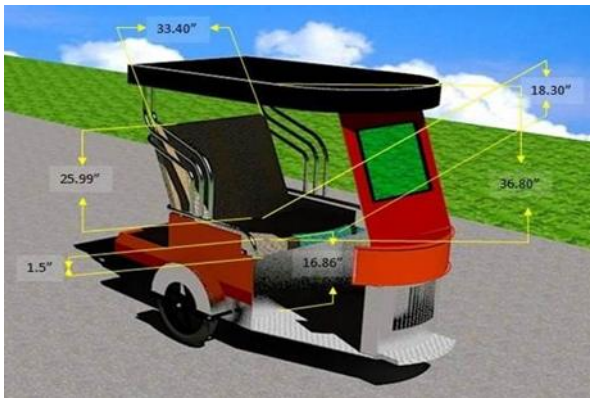


Figure 12. Proposed side car design

The proponent also considered the sitting capacity of the tricycle sidecar which is only designed for twocommuters only. The integrated tool box inside the sidecar which is perpendicular to the passenger seatshall not be used for sitting purposes on the proposed design. Moreover, the proposed design is not retroactive in effect. It will be implemented for those operators who will replace the old tricycles sidecars or those who will be acquiring new tricycles sidecars.


Figure 13. Proposed tricycle side car design

With the proposed ergonomic design intervention, there will be minimal cost adjustmentsfrom the current design considering the materials to be used in modifications of tricycle sidecar seat. However, the cost associated with the proposed design will be satisfactory and justified with the ease, comfort, convenience, and safety it will provide to the commuters.

## CONCLUSION

From the result of the analysis in the data obtained from 232 tricycles at different terminals in Lipa City,

and the anthropometric measurements of 200 commuters, the following conclusions were drawn:

1. LTFRB and MOTORPOOL's leniency and the inability to provide uniformed set of standards and guidelines resulted to continuous existence of variations on the tricycle sidecar seat design in Lipa City, Philippines.
2. Based on the proponent's data of tricycle dimensions, the existing design of sidecar seats, do not fit the commuters anthropometric measures therefore exposing the passengers to risk factors specifically, awkward posture.
3. There are variations in the sidecar seat design of the existing tricycles in Lipa City, particularly in terms of seat pan height, seat pan depth, seat back height, seat pan width, vertical (roof) clearance, and the cushion and upholstery.
4. Ergonomically designed seat pan height and inclination can prevent leg pain, low back pain and abdominal pain. Based on the evaluated of data gathered, the proposed seat pan height should be 16.86 inches based on $50^{th}$ percentile of female commuters. Also, properly designed seat pan depth can prevent buttock-to-popliteal pain andproposed to be 18.35 inches based on the $50^{th}$percentile women.It is also drawn from the study that the seat back height and width should be designed to accommodate the commuters sitting shoulder height and shoulder breadth to prevent back pain.The proposed dimension should be 25.99 inches based on the $95^{th}$ percentile of commuters and 33.40 inches based on the $95^{th}$ percentile of female commuters. Lastly, sidecar sitting height should be designedergonomically to prevent upper back pain and neck pain. Using the data collected, the proposed design should be 36.80 inches based on the $95^{th}$ percentileto accommodate tall commuters.
5. Tricycle sidecar seat design should fit the commuter's anthropometric measures. The proponent's proposed design was based on the results obtained from the commuters, thus, reducing if not eliminating the identified risk factors.Furthermore, satisfaction on riding on a tricycle does not only rely on how fast the commuters reach their destination but also on how comfortable and safe thecommuters were in their journey.

## RECOMMENDATIONS

In order to prevent risk factors and pains associated with sitting in a non-ergonomically designed tricycle sidecar passenger's seat, the following are recommended:

1. The proposed design is recommended to the Lipa Tricycle Franchising and Regulatory Board (LTFRB) in Lipa City which provides input or basis in setting standards for the design of tricycle sidecar passenger's seat as amajor requirement in securing tricycle franchise.
2. The proposed design is recommended to the MOTORPOOL department to be incorporated in the inspection guidelines of tricycle sidecar seats to ensure that operators/owners will comply with the design, thus avoiding design variations.
3. The design is also recommended to tricycle fabricators that will develop the prototype of this proposed design for commuters assurance that the tricycle sidecar seats will be assembled based on the standard design.
4. Although not retroactive in effect, the result of the study may be used as guidelines for those operators/owners who will apply for new franchise as well as those who will transfer the franchise from old unit to new one. By doing so, it will not contribute on the existing problem of tricycle sidecar seat design in Lipa City.
5. Disseminate information to the commuters in order to create awareness to safety relative to the existing design of tricycle sidecar's seat in Lipa City, and the associated risk factors.
6. It is also recommended to use the data gathered by the proponent with respect to sitting height of the tricycle commuters to establish a head clearance for the back-ride passengers.
7. The conduct of further studies on the whole structure of the tricycle including materials and their specifications is needed in response to continuous improvement to establish a whole structured ergonomically designed tricycle.

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