Overall Improvement for the Design of Motorized Tricycles in the Philippines - An Ergonomic Study

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Abstract

This thesis study is embodied on motorized tricycles in the Philippines for public utilization. Motorized tricycles is a common mean of passenger transport everywhere in the Philippines, it is the most popular means of transport in small towns and cities, especially in the rural areas. Unfortunately, the increased volume of commuters has also translated into higher number of complaints and even accidents, according to statistics compiled by the Philippine Pediatric Society, 54% of all injuries in the Philippines occur in the streets. Given the severe situation, this study aims to determine the factors that affects the comfortability of the passengers, to apply performance measures in order to determine best design of the motorized tricycle, to apply ergonomic solutions that would minimize discomfort experienced by the passengers, and to develop a prototype of an ergonomically designed motorized tricycle, that would be a standard blueprint, in the Philippines. These are achieved by conforming to the needs of the passengers via utilized ergonomics. The prototype of this tricycle has been fabricated. The discovered true factors—anthropometrics, biomechanics, and noise—were considered in the proposed motorized tricycles at the design stage.

Keywords
Tricycles, Comfortability, Ergonomics, Passengers and Scaled Prototype.

Introduction
Commuting in the Philippines is very much a part of the Filipino lifestyle. Riding motorized tricycles is a common mean of passenger transport everywhere in the Philippines. Unfortunately, the increased volume of commuters has also translated into higher number of complaints on experiencing discomfort and even accidents. Comfortability is one of the main aspects in the field of Ergonomics and a thriving application of this study is on public utility vehicles where most of the population is affected. There have been many published studies that dealt with improving vehicles in an ergonomic approach. Certain of which are Landicho's and Navarro's improvement on the driver's workstation area in jeepneys and motorized tricycles respectively. Previous studies only considered the welfare of the drivers and neglected the passengers. This thesis aims to design and fabricate a scaled prototype motorized tricycle to improve comfortability of eliminate significant factors that affects it. The passenger samples of this study underwent series of testing and analysis in order to yield specifications on the proposed designs.

This study supplied figures on its Needs Analysis upon utilizing the Nordic Musculoskeletal Questionnaire (NMQ) and Rapid Upper Limb Assessment (RULA). Upon justifying the need for improvement, the comparison of the Man-Machine Parameters through Anthropometrics versus Tricycle Dimensions was performed. Regarding the other factors, noise and temperature, simply the Situational Analysis were executed. Therefore, the concluded factors were considered in designing the proposed blueprint of the motorized tricycles using the Sketch-Up Software and also where virtual prototyping was performed.

There were initially two proposed designs for this study. The passenger and driver samples were the ones decided which design is best. The passenger samples were given more importance by multiplying there score by 60% and only 40% on the drivers. After consolidating the scores, the Design2 is the final product of this study and its blueprint is to be translated into a scaled prototype of 1 is to 10 (1:10). Refer to figures below for the proposed designs.

Design Considerations
In building the proposed designs of a motorized tricycle, there are factors—concluded significant factors are anthropometrics, biomechanics and noise—that must be considered. However for addressing the noise level factor, it was simply done by placing basotect foams and suspension system to control noise. Regarding the design's

measurement factors, the table given below encapsulates the entire idea. For example, the foot ramp of the tricycle must be aligned to the knee height of the 5th percentile of females. The percentiles were obtained by the formulae.

5th =Mean–Standard Deviation * Zvalue
50th Percentile =Mean
95th=Mean+Standard Deviation* Zvalue
Where Z- value of a 95% confidence level is 1.645.

The knee height was obtained by the given multiplier from Drillis' Link Length Studies, which was multiplied to the height of a passenger sample. The Link Length was proven in this study to be applicable as well to Filipinos. The tricycle dimensions and the corresponding anthropometric datum that are significant in the improvement of design is illustrated in the figure below. The values then obtained from abiding the table below were tested if it strays with Velasco's synthetic data. After testing, the results showed that it is within confidence interval and thus the sample size(n) of 30 passenger per gender cluster, leads to a total of 60 samples, is sufficient in order to conduct further analysis on the significant factors—anthropometrics and biomechanics. This study made sure that the 30 samples per cluster is in normal curve. This was executed by inputting the 60 heights in the STATISTICA software and validated the p-value if it is less than (<) 0.05.

Table 1. Tricycle Dimensions and Corresponding Anthropometric Requirements

TRICYCLE DIMENSIONS	ANTHROPOMETRIC DATA	PERCENTILE	GENDER	MULTIPLIER
A. Foot Ramp	Tibial Height/ Knee Height	5th	Female	0.285
B. Seat Depth	Buttock Popliteal Depth	5th	Female	0.53 – 0.285
C. Seat Width	Hip Breadth	95th	Female	0.191
D. Seat Height	Popliteal Height	5th	Female	0.285
E. Roof Height	Sitting Height	95th	Male	1 – (1 – 0.52)
F. Safety Handles	Functional Forward Reach	5th	Female	0.186 + 0.146 + 0.108
G. Leg Clearance	Buttock- Knee Length	95th	Male	0.63 – 0.285 + 0.039
H. Backrest Height	Sitting Height	50th	Male	1 – (1 – 0.52)

Figure A. Proposed Design1

Figure B. Proposed Design2

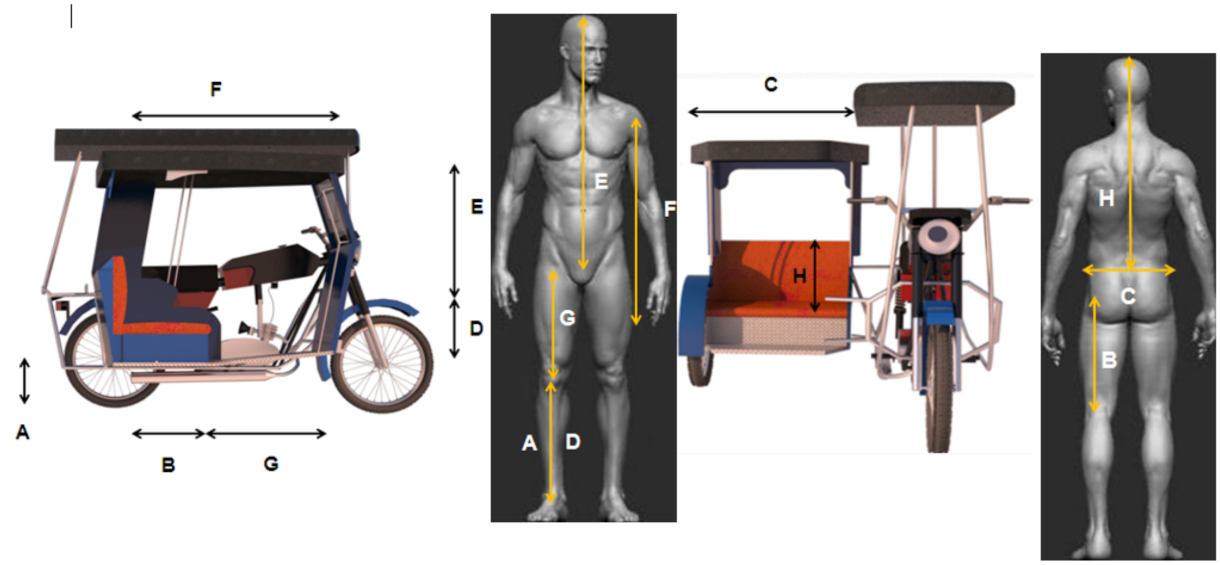


Figure C. Tricycle Dimensions and Corresponding Body Part

Other Considerations

Regarding the Needs Analysis, the separation of testing and analysis was done for those of the Back-ride (behind the tricycle driver on the motorcycle) and the Passenger Cabin—the two passenger area parts of an existing motorized tricycle. This was executed by comparing each tricycle dimension in the back- ride with that of in the cabin. The Z-testing was utilized in justifying a hypothesis. The table given below shows the tricycle dimensions in the cabin that have and does not have significant difference with those of back- ride. The tricycle dimensions that have significant difference must have assessment of the Needs Analysis separately, and those without significant difference can be assumed that they are with the same measurements.

Table 2. Z- Testing Result

CABIN VS BACK - RIDE		
TRICYCLE DIMENSION	**WITH NO SIGNIFICANT DIFFERENCE**	**WITH SIGNIFICANT DIFFERENCE**
Foot Ramp Height	✓	
Seat Depth		✓
Seat Height		✓
Seat Width		✓
Roof Height		✓
Leg Clearance	Not Applicable	
Backrest Height	Not Applicable	

Due to having majority of the tricycle dimensions are with significant difference between that of back- ride and cabin, RULA scores are separated—four(4), meaning change may be needed and investigate further, for the back- ride and five(5), meaning investigate further and change soon, for the passenger cabin.

Table 3. NMQ Result

			NO PROBLEM	WITH PROBLEMS			
for Cabin and Back- Ride Dimensions that are…			1	2	3	4	5
With No Significant Difference	ANKLES/ FEET		43	57			
With Significant Difference	NECK	*Cabin*	8	10	18	49	15
		Back- ride	15	5	51	17	12
	LOWER BACK	*Cabin*	7	10	13	70	
		Back- ride	17	25	43	15	
	SHOULDERS	*Cabin*	68	32			
		Back- ride	47	53			
	HIPS	*Cabin*	2	5	17	18	58
		Back- ride		17	2	27	36
	KNEES	*Cabin*	51	32	17		
		Back- ride	20	38	42		
Evidently Inconsistent	UPPER BACK		23	32	2	13	10
	ELBOWS		100				
	WRISTS/ HANDS		100				

Due to having indifference in the Z-testing result, as shown in the NMQ results, some body parts that is affected by the Z-tested tricycle dimensions have different results that were yielded from the cabin and back-ride. The values are in percentage (%) breakdown of the sample size(n) per gender cluster, 30 for male and 30 for female and a total of 60 NMQ respondents. The numbers 1 to 5 are simply the intensity of the comfortability felt. Only the intensity 1 represents that the body part does not feel any discomfort. The elbows and wrists/ hands of passengers does not feel discomfort when riding the existing motorized tricycles. This entails that in improving the design, the said body parts are need not to be considered.

Technical Description

In determining if the existing motorized tricycle measurements conforms with the attained anthropometric datum of this study, the existing tricycles dimensions were measured.

Methodology in this part was simply utilizing a measuring tape and situating the ends of it covering the pin- pointed parts in the shown illustration of tricycle dimensions above. The complex one was only with concerning to the seat width of the passenger back-ride. This study measured the seat width by first letting a tricycle driver occupy his seat. Once driver seat is occupied, the end of the measuring tape is place behind the driver's buttocks and is extended until the end of the back- ride seat which covers the metal extension of it. But, it must be noted that not all tricycle samples have metal extensions. Thus, average extension was obtained. Regarding with where the point of reference of the seat width, back of the driver, the average distance of the driver's back from the gas tank was obtained by the researcher. This was obtained by getting the males' 95th percentile of the difference of the anthropometric elements knuckle height and hip height. The anthropometric measure was obtained from the passenger samples' datum and was assumed that the male passenger samples were almost the same with that of the drivers—this is supported by the fact that both clusters are Filipinos and that the drivers' measurements were not explored by this study. The average distance of driver's back from motorcycle gas tank is 28.17 centimeter (cm) distanced from the tank. Therefore in the design phase of this study, the researcher must measure the recommended value for the seat width after measuring 28.17cm from the gas tank of the motorcycle.

Having only one variable—the tricycle dimension—be compared to 75 tricycle sample cases of it, made the researcher decide to utilize the 'Single Sample'. This is performed in STATISTICA Software. In the spreadsheet, there is only one variable which is the tricycle dimension and there are 75 cases. Z- testing in STATISTICA is performed using "T-test" as well. The means solved via Microsoft Excel is essential in the STATISTICA because these are the inputted values in the Test All Means Against textbox.

If the test projects that there are no significant difference within the 75 samples in a certain tricycle dimension, then the average of those 75 values is to represent the dimension of the existing or BFRVVG TODA tricycles. If it happens that the test indicates that the 75 values under a tricycle dimension are significantly different, then that particular dimension would be represented by a minimum and a maximum measurement. Having a large significant difference would imply that the researcher would be designing tricycles with different measurements—one for the minimum value and the other for the maximum.

Summing the tests done to tricycle dimensions in the passenger back- ride and cabin, all are with no significant difference and getting the average of the different 75 values in every dimension is accepted. The existing values for the back- ride and the passenger cabin is summarized in the table below.

Table 4. Existing Tricycle Measurements

EXISTING TRICYCLE MEASUREMENTS		
DIMENSION (in cm)	CABIN	BACKRIDE
Foot Ramp	26.1	25.2
Seat Depth	40.4	34.5
Seat Width	31.3	24.9
Seat Height	20.2	57.5
Roof Height	77.9	82.3
Leg Clearance	63.6	None
Backrest Height	34.1	None

Comparing the existing tricycle measurements with the obtained anthropometric values was then possible. In testing the comparison, the variance and Z- testing was performed. If it happens that the variance is high and the Z-test yields a 'with significant difference', the obtained anthropometric value will be used in the proposed design; but if not, the existing tricycle measurement will be designated for that certain dimension. The comparisons for both back- ride and cabin is shown below (the seat width measurements are already for 2 persons). For cabin, only the seat depth and seat width will abide the existing tricycle measurement as the proposed measurement and for back- ride, only the seat depth, leg clearance and backrest height.

Table 5. Comparison of Passenger Anthropometrics and Existing Cabin Tricycle Measurements

TRICYCLE DIMENSION	PASSENGER ANTHROPOMETRICS	EXISTING TRICYCLE MEASUREMENTS	Variance	Z- Testing (With/ Without Significant Difference
Foot Ramp	42.62	26.1	11.7	With
Seat Depth	36.64	40.4	2.7	Without
Seat Width	64.81	62.5	1.6	Without
Seat Height	42.62	20.2	15.8	With
Roof Height	95.74	77.9	12.6	With
Leg Clearance	52.29	63.6	8	With
Backrest Height	88.67	34.1	38.6	With

Table 6. Comparison of Passenger Anthropometrics and Existing Back- Ride Tricycle Measurements

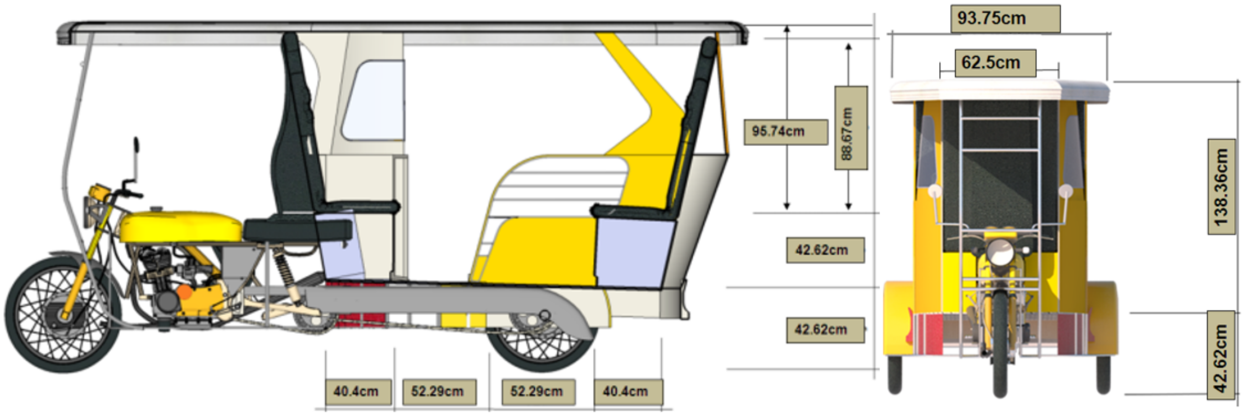
TRICYCLE DIMENSION	OBTAINED VALUES	EXISTING MEASUREMENTS	Variance	Z- Testing (with/ without significant difference)
Foot Ramp	42.62	25.2	12.3	With
Seat Depth	36.64	34.5	1.5	Without
Seat Width	64.81	49.9	10.6	With
Seat Height	42.62	57.5	10.6	With
Roof Height	95.74	82.3	9.5	With
Leg Clearance	52.29	none	None	N/ A
Backrest Height	88.67	none	None	N/A

As established, the Proposed Deign2 was the selected design as an end product of this study based from a set of criterion. Therefore, other parts that were considered in the analysis would not be needed. These parts are of the back-ride's dimensions because the conventional 2-seater at the back of the tricycle driver would no longer be located there, instead will be inside a cabin as well. These parts include the critical passenger's seat width on the motorcycle which starts from 28.17cm away from the gas tank and the metal extension that is placed supposedly to increase comfortability in the existing tricycles. Thus, the measurements that must be considered in creating the Proposed Design2 is summarized in the table below. All are in centimeters.

Table 7. Final Design Specifications

RECOMMENDED MEASURMENTS	
TRCICYLE DIMENSION	CABIN
Foot Ramp	42.62
Seat Depth	40.40
Seat Width	62.50
Seat Height	42.62
Roof Height	95.74
Safety Handles (not standard)	65.80
Leg Clearance	52.29
Backrest Height	88.67

See illustrations below for the final proposed design of motorized tricycles in the Philippines. The given recommended measurements were simply conformed with. The one in the left is a section view of the design where the tricycle is cut in half in order to see its inner scheme. The other is a front view of the design. There are two dimensions of the tricycle seat width and this is because the seat right behind the driver is for 2 persons, hence the 62.5cm, and the seat in front of which is for 3 persons, thus the 62.5cm is divided into 2 and multiplied by 3-93.75cm.



Conclusion

After this thesis was conducted the objectives of it are obtained. The core of those objectives is the factors that affects comfortability. The study concretely determined the factors that were given initially by the researcher, that are considered to be true—True Factors. Having said, the researcher divided the factors into Primary and Secondary true factors. The basis of the division is in the intensity of the factor into a passenger comfortability that the researcher found.

Primary True factors

The three primary true factors that affects the comfortability of a passenger is (1) the anthropometry measurements of the tricycle, (2) the postural effect of those measurements, and (3) the noise level that is being experienced by the passenger. The factors resulted in all the tool utilized that the passenger samples are feeling uncomfortable. In doing so, these factors should be greatly considered when making a standardized design of a tricycle.

Secondary Factor

The only true factor that is considered in this study is the temperature level. This is concluded with the results as basis. In the temperature questionnaire, a great portion of the samples were saying that they do not feel uncomfortable when riding a tricycle in terms of the temperature. This may be because the passengers of the tricycles do think that it is always hot in the Philippines. They are uncomfortable with the high temperature they felt, but when temperature is incorporated with the riding in a tricycle—the passenger samples instantly says that its not related.

The temperature level then is a low factor when determining the comfortability of passengers riding a tricycle. It is also seen in the linear regression that the relationship of the two factors—temperature and rating—is weak. The answer of the passenger samples were inconsistent in order to produce an impact to the other. Though the temperature level was found to be a weak factor for this study, the researcher still installed systems in the proposed designs in order to lessen the heat being felt. This is mainly because an ergonomic study aims to cater, if possible, everyone affected by the product.

Applied Performance Anthropometry Measures

In gauging the performance of tricycles in terms of the comfortability it offers to its passengers, different ergonomic tools were utilized. But before these tool were utilized, the justification of the passenger samples' criterion were concluded. The criterion are the passenger samples' being in a normal curve, the consistency of Velasco's *Anthropometric Data for Filipino Workers*, the applicability of the Link Length Studies to Filipinos, and the valid representation of a population from a sample.

Noise and Temperature Level

Situational analysis was conducted for the two factors. The researcher asked a passenger sample to ride in a tricycle sample and afterwards gave a questionnaire in order to assess the present situation where he or she experienced during the ride. The two variables, which are the level and the comfortability rating, in both factors are obtained in one situation or in a single time. The reading of the level was not obtained, using a sound meter, in a different day with that of the rating.

Applied Anthropometry Solutions

After analysis, the design for the tricycle measurements was made sure to conform with the results in comparing the *Obtained Values* and *Existing Values*. The two values' comparison were justified if the obtained values were truly the required measurement.

Applied Noise Solutions

The researcher applied solutions to the two factors by formulating an equation which the readings of the level must conform with. Linear regression were utilized for both in order to determine the relationship of the two variables, level and comfortability rating, and the strength of it.

Prototyping

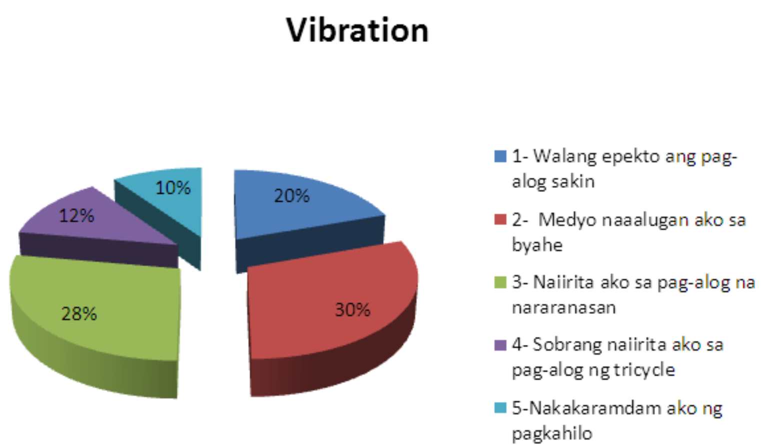
Before creating an actual prototype for the study, the researcher first outsourced a talent where the design where virtually created. The virtual design was evaluated, noticeably only for anthropometry, and if it already conforms with the recommendations of the researcher. The conformity to the recommendations was the ticket for creating an actual prototype.

Final Realization

Improvement of the Philippine tricycles are indeed needed. Though tricycles are already part of the Filipino lives, the acceptance that the existing tricycle design of the Philippines is weakly designed. This study shows that ergonomics must really be applied to it. This thesis shows that after all and in a usual vehicle- product in the Philippines, that product is not appropriate for the users. This is mainly because Filipinos has the attitude of *"Tiisin nalang para makapunta sa pararoonan"*. This trait is actually a good one for it simply shows determination even with tons of limitations. In seeing this trait from the Filipinos, the researcher wants to give a design that is always a part of our everyday and a product that would no longer give unconscious pain in the body.

Recommendations

The researcher has two (3) recommendations for further studies. One is to recommend to conduct studies regarding the vibration level in a tricycle. This was not executed in this study because of the limitation wherein the Mapua Institute of Technology has no gadget for gaging the vibration levels. The further studies must then find a tool that



would able them to measure the tricycle's produced vibration and determine as well the comfortability ratings of the passengers. In doing this, further studies would then have set of standards in a form of an equation wherein the vibration will not strike the ratings where the passengers are uncomfortable. The researcher recommends this, not only because it was not executed in the study. The researcher performed the initial step for the further studies—the needs analysis. The researcher simply made a questionnaire that would determine if there are passenger samples that are currently experiencing discomfort due to the vibration being felt. The researcher handed out the Vibration Level Questionnaire, which is seen in Appendix C roman numeral I, and the results are alarming.

The results that the researcher obtained are captured in the pie chart below. Same with the interpretations with the results in noise and temperature level, the noise level results could be interpreted. From the chart, it could be initially stated that only 20% of the 112 passenger samples said that they are comfortable with the vibrations felt in a tricycle. The rest of the passenger samples states that they feel uncomfortable.

More than half, 80%, of the samples wanted the researcher to improve the tricycle regarding the vibrations. The saying 'anything that cannot be measured, cannot be solved' defied the researcher's plan into tapping the vibration level evaluation. Due to this, the researcher was not able to perform further investigations with vibrations. Whether the vibration level and comfortability rating has a strong relationship or not was unknown. Thus, the researcher released this initial factor as part of the study and was not determined if this is one of the true factors affecting the comfortability of passengers in a tricycle.

When further studies would venture into the vibration level as a factor, a tip would be to utilize the vibration meter—Electromyography (EMG)—to determine if vibration affects the discomfort of passengers. Unlike in the previous study where the device is placed on the motorcycle, it would be inside the passenger- cabin and passenger area on the motorcycle.

There are aspects that must be taken into account when venturing into this is that vibration level might differ to where the vehicle is used and to the motorcycle used. In this part, the engine capacities that would be taken from Noise Level part would undergo analysis if it has an effect with the vibration level felt by passengers. With regards to where the tricycle will be used, it would be limited to the situation of the roads the samples would be taking. Thus, the situation of the roads where the samples pass would be documented.

The second recommendation is for a study to create an actual sized Improved tricycle design. In doing this, the further studies would be very real in a way that the verification stage of the study is well experimented. If an actual sized-working tricycle prototype is made, the passenger samples could again ride the prototype and the measuring of all datum—noise, temperature, Rapid Upper Limb Assessment scores, Nordic Musculoskeletal Questionnaire results—could be gathered once more. In that way, the comparison between the datum form the existing design and the proposed design is indeed concrete. The second recommendation was not executed by the researcher of this study for another constraint. This constraint is the resources. Creating an actual sized- working prototype would cost a lot. As an undergraduate, this is not possible for the researcher does not have big amount of money.

The third recommendation will be performed once the actual working prototype was made. This is by considering the weight of the passengers when riding a tricycle. By doing this, the future researchers would then be able to determine the more appropriate materials to utilized in order to make the tricycle design stable and balanced. The future researchers could examine the future deign by using Free Body Diagram (FBD) in determining what part of the tricycle must be heavy or light.

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