Creating a New Motorcycle Seat Design with Sorbothane Insert using MSCQ, QFD and 3D Modelling to Reduce Motorcycle Riding Discomfort and Vibration Exposure

Ryan Neil D. Trencio
Researcher
Industrial Engineering Department, Adamson University
ryan.neil.trencio@adamson.edu.ph

Ian Charl Nico V. Tubban
Researcher
Industrial Engineering Department, Adamson University
ian.charl.nico.tubban@adamson.edu.ph

Noe D. Enriquez, PIE, ASEAN Eng.
Research Co-Adviser
Director, Institutional Planning and Policy Development Office. IPPDO
Adamson University
noe.enriquez@adamson.edu.ph

Dr. Venusmar C. Quevedo, PIE, ASEAN Eng.
Research Adviser
Vice President for Administration
Adamson University
vcquevedo@gmail.com

Abstract

This study is intended to design a motorcycle seat with Sorbothane insert using the MSCQ, QFD, and historical anthropometric data, to strategically reduce overall vibration exposure and motorcycle riding discomfort of riders. The researchers collected data from commercial and non-commercial motorcyclists through the form of an online MSCQ. The data is then subjected to ANOVA and correlation analysis tests which showed that scooter and standard type motorcycles show no significant differences between their vibration damping and discomfort reducing properties. Sorbothane, together with the properties as studied through the MSCQ analysis are then used in the QFD-HOQ model where the functional requirements are set for the new motorcycle seat design where local, historical anthropometric data was also considered. In the end visual and observational comparisons between current motorcycle seat designs and the new design were put to light in reference to the objectives of this study.

Keywords
Motorcycle Seat Design, MSCQ, Quality Function Deployment, Motorcycle Riding Discomfort, Vibration Exposure, Ergonomics

1. Introduction
In recent years, logistics, warehousing, and freight requirements in small and medium enterprises driven by a rise in consumer spending brought about a massive increase in the demand for motorcycle heavy, Point-to-point Ridesharing, Express Courier/Parcel Delivery Services, and Food Delivery services in the Philippines as a relative effect of the continuous increase in the number of the middle class in the country. Motorcycles have become very popular and

widely used in the Asian urban setting primarily because of its ability to bypass traffic in crowded cities and areas, compactness, and low fuel consumption (Shafiei et al., 2015).

Previous studies state that riding motorcycles can cause fatigue and discomfort due to maintaining body posture and prolonged exposure to external forces. Motorcyclists experience discomfort and body pain particularly in the areas of the body like the lumbar part and buttock area thus, improving the current motorcycle seat builds is necessary to improve motorcycle riding comfort (Nadirah et al., 2020). According to research, motorcycle riding has been a cause of multiple musculoskeletal disorders and diseases. Studies show that one of the top contributors in the acquisition of such diseases and disorders is the overall vibration exposure of the motorcycle riders. According to the study of Wójcik and Trybulec (2017), spinal pain is one of the most frequent problems experienced by the general population of motorcycle riders. In very low vibration levels in lab conditions, static positions are the primary considerations that influence seating comfort in motorcycles, but there is a need to further establish dynamic factors especially when the vibration reaching the seat is aw= 0.2 m/s2 on actual road conditions (Velagapudi & Ray, 2020). The vibration from the road roughness induces cushion vibration which was relatively uncomfortable for riders (Feng & Jun, 2020).

The aim of this study is to develop a new motorcycle seat design with a Sorbothane insert, to reduce the whole-body vibration exposure and discomfort of motorcyclists in the Philippines.

1.1 Objectives

The aim of this study is to develop a new motorcycle seat design with a Sorbothane insert to reduce the whole-body vibration exposure and discomfort of motorcyclists in the Philippines.

The researchers' specific objectives are the following:

a) To identify the ways that motorcycle seat vibration exposure can be reduced by improving the design.
b) To determine the ways to enhance the current motorcycle seat designs to improve motorcycle riding comfort.
c) To effectively compare the differences between the new design and the currently used motorcycle seats.

2. Literature Review

Motorcycle Vibration

Engine vibrations are a result of oscillations caused by an equilibrium point (Chompan, 2019). Engine vibration is characterized as a semi-periodic signal**.** In the similar study of Chompan (2019), it has been found that engine vibration travels through different parts of the motorcycle. The vibration of motorcycles is mainly transmitted to the human body through the motorcycle seat cushion and handlebars, which belongs to the local vibration and whole-body vibration, respectively. (Feng & Jun, 2020). It has been identified that the surface area under the rider's buttock is fitted with a lower cushion height. The front seat cushion is also often rounded in shape and offers a negative effect to the rider. (Nadirah et al, 2020).

In an article made by Feng & Jun, (2020) entitled: "Analysis of motorcycle vibration comfort based on rigid-flexible coupling model", results shows that the high-frequency vibration of engine accounted for the most vibration at the handle when driving B-class road at 60 km/hr is not comfortable in both vertical and horizontal directions with a uniaxial weighted acceleration root mean square of aw= 1.02 m/s2 & aw= 2.61 m/s2 respectively, while vibration comfort level at the cushion was relatively uncomfortable for both vertical and horizontal directions with a uniaxial weighted acceleration root mean square of aw = 0.95 m/s2 & aw= 0.34 m/s2.

Whole-Body Vibration Exposure

According to Ismail et al., (2015), Whole-body vibration (WBV) is an energy oscillation which is transferred to the human body, and it usually happens through a supporting system, such as a seat or a platform. Whole-Body vibration is used to describe a situation when the whole environment is undergoing motion. It occurs when a vibrating surface supports the body. Actions such as: sitting on a vibrating seat, standing on a vibrating floor, or lying on a vibrating bed; are the main possibilities of whole-body vibration.

Recent studies show that multi-axial whole-body vibration exposure impairs postural stability which plays a vital role in maintaining motorcycle-riding comfort (Tobalina-Baldeon et al., 2019). Another study indicates that WBV raises the risk of spinal and sciatic pain (Amiri et al., 2019). The critical contact points (motorcycle seat, handle, foot levers) between a motorcycle and its rider. Most vibration is felt by the rider relative to the nearest body parts where most discomfort is felt. (Khamis et al., 2016).

Musculoskeletal Disorder and Fatigue
Musculoskeletal disorders such as lower back pain and discomfort were more prevalent and significant among occupational motorcyclists than non-occupational motorcyclists. It is also concluded in the study of Ogundele, (2017), that the occurrence of Lower Back Pain (LBP) is high among commercial motorcyclists. The prevalence of this among commercial motorcyclists is approximately 41%. The daily exposure to combined WBV and mechanical shock was significantly associated with the prevalence of lower back pain and neck pain in operators of quad bikes (Johanning, 2015).

Studies show that one of the most significant factors surrounding the acquisition of such diseases and disorders is the overall vibration exposure of the motorcycle riders especially those who are consistently exposed to long periods of riding the motorcycle, where riding posture and balance are most of the time impaired because of whole-body vibration exposure.

Ergonomics and Anthropometry
Anthropometry is the science that defines physical measures of a person's size, form, and functional capacities. Measurements like elbow height, hip breadth, overall statute, knuckle height, popliteal height, or distance from the floor to the back of the knee; these measurements play an important role in designing tools, cars, and more to fit the human body. Anthropometry varies from each human, and it is one of the most influencing factors on seating comfort, identifying the shape, properties and adjustment tracks of seats in the development process (Heckler, Wohlpart & Benger, 2019). Rahman et al, (2018) defined Anthropometry as a science dealing with physical measurements of individual humans, such as size, form, and functional capacities. It is strongly utilized by manufacturers as a basis for designing new products for the market.

Sorbothane
Sorbothane is a viscos-elastic polymer, and it has a very high damping coefficient meaning it has a high shock absorption, good memory, vibration isolation and vibration damping characteristics. Unlike other materials with one of these characteristics, Sorbothane combines all of them in a stable material with a long fatigue life. Sorbothane also has a low creep rate compared to other polymers such as rubber, neoprene, silicone, etc. Because Sorbothane is a non-Newtonian material, stress is not proportional to strain, and mechanical energy is lost by conversion to heat. It also comes with various material grades of thickness and sizes, i.e., 30, 40, 50, 60, and 70 duo, a hardness unit measured with a durometer.

Research about Sorbothane has proven its effectiveness in mitigating and damping vibrations. Sorbothane inserts for force mitigation, and vibration reduction and reduction of linear and rotational acceleration are more effective than the original paddings used in helmets for football. (Zuckerman et al., 2016). Similarly, these materials are manufactured as anti-vibration gloves, palm pads, tool wraps, and shoe insoles to minimize the impact of energy.

3. Methods

This study evaluates the significant factors surrounding motorcycle seating comfort and vibration exposure using a modified MSCQ (Motorcycle Seating Comfort Questionnaire), dedicated to providing experiential qualitative feedback from test participants that would engage in the study.

The researchers will develop a modified questionnaire based on the MSCQ (Motorcycle Seat Comfort Questionnaire) to determine the significant factors surrounding motorcycle seats that may be affecting the riding comfort and vibration exposure for the test subjects in the local setting.

After gathering the results, the researchers aim to establish the correlation of the motorcycle seat designs with seating comfort and vibration exposure. Finally, based on the key improvement points unraveled from the results of the MSCQ, the researchers will create a new motorcycle seat design with Sorbothane insert, which aims to reduce the whole-body vibration exposure and improve motorcycle riding comfort.

To determine the number of respondents needed for the study, the researchers retrieved data that would serve as a basis for the population of two wheeled motor vehicles in the Philippines. The data reference for the sample shows the number of motorcycles in the Philippines which relates to 5.2 % of the population where per 1,000 population, there are 52 motorized two-three wheelers. The Philippines' population currently stands at 108.1 M as of 2019, there are expected to be around 5.6 M motorcycles that are currently in use. A simple random sampling technique is utilized in this study as it is the most viable sampling technique that can be used in the current situation due to the pandemic restrictions.

The researchers used Slovin's formula as shown below with an acceptable margin of error of 9% which yields to not less than 123 respondents for the survey. As the number of samples have been determined by using Slovin's formula, the researchers shall then gather respondents who must qualify to a certain set of criteria including a minimum of 2-3 riding hours per ride for commercial motorcyclists, a minimum of at least once a week of riding for non-commercial motorcyclists, exposure to main roads, class B-roads and is at least 18 years of age.

4. Data Collection

The researchers aim to gather qualitative data based on the answers from the MSCQ filled-up by the respondent riders. The gathered data from samples shall then be organized and filed for analysis and validation using statistical techniques.

5. Results and Discussion

The following information has been gathered using Google Form distributed through online engagements either through group discussions, social media platforms, and through email. The researchers also intended to target commercial motorcyclists, regular motorcycle riders, and other casual motorcycle users' social media groups and organizations in distributing the survey. The tables and data presented exhibit the findings from the use of the MSCQ.

Table 1: Count per Type of Motorcycle Used

Type of motorcycle Used

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Standard Type Motorcycle	31	18.2	18.2	18.2
	Cruiser	2	1.2	1.2	19.4
	Sports Bike	4	2.4	2.4	21.8
	Dual Sports (Adventure Sport)	5	2.9	2.9	24.7
	Scooter	123	72.4	72.4	97.1
	Moped	5	2.9	2.9	100.0
	Total	170	100.0	100.0	

The researchers decided to conduct an analysis of variance between motorcycle types in relation to their MSCQ results but after the preliminary examination of results, the scooter type motorcycle is shown to have the highest usage rate among other types of motorcycles amounting to 123 users out of 170 respondents at 72.4 percent followed by standard type motorcycle with 31 users at 18.2 percent. (Table 1)

Table 2: Count per Motorcycle Used (Cleaned)

Type of motorcycle Used					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Standard Type Motorcycle	31	20.1	20.1	20.1
	Scooter	123	79.9	79.9	100.0
	Total	154	100.0	100.0	

Because of the insignificant figures obtained from cruiser, sports bike, dual sports, and moped with frequencies of 2, 4, 5, and 5 respectively, the researchers decided to focus on the motorcycle seat design of scooters and standard type motorcycles reducing it to a total of 154 valid responses for the analysis. (Table 2)

Table 3: ANOVA Test of Seat Comfort Characteristics Between Scooters and Standard Type Motorcycle

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Overall Seating Comfort	Between Groups	1.026	1	1.026	1.005	0.318
	Within Groups	155.130	152	1.021		
	Total	156.156	153			
Seat Frame	Between Groups	0.072	1	0.072	0.064	0.800
	Within Groups	168.688	152	1.110		
	Total	168.760	153			
Seat Cushion/Padding Contour	Between Groups	0.100	1	0.100	0.078	0.781
	Within Groups	194.757	152	1.281		
	Total	194.857	153			
Seat Width	Between Groups	0.212	1	0.212	0.202	0.654
	Within Groups	160.054	152	1.053		
	Total	160.266	153			
Burning Sensation	Between Groups	1.262	1	1.262	0.899	0.345
	Within Groups	213.419	152	1.404		
	Total	214.682	153			
Pressure Under Buttocks	Between Groups	1.975	1	1.975	1.438	0.232
	Within Groups	208.862	152	1.374		
	Total	210.838	153			
Buttocks Support	Between Groups	0.199	1	0.199	0.144	0.705
	Within Groups	210.138	152	1.382		
	Total	210.338	153			
Lumbar (Spine) Support	Between Groups	0.256	1	0.256	0.172	0.679
	Within Groups	226.783	152	1.492		
	Total	227.039	153			
Seat Length	Between Groups	1.128	1	1.128	0.939	0.334
	Within Groups	182.586	152	1.201		
	Total	183.714	153			
Seat Cushion Firmness	Between Groups	0.224	1	0.224	0.182	0.671
	Within Groups	187.704	152	1.235		
	Total	187.929	153			

The ANOVA shows that there is no significant difference between each of the properties and characteristics of the scooter and standard type motorcycle seat designs. Each of the properties and characteristics that are compared using the ANOVA showed p-values or significance levels with the least p-value of 0.232 > 0.05. In this case we accept the null hypothesis. Essentially, the findings show that both motorcycle seat designs for standard type motorcycles and scooters, are similar to each other in general. (Table 3)

A correlation analysis between the results for each MSCQ section is conducted to establish the relationships between them to be used as complementary determining factors for the HOQ model, to more accurately define the customer requirements and functional requirements for the new design

Quality Function Deployment Methods were used to create a novel motorcycle seat design suitable for a scooter type motorcycle. A planning matrix involving an HOQ (House of Quality) Model as determined by the researchers, is used to establish the customer requirements and initial functional requirements obtained through the two MSCQ sections. Through analyzing the correlation analysis results, the researchers identified the direction of improvement for each functional requirement in the HOQ.

The seat features for the new motorcycle seat design are a combination of MSCQ and RRL results which helped the researchers create a 2 phase HOQ model where Customer Requirements are turned into the new motorcycle seat specifications.

The Customer requirements for the first HOQ Table as shown in Figure 1. Is a list of the motorcycle seat characteristics. The motorcycle seat is very simple in nature and can be considered as a feature itself. In the first HOQ. The researchers went straight to assessing the motorcycle seat functionality. After the functional requirements were determined the researchers assess the direction of improvement of each requirement by determining if the requirements are high is better, specific amount, and lower is better. The interaction between functional requirements were also assessed if the requirements have strong positive, positive, negative, and strong negative interactions. The researchers also determined the relationship of the functional requirements to the customer requirements. The "Hows" are ranked according to their correlation of fulfilling each of the "Whats".

The initial functional requirements in the model are gathered from different related literatures as explained below.

1. Can carry at least 2 people- Motorcycles are designed to only accommodate at utmost 2 passengers, mainly the driver and pillion passenger. That is why motorcycles will only have one set of foot pegs in the pillion passenger seat. Safety has been considered as additional passenger means additional weight that is needed for the motorcycle to support.

2. Can carry loads of between 184.4 - 236.2 kg without permanent deformation - The seats should be able to carry loads that are in between the specified value. The weights came from the 95% tile of the mean of the weights of Malaysians which is 92.2 kg (Del Prado-Lu, 2007), the researchers considered the average weights of Malaysians the same as the average weight of Filipinos due to similar body measurements and anthropometric data; the value is multiplied by 2 to arrive at the value of 184.4, since the seat can carry 2 passengers. The value of 236.2 kg came from the 95% tile of the mean of the weight of Malaysians plus the maximum weight of packages shipped by express courier companies which is 144kg in weight. The seat should also be able to be compressed to conform to the body, the foam should be able to distribute the weight across the seat and allow it to return to its normal state/shape when no weight is present.

3. Seat Area Allowance - The seat dimensions should accommodate riders' dynamic movements for maneuvering and controlling the movement of the motorcycle. It should allow the rider to adjust into a sitting position which is perceived as comfortable. This can be achieved by following the anthropometric measurement of people while seated. The measurement would provide the researchers data for improvement and adjustment on the dimensions of the seat.

4. Shock Absorption - The motorcycle seat should be able to absorb sudden impacts when the motorcycle is passing through sudden humps and pits on the road. Vertical impact is caused by this, the motorcycle already has a suspension mechanism to absorb such shocks caused by bumps, but the seat should also provide another barrier for the rider not to experience these shocks. The main material that will be used, which is sorbothane, would help mitigate and absorb shock. According to the study of Zuckerman et al ,2016, It had been found that a 70 Duro Sorbothane demonstrated a 5% - 10% reduction in linear acceleration which helps decrease forces transmitted to the brain; the study proves the efficacy of Sorbothane to mitigate impact force.

5. Overall Vibration Reduction - The seat would significantly suppress vibration experience and transmission from the seat to the body that is in contact with the seat. The researchers choose Sorbothane as a main material

that would help absorb vibration, because it has excellent vibration damping cap abilities as seen in Figure 9 compared to other polymer materials

6. Lumbar and hip support - Several research and other related literature have concluded that there is a great need for motorcycle seats to have a lumbar support because discomfort, disease, fatigue, or pain are common in that region as it is seen in Figure 5. A lumbar support would be added to the region of where it is closely connected to the motorcycle seat. Lumbar support would alleviate the pressure and consequently lower pains that are experienced in the lumbar region and hips. A two-later, rigid steel and flexible skin indenter model in ANSYS V13 which was retrieved from the study of Mathurkar, 2016. It shows the deflection of seat cushion foam and supportive structure as well as a human buttock, thigh and lower back soft tissue when seated, the image also reflects the compression of body tissue through sitting in a seat, this would serve as a guide on how a lumbar support would be incorporated in the design.

7. ILD (Indentation Load Deflection) - This is a value that represents a force needed to compress natural latex, polyurethane, and other foams. This is used across various industries such as mattresses, car seats and furniture. ILD is given to a layer of foam and not the entire finished product. Mattresses will carry a general firmness rating of soft, medium, or firm while a layer within the mattress will have its own ILD rating. The ILD range of the foam that will be used as an ILD range of 30.5 ILD to 34.5 ILD which translates to Firm firmness. A Polyurethane Foam which has a foam density of 1.2 lb and an ILD rating of 33 will be used as a foam.

8. Maintains temperature when exposed to heat or gets wet - Considering that motorcycle seats will be constantly exposed to heat, there is no doubt that the seat will be hot due to exposure to heat and sunlight. The seat of the motorcycle should not store heat and would insulate it as it would give a burning sensation to the rider when seated. The two layers that should resist changing temperature are the foam layer and the seat cover or the upholstery. The materials that are to be used for the cover and foam are: Vinyl Fabric, a synthetic resin or plastic consisting of polyvinyl chloride. This material is less prone to cracking and fading when exposed to sunlight; Open-cell polyurethane foam will be used as the foam as it has excellent insulating capabilities. It is resistant to a wide range of temperatures ranging from -200°C to +135°C.

9. Weather Resistant - The seat of the new seat design should be weather resistant as the seat gets exposed to various weather conditions. In the Philippines, the climate is tropical and maritime. It is characterized by relatively high temperature, high humidity, and abundant rainfall. Vinyl has a greater capability to not absorb water as it is not porous, it is less likely to crack and tear when exposed to extreme heat unlike leather as it can absorb moisture and gets fade and crack when exposed to extreme heat

10. Anti-slippage Mechanism - The material that will be used to prevent slippage is a polyester cover for the motorcycle seat. Air mesh fabric is made by a knitted machine, which is polyester yarn. The air mesh fabric is also known as sandwich fabric, because of its three layers. The surface is a mesh design as seen in figure 11, the middle layer connects the bottom and upper layer. The fabric looks like a net and it's very flexible and is designed for airflow and cushioning. Due to the mesh design, it also prevents the rider from slipping especially when wearing clothes that can slip easily on the cover of motorcycle seats. In addition to the material, modification on the seat contour would be made to prevent the rider from ejecting the motorcycle seat when passing through sudden bumps and potholes. This would ensure that the rider would be able to remain seated.

Legend

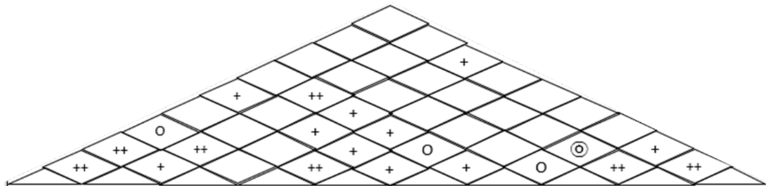
INTERACTIONS	
++	SP
+	P
O	N
◎	SN

DIRECTION OF IMPROVEMENT

▲	higher is better
▫	specific amount
▼	lower is better

RELATIONSHIP

H	9
M	6
L	3
	0



		Direction of Improvement	▫	▲	▲	▲	▲	▫	▼	▼	▫	▫		
			Functional Requirements (system features)											
Relative Weight	**Customer Importance**	**Customer Requirement**	Can carry at least 2 passengers	Can carry between the loads of 184.4 kg - 236.2 kg without permanent deformation	Seat gives room for adjusting riding posture and position (Seat Area Allowance)	Protects User from bumps and reduce vertical impact on buttocks area by 5 - 10% percent (Shock Absorption)	Can reduce vibration level by 50% percent	Seat supports the lumbar and hip of the driver	Indentation Load Deflection of Foam lower than 33 ILD	Seat maintains temperature when exposed to heat and gets wet	Seat is weather resistant	Anti-slippage mechanism	**COMPLETENESS**	
9%	10	No Burning Sensation when moving and adjusting position			M			L	L	H	M	H	260	26
11%	11.911	Seat provides spine and tailbone support			L	M	L	H	H		M	L	321.5835	27
10%	10.61	Seat supports buttocks area comfortably	L	L	M	L	H	L	H	L	L	M	318.3	30
9%	9.878	Pressure Under buttocks is light enough not to hurt		M		H	L	M	H	L	L		266.706	27
7%	8.2115	Seat allows knees to be kept against the frame/body	L	L	M	L	M	L	M			M	131.384	16
8%	8.74	Seat allows adjustment on riding posture	H		H			M	H	L	L	L	288.42	33
7%	8.049	Seat allows to be firmly seated when braking	L		M	M	M	L	M		M	H	209.274	26
7%	7.8455	Seat is large enough to hold both rider and passenger with out crowding	H	M	H			M					188.292	24
7%	7.927	Seat is able to carry luggage and saddle bags, parcels, etc.	H	H	M	M		L	L		L		214.029	27
7%	8.13	Seat does not eject rider when passing through sudden humps and pits	L		L	H	M		M		L	L	154.47	19
10%	10.61	Low Vibration Exposure		L		M	H	H	L		L		254.64	24
7%	7.6425	Seat allows to be firmly seated when turning	L		L	L	L	M	H		L	H	198.705	26
		SPECIFICATION (target amount of HOW's)	m^2	kg	cm				ILD / lb	Degree Celsius (°C)				
		Importance Rating Sum (Importance x Relationship)	263.2555	153.945	311.345	304.0255	293.5825	349.8	540.7375	119.228	153.416	316.4685		
		Relative Weight	9%	5%	11%	11%	10%	12%	19%	4%	5%	11%		

Figure 1: 1st Level House of Quality (Functional Requirements)

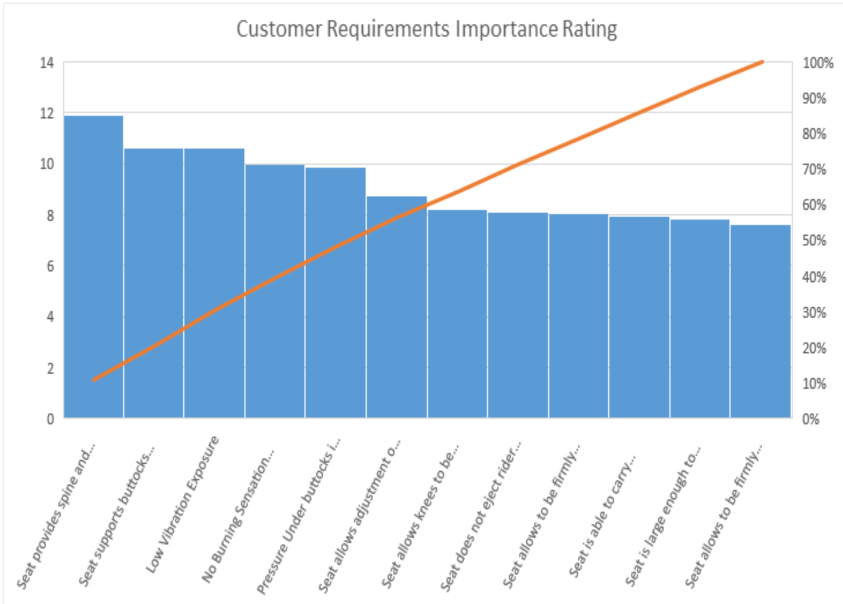


Figure 2: Customer Requirements Importance Rating

As seen in the importance rating gathered from the integration of the MSCQ results to the HOQ customer requirements, it is seen that the top 1,2, and 3 factors of the current motorcycle seat designs which need improvement are the spine/lumbar support, buttocks support, and vibration exposure respectively. The customer importance rating is computed by plotting the MSCQ gathered scores for each requirement and multiplying it by a factor of 5. The factor of 5 is used simply to establish a good spread among the results and more clearly see the difference between the factors' importance between each other.

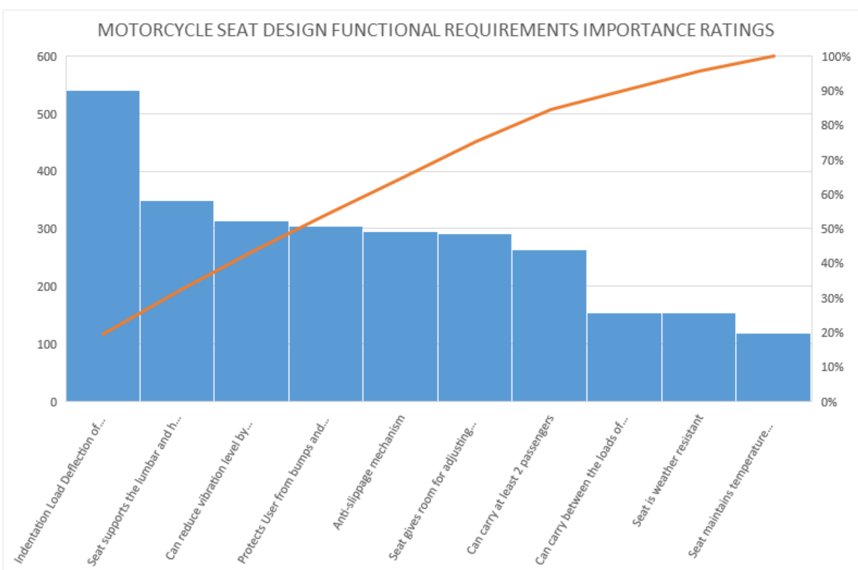
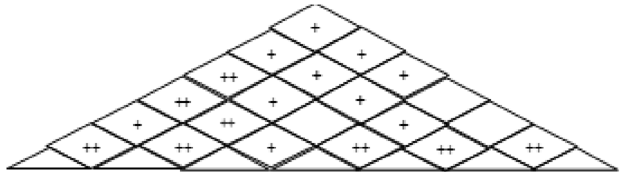


Figure 3: Motorcycle Seat Design Functional Requirements Importance Ratings

The Figures 1, 2 & 3 above shows the ranking of importance for each functional requirements established by the HOQ model after tallying the sum of the relationship scores between each customer requirements and each functional requirement which is then multiplied by the customer requirement importance rating. With this data, we can see that in relation to the customer requirements, the top 1, 2, and 3 functional requirements include, the Indentation Load

Deflection of the cushion foam, followed by the existence of a lumbar and/or a spine support, and finally the vibration reduction functionality.



			System Characteristics								
		Direction of Improvement	▲	▲	▲	□	□	□	□		
Relative Weight	Importance Rating	System Functionality	Sorbothane Seat Padding in Rider's Seat Space	Seating space of driver seat	Seating space for pilion rider (back ride/luggages/parcel)	Seat Countour Design matches rider lower limb curves	Lumbar and Buttocks support	Seat Cushion Material	Seat Cover Material	COMPLETENESS	
9%	263.26	Can carry at least 2 passengers	L	H	H	M	M	H		8950.687	34
6%	153.95	Can carry between the loads of 184.4 kg - 238.2 kg without permanent deformation	H	H	H		L	H		5695.965	37
10%	291.35	Seat gives room for adjusting riding posture and position (Seat Area Allowance)	M	H	H	H	H			11362.455	39
11%	304.03	Protects User from bumps and reduce vertical impact on buttocks area by 5 - 10% percent (Shock Absorption)	H	M	M	H	H	H		12789.071	42
11%	313.34	Can reduce vibration level by 50% percent	H				M	H	L	6893.447	22
13%	349.8	Seat supports the lumbar and hip of the driver	H	H	M	H	H	H	M	17839.8	51
19%	540.74	Indententation Load Deflection of Foam lower than 33 ILD						H	L	5407.375	10
4%	119.23	Seat maintains temperature when exposed to heat and gets wet	H				L	H	H	3338.384	28
6%	153.42	Seat is weather resistant	H					H	H	4142.232	27
11%	295.25	Anti-slippage mechanism	M	M	M	H	L	M	H	9152.7035	31
		SPECIFICATION (target amount of HOWs)	m^2	m^2	m^2	cm					
		Importance Rating Sum (Importance x Relationship)	14566.813	11322.9315	9224.1315	11953.5375	10804.738	20665.4595	7014.5085		
		Relative Weight	17%	13%	11%	14%	13%	24%	8%		

Figure 4: 2nd Level House of Quality (System Characteristics)

After establishing the importance ratings of the functional requirements from the 1st Level HOQ, the researchers identified how the new motorcycle seat can provide such functional requirements through characteristics that were established through RRL's. These characteristics include a) Sorbothane Seat Padding in Rider's Seat Space, b) Seating space of driver seat, c) Seating Space for pillion rider (back rider / luggage/ parcel space), d) Seat Contour Design matches lower limb curves, e) Lumbar and Buttocks Support, f) Seat Cushion Material, g) Seat Cover Material. These features are again analyzed and related to the functional requirements in order to establish the proper relationship between functional requirements and characteristics that would be taken into consideration during the actual designing and modelling of the new motorcycle seat.(Figure 4)

The researchers used a modular representation of the motorcycle seat to be designed using the Fusion 360 app. The key characteristics cited in the HOQ are then grouped into sections that helped to more effectively break down the key components and features of the motorcycle seat which included the (a) sorbothane seat padding in rider's seat space, (b) seating space of driver seat, (c) seating space for pillon rider, (d) seat contour, (e) seat cushion material, and (f) seat cover material; each serving a purpose to address the previous requirements from the 1st level HOQ.

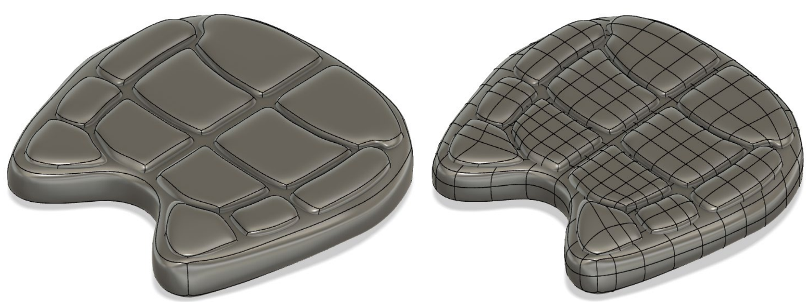


Figure 5: Orthographic View of 3D Model of Meshed Sorbothane Motorcycle Seat Padding

The Figure 5 above is an orthographic 3D model view of the Meshed Sorbothane Motorcycle Seat Padding. The design of the seat padding is based on the contact points determined in the studies of Mathurkar, 2016; Velagapudi, 2019 & Dangal et al, 2021. In the study of Dangal the pressure map determined in the study is for aircraft seat-pan although this was the case, it was considered that the pressure segmentation among the areas were also the same for motorcycle riders who ride for prolonged periods as seen in the pressure map in Mathurkar's study, as well as the seat interface pressure of motorcycle seats in Velagapudi's study.

The meshed part which are the parts of the sorbothane padding that are slightly elevated and have spaces in between the meshed parts of the pad. Meshed pads on seat are designed as such so that when there is a weight or force that is in contact with the meshed part it will dissipate the force and the mesh will deform allowing it to be expanded into the spaces, through this reduce the pressure on the buttock area during prolonged period.

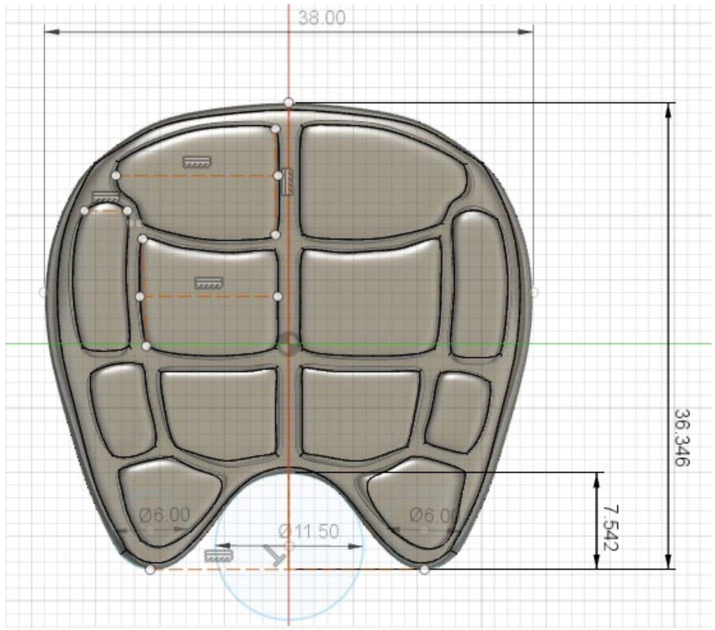


Figure 6: Dimensions of Meshed Sorbothane Motorcycle Sea Padding

The above Figure 6 also shows the dimensions of the Meshed Sorbothane Seat Padding. The dimensions are in centimeters (cm) and follows the anthropometric measurement of seated individuals in the study of Del Prado-Lu, 2007. The anthropometric measurement for sitting is used, the hip breadth, buttock popliteal length, and buttock width. The researchers considered the 95th percentile of the measurements of each of the parts previously mentioned, this ensures that the measurement of the seat pad would accommodate the majority of the anthropometric measurements of the population.

Figure 7: Orthographic View of 3D Model of Modified Motorcycle Seat
Upholstery with Sorbothane Insert

Figure 8: Top View, Side View, Front View of the 3D Model of Modified Motorcycle Seat Upholstery with Sorbothane Insert

Figures 7 & 8 shows a 3D model of the Modified Motorcycle Seat Upholstery. This model was created in Fusion 360 through Design Free Form Tool. In designing the motorcycle seat, the researchers first consider the type of motorcycle that would be a reference in modifying a seat. Different types of motorcycles would require different types of seats. During the Analysis Phase of the study, the researchers considered Standard Type Motorcycle and Scooter type motorcycles as a motorcycle type for the design consideration. The two of these motorcycle types are commonly used in the country and are preferred by both commercial and non-commercial motorcycle riders, arguably due to its practicality, being small and lightweight; scooter and standard type motorcycles are able to maneuver through busy sections of the road. It is also practical for the riders to choose and have these types of motorcycle because of its structure and ease of control.

Since it was made using the Design Free Form Tool, the researchers created the design from a rough sketch and modelled the design according to the anthropometric data for sitting posture. The researchers first get a reference figure or image of a motorcycle seat of which a seat from a scooter type motorcycle. To further improve the current design, anthropometry data was utilized in which the measurement from the 95th percentile is used so it would cater to the majority of the population's measurements.

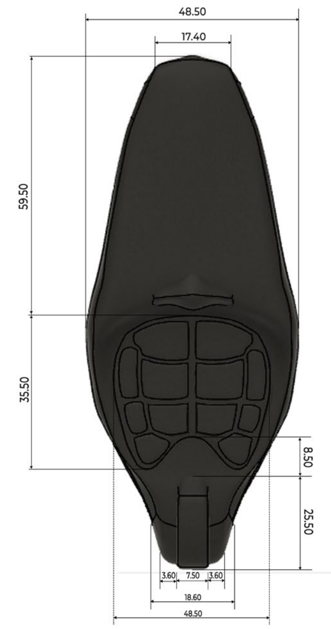


Figure 9: Top View Seat Dimensions of Modified Motorcycle Seat Upholstery

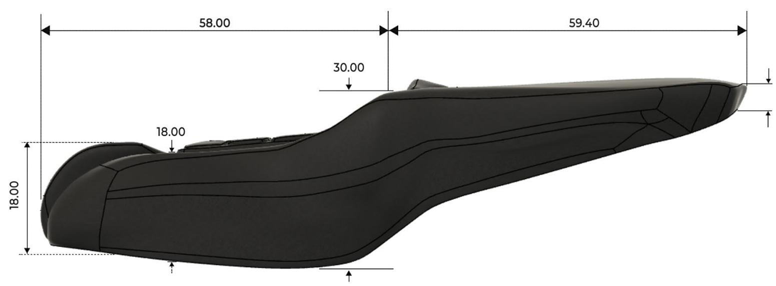


Figure 10: Side View Seat Dimensions of Modified Motorcycle Seat Upholstery

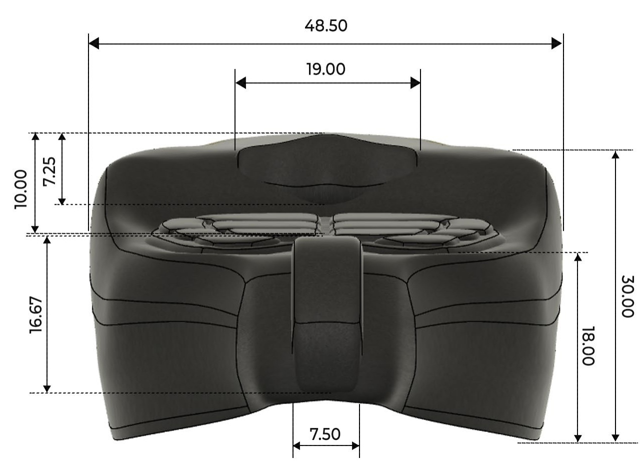


Figure 11: Front View Seat Dimension of Modified Motorcycle Seat Upholstery

The researchers followed the design requirements from the Qualify Function Deployment Diagram or House of Quality of which the customer requirements want a seat that supports the lumbar and hips of the rider, seat gives room for adjusting of posture and position, can carry at least 2 passengers this also includes packages, parcels, and deliveries, and lastly, would reduce vibration levels up to a certain percentage; To Support the design, measurements and dimension of the design are added as seen in Figures 9-11 and can be adjusted based on the requirements, and preference according to the user and motorcycle type.

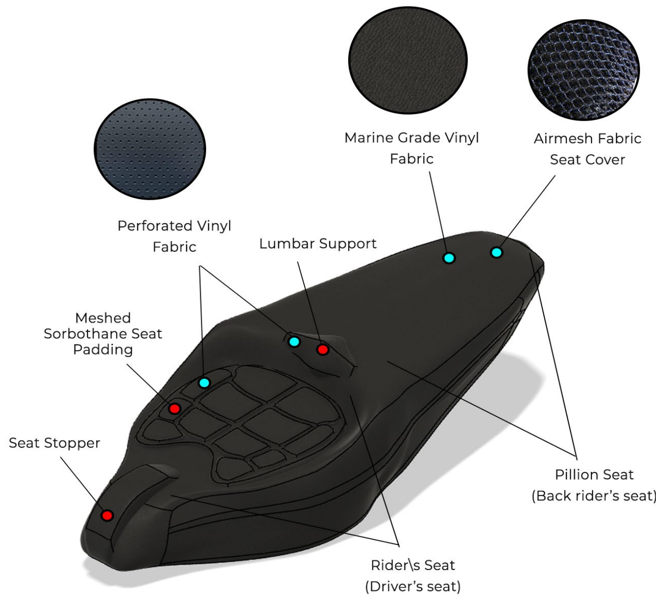


Figure 12: Seat Parts and Cover Materials of the Modified Motorcycle Seat with So

The Figure 12 above shows a 3D model of the Modified Motorcycle Seat Upholstery. This model was created in Fusion 360 through Design Free Form Tool. The researchers created the design from a rough sketch and modelled the design according to the anthropometric data for sitting posture. The researchers also followed the design requirements from the Qualify Function Deployment Diagram or House of Quality where the customer requirements require a seat that supports the lumbar and hips of the rider, seat gives room for adjusting of posture and position, can carry at least 2 passengers this also includes packages, parcels, and deliveries, and lastly, would reduce vibration levels up to a certain percentage. The lumbar support would envelop the buttocks and lumbar, supporting the rider so whenever the rider would be on the road for a prolonged period of time a lumbar support would aid and reduce the stress in the lumbar and buttocks area. Additionally, the researchers designed a stopper in front of the motorcycle seat situated between the thighs of the rider which would ensure that the rider will not get ejected and put out of position during certain situations

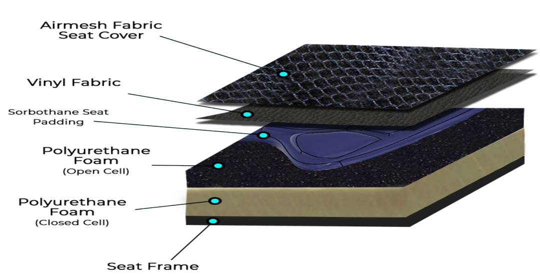


Figure 13: Motorcycle Seat Layers

The Figure 13 above displays the different layers that make-up the Modified Motorcycle Seat Upholstery. The first layer would be the seat frame or base plate. Next is a very firm Closed Cell foam which would serve as a base for the seat foam layers; next would be the less dense and less firm Open Cell Foam that would help give comfort to the rider and pillion rider; Sorbothane Seat Padding which is located on the Riders seat is inserted into the Open Cell foam with the Meshed Paddings exposed so it would be in contact with the riders' buttocks to dissipate force and load. It acts as a barrier to reduce vibration excitation from the engine and vibration due to various road conditions. The Sorbothane Padding will be covered by Perforated Vinyl Fabric which makes a breathable padding, and Marine Grade Vinyl Fabric to cover the foam and other areas of the seat; lastly, the seat will be covered with an Airmesh Seat Cover for better grip and added breathability

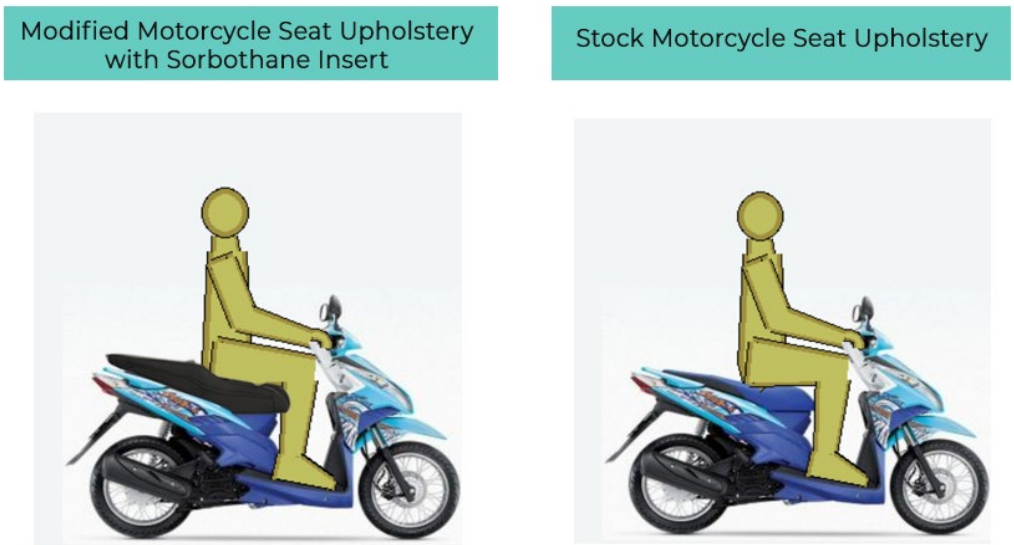


Figure 14: Comparison of Mounted Modified Motorcycle Seat Upholstery and Stock Motorcycle Seat Upholstery

It can be seen that the new design has a better lumbar and back support compared to the stock seat. Improvements are also on the structure of the seat as the Pillion seat was increased in height to envelop the buttocks and lumbar of the rider. The rider's seat was also integrated with a Sorbothane insert and a seat stopper. Due to pandemic restrictions and the limitations of the researchers, no actual prototyping was made while testing of the compatibility of the seat design to other motorcycle types and models were also not explored. (Figure 14)

Leather is the premium option for seat covers; it gives more comfort than vinyl, but it requires additional care and maintenance in order for it to last long. The modified seat utilized a material that is made to withstand weather conditions that can highly contribute to the deterioration of seat covers due to weathering. An Air Mesh seat cover is also added to act as an additional barrier that may help increase comfort, prevent slippage and protect the seat volatile weather conditions.

6. Conclusion

The researchers were able to establish the scooters and standard motorcycles' seat design improvement areas, including adding a lumbar support, reduced vibration exposure due to road and engine excitation, softness of seat cushion, and others, which can be improved to enhance motorcycle riding comfort. The researchers have strong evidence that the perceived amount of vibration experienced by the riders, particularly from the motorcycle seat, negatively impacts their motorcycle riding' comfort, that points to the need for a better motorcycle seat design (on scooters and standard type motorcycles. The research also established that the new motorcycle seat design has significantly more attributes and features to provide more comfort for the rider including a lumbar support, Sorbothane mesh padding, anti-slippage mechanism, air-mesh cover, and improved contour with cushion layering.

The researchers recommend developing a prototype for the new motorcycle seat design from this study. Actual or laboratory testing for the evaluation and verification of vibration reduction and comfort improving properties of the new motorcycle seat design can also be done to further enhance the new design. It is also recommended that further studies on the product marketing, feasibility, and safety be done in future.

Lastly, the researchers recommend that future studies consider expanding the HOQ model via the inclusion of a more comprehensive comparative analysis among other competitors for the better appreciation of the product material. While the study can be used as basis and/comparison, similar studies using the same or an improved version of methodology can be conducted for a broader set of motorcycle types.

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Biographies

Ryan Neil D. Trencio, a graduate of Bachelor of Science in Industrial Engineering batch 2022 in Adamson University. He lives in Parañaque City and is an active Student Leader in both local and national student organizations during his college years. He is formerly the VP for Communication of PIIE-ORSP AdU Chapter, and an Assistant VP for Communications of PIIE-National Student Chapter a premier national student organization for Industrial Engineering students. He is a Lean Six Sigma Yellow Belt Certified; He gained his internship experience at SEAOIL PH INC., as a HR Intern and started his professional career as a Transportation Planning Officer at Flash Express (PH) Co., LTD., Inc

Ian Charl Nico V. Tubban, member of the Bachelor of Science of Industrial Engineering of Adamson University class of 2022, is a Kayan Chan Foundation scholar since 2020. He lives in Las Pinas City with his wife and two kids and has been a working student for the most part of his stint in the university. He also has been a part of a team that represented Adamson University in two PIIE-ORSP Regional Quiz Bee competitions placing 4th and 3rd respectively during the years 2020 and 2021. He finished his internship program with Entegra Systems Company in August 2021 and started working as the Marketing Officer for AduNEST (Adamson University Neo Science and Technology) Incubation Center in the same year.

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Noe D. Enriquez, PIE, ASEAN Eng. Is the Director, Institutional Planning and Policy Development Office. IPPDO of Adamson University. He finished his Degree in Bachelor of Science in Industrial Engineering from Adamson University. On the course of his professional career, he became the Chairperson of the Industrial Engineering Department. He is also one of the Board of Trustees of the Philippine Institute of Industrial Engineers and an adviser of the Philippine Institute of Industrial Engineers – National Student Chapter (PIIE-NSC) a premier student organization of PIIE.

Venusar Quevedo. Dr. Venusmar is a Associate Professor of the Industrial Engineering Department at Adamson University, Manila, Philippines**.** Dr. Quevedo holds a Bachelor of Science degree in Industrial Engineering from Adamson University and both her master's degree in Industrial Engineering and Doctor of Philosophy in Educational Evaluation and Research from University of the Philippines. She has been recognized as one of the Inspiring Woman Engineer by the Philippine Technological Council with her more than 35 years of experience and contribution in the industry. She has taught courses in management, feasibility and engineering research for engineers. She has published and presented research papers both local and international.