Design and Evaluation of Aesthetics and HMI Aspects of Amphibious Vehicle for Amusement Purpose

A Thesis Submitted to the
University of Petroleum and Energy Studies

For the Award of

Doctor of Philosophy

in

Design

By
Debashis Majumder

March 2023

Supervisor
Dr. Anirban Chowdhury
Sr. Associate Professor, School of Design,
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SCHOOL OF DESIGN
UNIVERSITY OF PETROLEUM AND ENERGY STUDIES (UPES),
DEHRADUN-248007, UTTARAKHAND, INDIA

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DECLARATION

I declare that the thesis entitled ` Design and Evaluation of Aesthetics and HMI Aspects of Amphibious Vehicle for Amusement Purpose' have been carried out by me under the guidance of Dr. Anirban Chowdhury, Associate Professor of School of Design, University of Petroleum and Energy Studies, Dehradun. No part of this thesis has formed the basis for the award of any other degree or diploma previously.

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CERTIFICATE

This is to certify that the thesis work presented herein by Debashis Majumder was undertaken under my guidance and supervision. The volume of work presented here, for the Doctor of Philosophy (Ph.D.) award in `Design' from the School of Design of the University of Petroleum and Energy Studies (UPES), was not submitted by him earlier for any other degree or diploma.

He has undergone all specified courses and fulfilled all the requirements of rules and regulations as mentioned in the Ph.D. ordinance for submitting the thesis for his Ph.D. degree at the University of Petroleum and Energy Studies (UPES).

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DEDICATION

I would like to dedicate this thesis paper to my late parents and my family members and my teachers and mentors who made immense contributions to my success.

ABSTRACT

An amphibious vehicle is a vehicle that can run on land and water as well. Amphibious characteristics of the vehicle were thought of first time, at the time of World War II. Several attempts have been made to make a military vehicle with amphibious characteristics. Some of the models are very heavy, costly, and few in number. The requirement for commercial amphibious vehicles is searched out by many marketing organizations and good potential is claimed. There are few companies like Gibbs Corporation, the USA who make Amphibious Jeeps. But they are few in number and very costly. India is geographically blessed with rivers, lakes, and seas around it which makes it a very versatile and rich area for use of amphibious vehicles. It can be a very meaningful and efficient means of transport also. Tourism in India is one of the main sources of revenue for many states. Water tourism and water-based tourism getting more and more popular. Ecotourism requires a vehicle that is compatible with land, water, and soft soil. It can provide added freedom of exploration also. There is a large number of eco-parks in various states in India which are gifted with natural resources and flora and fauna. In this thesis, an effort has been made to design and develop the concept of amphibious vehicles for certain states of India to adopt and use the amphibious vehicles for amusement purposes. From the state of Uttarakhand to Kerala there are many places where water bodies, lakes, and rivers can be used for amusement parks and use amphibious vehicles for a unique experience. Because of this, an effort is made to build amphibious vehicles first for entertainment uses before exploring applications in other fields. This thesis focuses on the design framework, including HMI aspects and the emotional design process in designing the amphibious vehicle. The process shows how `the inspiration of a `duck' which is an amphibious animal can visually influence the design of the amphibious vehicle. Thirty keywords for the amphibious vehicle were

selected based on application. The keywords were explored with possible design concepts and then they were rated by a group of prospective male and female different users. The statistical analysis of the keywords becomes a base for concept development. This process was repeated for concept development from frog as an inspiration for an amphibious vehicle. The quantitative analysis of two concepts was done by the statistical method using SPSS software. The effective parameters for AV design were identified and user preferences were ratified. The design parameters for AV design for amusement purposes were identified. This framework can be repeated

for other applications using AV.

In order to realize the concept, a CAD model is made and manufacturing aspects were also worked out. Keeping sustainability in mind the AV is made to run on a battery. The electric AV is suitable for future generations and is environmentally friendly. AV as a separate category of a vehicle can be designed for various applications in India. Flood relief, disaster management, border patrol, forest guard applications, etc. Amphibious characteristics can be seen as an essential requirement in the Indian context. By using the Design Framework for AV, the design can be customized for each application that users will feel comfortable with and like to own or purchase.

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CHAPTER 1

Introduction to Amphibious Vehicles and Eco-Tourism in India

Abstract

The attraction toward water and water-based activities has remained a favorite activity of humans for a long time. Water-based vehicles existed for a long but not many developments happened for these types of vehicles. Compared to land vehicles, there are very few developments happening in boat design or ship design. The Waterside has soft soil or sand where any land vehicle or water vehicle does not work. In order to explore nature, especially where a water site is available, an amphibious vehicle (which can work in water and muddy soil also) is thought of as a better option. India is surrounded by sea on all three sides and has plenty of lakes, lagoons, rivers, etc. The amusement parks and science parks are made for adventurous expeditions. Uttarakhand has many tourist sides that can be developed as amusement sites. Tehri dam site and Asan barrage site in Uttarakhand are some of the areas which can be explored for amusement parks, and the application of amphibious vehicles can be tried. Even though India has the infrastructure and does not have a previous record of usage of amphibious vehicles, in this thesis, the possibility of use of the amphibious vehicle in India is scoped out. Various social and ethnographic characteristics are taken into consideration, and design possibilities are worked out and reported about the feasibility of amphibious vehicles for amusement purpose in India.

Keywords: Amphibious Vehicle, Amusement Parks, Ethnographic Character, Water expedition, Uttarakhand amusement sites,

Key Findings:

- India has suitable conditions to use the amphibious vehicle for amusement purposes.
- Many states in India have suitable water bodies and nature parks where the amphibious vehicle (AV) can bring newness and joy.

1.1 Introduction

The tourist industry is one of the most significant contributors to the state's service sector in Uttarakhand. It has constantly moved up in recent times and improved in diverse directions. More than 20% of the state economy is dependent on this sector, as per the government audit. A wide variety of industries, services, and economic activities are involved in tourism. Providing a trip experience includes providing transportation, lodging, meals, retail stores, entertainment venues, etc. (Mathieson, A., & Wall, G., 1982). It also contributes to the socioeconomic development of the state. The introduction of Amphibious Vehicle in Eco-Tourism of Uttarakhand can bring new dimensions. It can offer innovation and attraction to tourists and provide users comfort to travel in areas where water is around, like lakes, rivers, reservoirs, etc. (Shirsath et al., 2015).

Amphibious vehicles had been a conscious effort on all the mobility front. The wish to float on water with the same mobility device used on land had been tried out in various forms. Recreational activity is perhaps the largest sector in AV. The 1950s saw several variations of this vehicle documented in history (Wilfred, 1964). If we look at the existing amphibian vehicles, we can see that all of them were converted from land vehicles depending on user needs. There are three different car, Jeep, and bike shapes. When we perform a job analysis on an AV that is not a land vehicle, we find that the shape and structure are not suitable for a water vehicle. Bio-inspired designs are those for which inspiration has been taken from nature or any natural elements like creatures, insects, animals, etc. (Jones & Platzer, 2006). Natural elements often reflect certain emotions.

1.2 Nature-based tourism (eco-tourism)

Since the beginning of time, people have relocated for a variety of reasons, including exploration, adventure, recreation, taking advantage of nature's bounty, experiencing climatic conditions that are different from their specific location, and having fun. (Mathieson, A., & Wall, G., 1982). Tourism, economic, physical, and social effects of tourism. According to Longman, tourism is "the temporary movement of people to locations outside of their usual places of work and residence, the activities engaged in during their stay in those areas, and the facilities established to accommodate to their needs." The effect of tourism on the Indian economy is depicted in Figure 1.1.

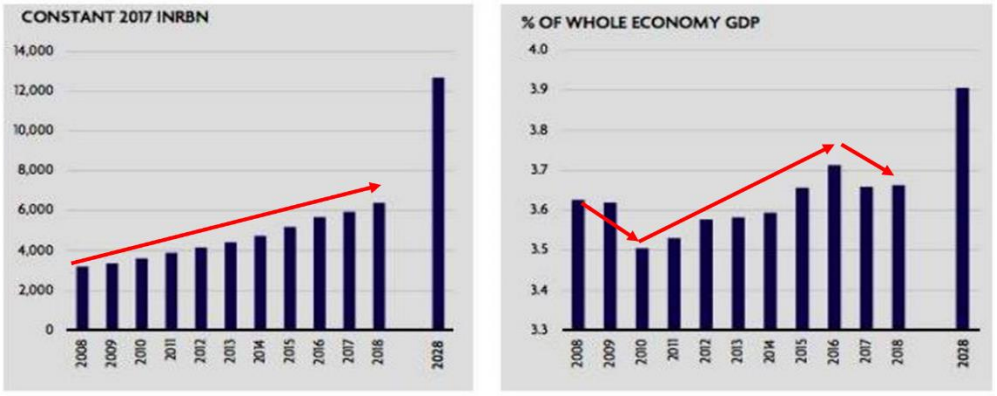


Figure 1.1. India's Direct contribution of travel and tourism to GDP (Mathieson, & Wall, 1982).

Nature-based tourism encompasses ecotourism, adventure tourism, extractive tourism, wildlife tourism, and nature retreats since it depends on experiences directly connected to natural characteristics. (PATA, 2004). The main approaches used by many industrialized and developing countries to sustainably integrate national parks, reservoirs, economic growth, and rural development in recent years have been the rise of nature tourism and ecotourism (Christian, Potts, Burnett & Lacher, 1996). The term "nature travel" (or occasionally "nature-oriented tourism") is used to describe a type of tourism that "combines education, enjoyment, and frequent adventure." (Laarman & Durst, 1987) (Boo, 1990) use the term "ecotourism" interchangeably with "nature

tourism," which she defines as "traveling" to relatively undisturbed or uncontaminated natural areas with the specific objective of studying, admiring, and enjoying the scenery and its wild plants and animals, as well as any existing cultural manifestations," throughout their major study of Latin America. (Ceballos, 1996).

1.3 Nature-based tourism in Uttarakhand

India offers a wide range of opportunities for nature-based tourism due to its numerous forest and grassland ecosystems, including alpine pastures, desert thorn forests, and tropical rain forests, as well as unique geological landscapes, rivers, valleys, breathtaking coastlines, and towering mountain peaks. The Asiatic elephant, clouded leopard, tiger, snow leopard, Asiatic lion, and one-horned rhinoceros are just a few of the thousands of species of wild animals and plants that call these forests home. Eighty-seven percent of the state of Uttarakhand, which has a total area of around 53,483 sq km and is located in the western Himalayan region, is made up of mountainous terrain (Chen, & Chuan, 2011). Exceptionally beautiful Sages, pilgrims, and other tourists have traveled to the state since ancient times. For a multitude of reasons, including spiritual ones, to take advantage of its unique environment, to witness rare wild animals and birds, and to escape the midsummer heat on the plains, millions of people travel to this breathtaking Himalayan state. Although minimizing negative effects on the natural environment and socio-cultural environment is an essential aspect of ecotourism, it is also an essential strategy to protect natural regions, such as Uttarakhand's geographical location and topography (Chaudhary, Kumar, Pramanik & Negi, 2021).

Uttarakhand is the 27th state in India, having two major divisions, namely Kumaun and Garhwal region, with 13 districts. There are 17 rivers and 31 lakes in Uttarakhand. Three fourth of the area of the state have Hilly areas and jungles. This makes Uttarakhand an ideal place for nature tourism. The lakes are the places of major attractions, and surrounding natural places are ideal for nature-loving people. (Jaiswal & Bisht, 2017).

(A) (B)

Figure.1.2 Google locations of some places in Uttarakhand which has water-based expeditions (Jaiswal & Bisht, 2017) (A) Asan River near Dakpatthar and (B) Water Reservoir at New Tehri.

Millions of people visit these national parks, sanctuaries, and conservation zones yearly. Additionally, it makes a substantial contribution to the preservation of these areas and the growth of environmental awareness among residents and visitors. Six national parks, seven wildlife sanctuaries, and four wildlife conservation reserves have been established in the state for numerous biological regions.

1.4 Land –Water sites in India

Ecotourism depends on capacity development. It improves the socioeconomic status in the area by generating income and giving the locals specialized skills. The initiatives for skill development for this sector of the economy in the state are summarized below (Kala, 2013).

Table 1.1 Land water sites in India

ECO PARKS	ECO PLACE	ECO FAUNA
Kamala Bird Sanctuary	Rabangla	Rufous-Necked Hornbill
Parambikulam Wildlife Sanctuary	Chilka Lake	Himalayan Tree Pie
Bheemeswari Wildlife Sanctuary	Sangla Valley	Red-Billed Blue Magp
Simlipal Tiger Reserve	Naggar	Red Fox
Namdapha National Park	Dalhousie	Himalayan Black Bear
Neoravalley National Park	Rishikesh	Scarlet Miniet
Bharatpur Bird Sanctuary	The Floating Islands	Blue Mormon
Periyar Sanctuary	Nokrek Biosphere	Blue Whistling Trush
Bandipur National Park	Tawang Pass	Himalayan Gorel
Sariska Tiger Reserve	Simonga	Himalayan Gorel
Ranthanbhor National Park	Coorg	Himalayan Musk Deer
Corbett National Park	Connor	Himalayan Musk Deer
Kanha Tiger Reserve	Mahabalipuram	Hoolock Gibbon
Dachigam National Park	Sela Pass	Lammer Geier
Dudhiwa National Park	Sonmarg	Malayan Giant Squirre
Nagarhole National Park	Kumbhalgarh	Raven

1.5 Scope of adventure sports

Due to its distinctive natural environment, which includes woods, alpine pastures, steep mountains, and swift rivers, Uttarakhand also supports several adventure sports. These activities help India's nature-based tourist industry (Lascurain, 1996). The government's ecotourism website is depicted in Figure 1.3.

Water-based Tourism has been given prominent importance, and the trend is growing rapidly. Building Adventure Park is one of the ways to improve the tourist attraction in Uttarakhand. Adventure and water park vehicles are fun vehicles for a comfortable tour of the tourist in the park. An amphibious vehicle is a vehicle that can run on water and land and can be comfortably used by tourists (Börekçi, Kaygan, Hasdoğan, 2016).

1.6 Other National Institute for Water sports

Many water-sports-based adventure institutes are trying to promote water-based adventure sports in India. There are some examples of that given below. Some of the organizations for the training of adventure sports are shown in Figures 1.3.A-E. Amphibious tourist initiatives have been operating for many years in Brisbane, Singapore, Ottawa, Montreal, Toronto, and Nova Scotia in Canada, New York, Washington, Miami, Philadelphia, George, and many other American cities, which are currently quite popular in industrialized nations. On Australia's gold coast, 36 maritime professionals, including engineers from China, Australia, Italy, the United States, and Germany, gathered in 2001. They continuously improved the speed, functionality, and performance of amphibious vehicles. After five years of work, they eventually produced the expensive, million-dollar Australia International Amphibious Cruise Ship, also known as the "Adventure Duck" Amphibious Sightseeing Ship. Amphibious projects were also utilized in the tourism sector in Cairns, Brisbane, and other well-

known tourist destinations. (Pauw, Ingrid, Kandachar, Karana, Peck, and Wever, 2010).

Figure 1.3. India's Government's policy on Eco-Tourism for all states: A) Conceptual model of NIWS, Goa; B) Himalayan Adventure Institute, Tehri, Uttarakhand; C) Himalayan Academy of Water Sports; D) Adventure Sports Training, Tehri, Uttarakhand E) India's government's policy on eco-tourism for all states

1.7. Requirement Analysis using a Survey from Indian audience

A survey was conducted among Indian citizens to understand the necessities of amphibious vehicle in Indian context for amusement purpose. A total of 73 participants participated in this survey. Results of this survey reflect that around 68.6 % of people are aware of amphibious vehicles and they (51.4%) mostly heard about it from social media. About 77.1 % Indians are interested to see amphibious vehicle in near future. The design of the vehicle should be both minimal and tech oriented (62.9% people said that) and the vehicle should be 2-5 seater (52.9% people said that). Around 38.6% Indians suggested that amphibious vehicle has future implementation possibility in India; in addition, 50% people said `May be'

there are possibilities. Most of the people wants any kind of amphibious vehicle (54.3%) but they want it for both under water and on water surface (27.1 % under water, 18.6% over water). Approximately 31.4% Indian occupants want amphibious vehicle for luxury and 27.5% want it as essential commodity. Around 90% of users said that it will be required for aquatic tourism. Around 41.4% users said that it should be using electric power as a type of energy. Please see Appendix **1** for detail survey results.

1.7 Chapter Synopsis

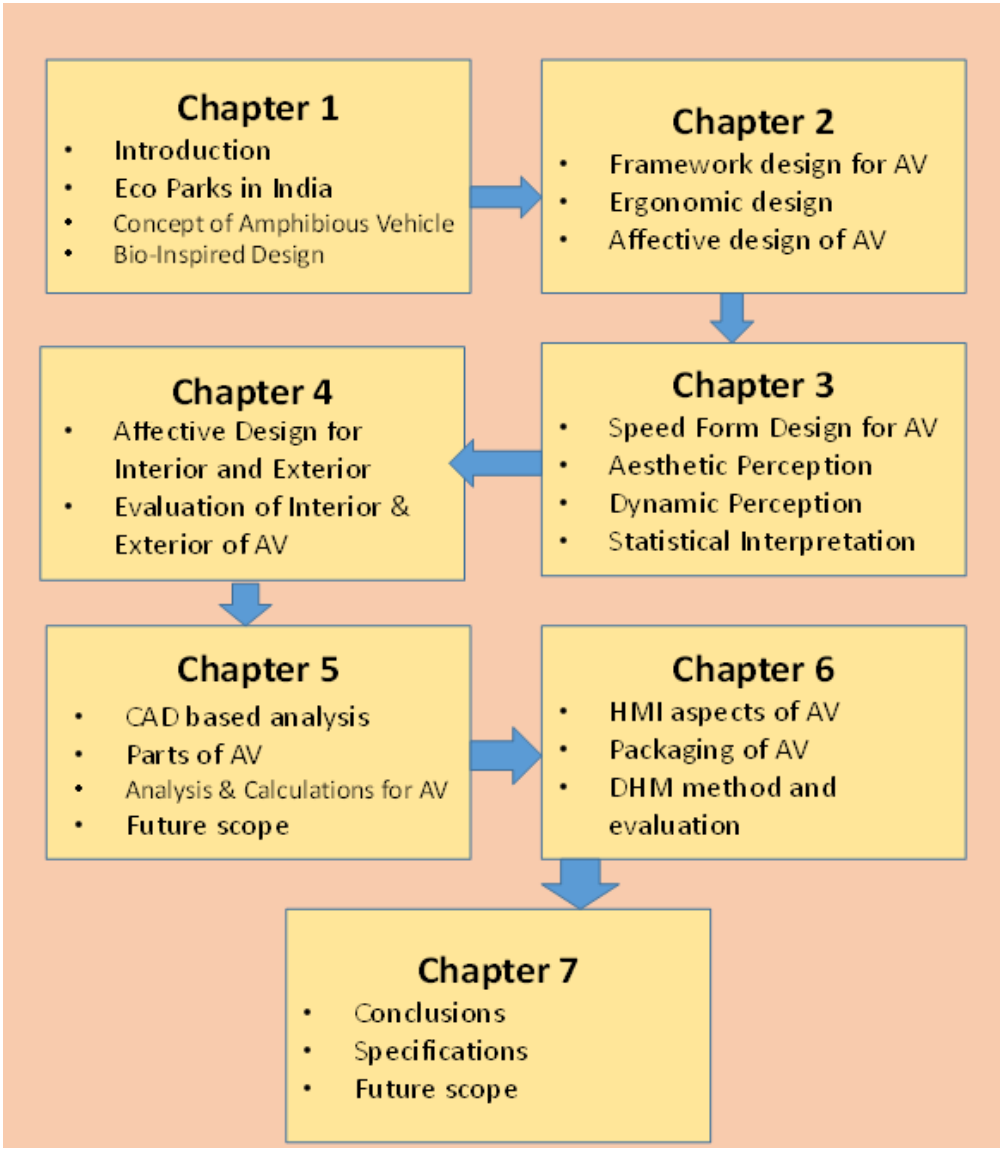


Figure.1.4 Chapter Plan.

1.8 Brief of Chapter 1

India is surrounded by sea on all three sides. It has plenty of rivers, dams, lakes, and inland waterways, making it suitable for exploring land and water vehicle for various requirements. Land and water vehicles can be called amphibious vehicles, which have various requirements in time. Amphibious Vehicle (AV) was used in defense applications during World War II but was not reused. AV can be used for recreational purposes as a human is attracted to the water, and water parks are becoming popular in India. An AV can give freedom and newness to recreational activity when it is designed suitably for mass usage in a commercial application. Apart from that, Uttarakhand has an eco-tourism concept that is getting very popular in the state. AV in Eco-Tourism can boost attraction, comfort, and innovation in the tourism sector for recreational activity.

1.9 Brief of Chapter 2

Amphibious Vehicle was used first in World War II for military requirements. Many different ideas were executed in a small way after this. People have tried to convert land vehicles to water vehicles; in many attempts, amphibious was made in India as a trial attempt by Saidullah, which was a prototype to prove the idea.

An amphibious jeep, scooter, or car is made by Gibbs company in the USA. An amphibious bus is made in The Netherlands and runs successfully. The overall presence of AV in totality is not found as continuous and more in number. Many types of AV are found in the history of AV (Börekçi, N. A., Kaygan, P., & Hasdoğan, G, 2016). Mostly it was an experimental result or small business.

The design of AV as per user requirements can help improve the aesthetic and ergonomic aspects of design. The design aspects related to aesthetics and HMI of AV are discussed in this thesis. An attempt is made to create a design framework for AV that addresses specific requirements related to aesthetics, styling, and HMI aspects in design (Bordegoni et al, 2012).

Many states in India have waterways as one of the most comfortable ways of transportation. Kerala and West Bengal have many rivers and lakes, lagoons, etc., which makes a reasonable possibility of introducing AV for transportation. Uttarakhand state has a tourism focus for the developing economy. AV has a good

possibility for eco-tourism as a recreational vehicle. This can give freedom and privacy and boost eco-tourism.The research done on Indian customers shows that there are expectations and wants for AV.

1.10 Brief of Chapter 3

The visual design of amphibious vehicles consists of exterior form design and interior design. In order to meet AV design with the user's psychological requirements, a contextual design exercise was performed. The contextual mood board was created based on bio-inspired creatures. Let us assume that Amphibious Vehicles are in some way or other connected to amphibious creatures if you consider external form design. A form design exercise was performed based on bio-inspired creatures. The external look of a frog, a duck, and a dolphin was taken into consideration. A creative exercise of abstraction from the design form of these bio-inspired creatures was performed. This is called speed form design. The 3D models were created from the sketches, and while creating speed forms, aesthetics were a significant consideration.

About 30 effective keywords were selected that matched users' psychological requirements. A group of users (total of 22) which includes males and females, were interviewed with these 3-speed forms. They were requested to evaluate the three-speed forms about the 20 chosen keywords. SPSS software was used to evaluate the results statistically. Descriptive and inferential statistics were employed. The Friedman ANOVA and Wilcoxon signed test was carried out using SPSS software. It was discovered that speed form 1 (inspired by a frog), out of the three-speed forms examined in this study, was the most popular. Although the chosen speed forms all included dynamic qualities, the speed form was more aesthetically beautiful than the other speed forms. Therefore, when designing amphibious vehicles used for amusement, speed form 1 may be taken into consideration.

Since the Friedman test's p-value is more than 0.05 [(2) = 2.564; p=0.28], there is no discernible difference in the dynamism value of the speed variant. No significant difference was discovered in repeated comparison tests for the mean values of dynamism for different speed forms since p values are above 0.05 when comparing the dynamism values in different combinations for three variations of speed forms.

The study, as mentioned above, demonstrates that when it comes to AV design, use favor aesthetics over dynamism. The three models' Chi-Square Test results for

0.035, which is less than 0.05, support the null hypothesis. The two characters differ significantly from one another. In contrast to the dynamic character, which does not influence how users choose their form, the aesthetic character is in charge of how users ultimately choose their form. The results of the user survey also demonstrate that Form 1 is chosen by most users.

1.11 Brief of Chapter 4

The success of AV design largely depends on its exterior and interior design. The design language of AV design depends not on its internal components but on the related image of water-based amusement, which is in the user's mind. Bio-inspired concept design is taken up as a concept for AV design. Here we have experimented with bio-inspired concepts, which are mainly taken from amphibious creatures like ducks &frogs. The body construction of frogs and ducks is studied, and speed concepts are generated from those rated against aesthetic parameters by users (Davis, 2012).

The design functions of AV sometimes are very similar to some biological organisms. It may match some aspects of creatures or birds or any other animal. AV functions by nature are synonymous with creatures like ducks, frogs, etc., which are amphibious (Wang, 1995) (Benyus, 2020). Here concepts are generated from frogs as inspiration. Compare both concepts for user reactions. The final model was taken for further detailing. The backward confirmation from the user-by-user survey conveys a scope for improvement in aesthetics. The alternate concept AV form design inspired by frogs was also tried out.

The process of AV form generation is iterative and depends on the user's reaction to each feature. CAD design is used to model AV form generation and work out details (Chen, Hoyle, Wassenaar, 2013). The practical design of AV was divided into two parts—exterior and Interior design. Since the user interaction with AV is both in terms of appreciating and owning, it is visually and psychologically connected with users (Nagamachi, M., 2010). The methodology followed was known user reaction for two types of concepts derived from Bio-inspired design. A Duck beak inspired one design, and Frog inspired the other design. Both are amphibious creatures, but their designs had varying amounts of design elements required for AV design (Baldovino, R. G., & Garcia, G. R., 2016). Users were given 30 keywords, and they were asked to ratify on a 1-7 scale, depending on their choice. A total of 81 target users (male and female) in

the age group of 17-35 were taken into consideration. (Wang et al., 2018). Initially, brainstorming on effective keywords related to AV was done. Since nature-based or contextual design is considered here as a base, words related to the context of AV for recreation were considered a base.

The detailed design for AV, which includes interior & exterior design, was made for two sets of concepts. A duck inspired one, and a frog inspired the other. The visual aesthetics of both are different. These concepts were ratified on a 1-7 scale by 38 users of both genders aged 18-55. The users were given 30 appropriate attributes or keywords. Users were asked to reflect on them with numbers. These numbers were then taken for statistical analysis and ANOVA. By suppressing less significant components, the comparison is made.

The Varimax rotation matrix was applied, and a component having a coefficient less than 0.8 was suppressed. Maximum iteration of 25 applied. Through Factor analysis and ANOVA, four parameters had significantly high values and were found in concept 2.

1.12 Brief of Chapter 5

A CAD model was made based on a bio-inspired design, and extensive prototyping was done. The vehicle's dimensions were determined by drawing design inspiration from current electric land vehicles like the Nissan Leaf and Chevrolet Bolt. The first phase is to model the mechanical parts after the ladder-type chassis, such as the suspension, differential, motors, seats, and, eventually, the body. (Owen, J., and Tovey, M. 2000).

A conceptual design for an amphibious vehicle was looked into for contemporary leisure activities. The research was done on technical viability, various user interface elements, and the design concept considered the psychological side of the user's thinking. When designing AV, an amphibian animal such as a duck or frog was considered an inspiration. Its body construction's form feature produced a unique sort of vehicle. The distinctive visual design element invites and piques interest in using the amphibious vehicle for leisure activities. This will help amphibious vehicles regain market share, and its unique advantage will benefit humanity.

1.13 Brief of Chapter 6

This chapter deals with the realization of a design into an actual prototype. Apart from the CAD model, the validation is done using digital human modeling (DHM). The ergonomic considerations and anthropometric considerations are taken into account. The initial Design faced some issues as part of the analysis. Necessary modifications are undertaken to make the AV design meet the design considerations. The Vehicle interior and dashboard operations are evaluated using RULA and REBA methodologies. The CAD model, along with the digital human model tested with RULA. The neck position for visibility of the instrument panel needed modification. The height of the instrument panel was increased, and the bend in the neck was reduced. The space requirement for two persons in AV was less as the arm-to-arm space interfered. The AV's width and the seat's space were increased to make it comfortable. The ingress step was at a height that was causing leg muscle stress. An additional step was designed to get into the AV. Additionally, a handle is provided when ingress into the vehicle. With all this modification, a scaled-down (1:10) model was done.

1.14 Brief of Chapter 7

The requirement of the amphibious vehicle in India and its interpretation as an amusement vehicle was done as an exercise in this paper. The framework of AV design and Bio-Inspired design approach was applied to create a design for Eco- Parks in India. Evaluation of its interior & exterior design done for finalizing the design. It is recommended for new applications and benefits. New and special-purpose applications can be found with amphibious characteristics to provide an upper edge for applications in rural India (Farr, D., 2011).

The present thesis only extended it once prototype creation and working model creation—the exact specifications of the battery and electrical components. However, the buoyancy and speed calculations, including structural finite element analysis, are done. The prototyping and testing are kept for the future scope of work from the present thesis work. Proposals are sent to DRDO for prototype creation for AV for Border Patrolling.

1.15 Literature Survey Summary

Following are summary of literature survey done on this topic.

Table:1.1 Summary of Literature Survey

Themes	Details	Findings	Inferences	Gap
Boat manufacturing	20 papers are studied	Motorised Boats structure is studied	Limitations on shore/less depth of water	Not suitable for land and water movement
Patents on AV designs	50 Patents	Customized design heavy on technical aspects. Visual and ergonomic aspects are missing	Design with focus on Ergonomic & Aesthetics required	Mostly for military applications and bigger vehicle in focus.
Aesthetics & Form Design	50 Papers	Automotive vehicle heavily depends on Form design	Form Design is also applicable on Amphibious Vehicle	Amphibious Vehicle is very few in number and inconsistent
User Research	20 papers	User research methods for automotive design	User research can be done to know more about AV users	For AV user reserch data is not found
HMI & Digital Design	10 papers	For user comfort this process is very useful for automotive design	Similar study can be done for AV which can benefit the design of AV	Similar study for AV design is not found

1.16 Conclusions

The application of Amphibious vehicles can be explored in India. It can be explored in various applications, including adventurous sports and amusement parks. It can be checked for use by the general public (Indian Males and Females) for easy operation. The design of AV can be made attractive so that it can be inviting to the general crowd. The design of AV can have a separate frame pertinent to its applications. Further deep dive can be made to research the design process of amphibious vehicles for the Indian context.

CHAPTER 2

Theoretical Framework and Design Process Followed to Design an Amphibian Vehicle

Abstract

An amphibious vehicle is not a new idea conceptually. The principle was tried out in military vehicles during World War II in 1939. Since then, AV has a military use in many countries. The applications for cars, jeeps, trucks, and other applications were tried out much later. In many countries, new attempts were made to convert land vehicles into floating vehicles, mainly for surprise or tourist attractions. It was not found to be made by the commercial method. The numbers of this kind of vehicle were few and did not sustain for a long time. The attempt is made here to systematize the process of AV production. Since this type of vehicle has potential commercial use and can be required in large numbers, a design approach or theoretical framework is made, keeping the specific requirements of amphibious vehicles in view. An approach to bio-inspired concept design is introduced including consideration of aesthetic and HMI evaluation to create the design occupant friendly. The AV is designed for amusement purposes. Hence, user involvement and acceptance of the look of the AVs are important. The ideation methods and evaluation methods are described in other chapters of this thesis.

Keywords: AV for amusement purposes, Bio-inspired design concepts, Framework Design of AV, Ideation Methods, User-friendly design,

Key Findings:

- Traditional AVs were mostly used for military use.
- AV for common people's use requires a change in the approach to design.

2.2 Bio-Inspired Design

Bio-inspired designs are those for which inspiration has been taken from nature or any natural elements like creatures, insects, animals, etc. (Jones & Platzer, 2006). Natural elements often reflect certain emotions. This comes from the look of the organism or functions of the same. The similarity in characters and mechanisms like body structure, features, color, and texture are inspirations for product design. It is also called Bio-mimicry. For example, the fast-moving two-wheelers are often inspired by leopards or Cheetah, which is the fastest animal on earth. It brings a resemblance to the semantics of product design. The amphibious vehicles found in history look wise uninspiring, and technical. For the purpose of making it interesting to the users and giving meaningful shape, a bio-inspired design process is selected. Here concepts are done from Ducks and Frogs, which are amphibious in nature. The evaluation of concepts is done by the user survey method. The user preferences are identified (Kozlov, Chowdhury, Mustary, Loganathan & Alam, 2015).

2.3 History of Amphibious Vehicles

The amphibious vehicle was first found to be developed long back in history, in 1805. Oliver Evan of the United States designed the self-propelled steam-powered and wheeled dredging barge named Orukter. The objective was to travel around the world on land and water (Woodside, Sood, & Miller, 2008).

Until the late 1920s, the effort was to unify a boat and an automobile by simply putting a wheel and axle to the boat and hull and, in other words, getting a rolling chassis on water. One of the first well-documented cases of an amphibious vehicle was in 1905 when a petrol-powered carriage was made on water: the three-wheeled carriage where the front wheel for direction was used and the rear wheel for power. Fins were provided on spokes for propelling water. Since the 1920s development of amphibious vehicles has significantly diversified into other areas. Applications were created for recreation, expeditions, search, and military applications (Ridden, 2015). In some cases, it was just a conversion of a land vehicle into a floating body. In some instances, integrating amphibious characteristics into the existing vehicle was central to the theme (Ferreira, Furini, & Silva, 2007).

Amphibious vehicles had been a conscious effort in all the mobility front. The wish to float on water with the same mobility device used on land had been tried out in various forms. The following varieties of amphibious mobility devices have been identified and shown in **Figure 2.1.**

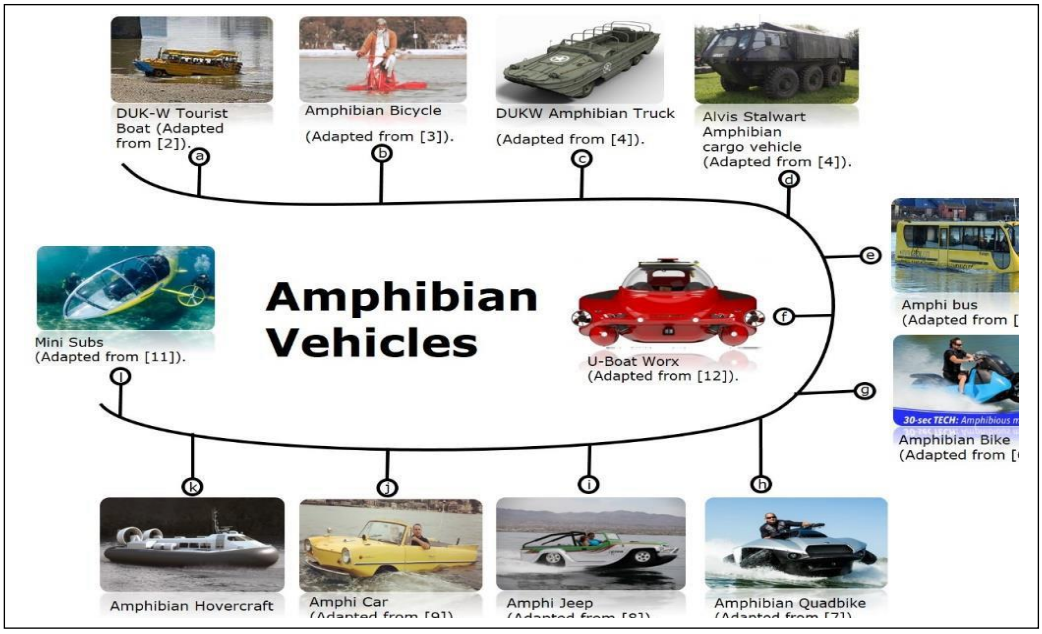


Figure 2.1. Different types of AV usage in history in different countries in the world.

2.4 Introduction and Background

It has been determined that the human race first began to colonize territory about 200,000 years ago, all over the world. The particular vehicle is capable of traveling independently on land and in water. There have been very few attempts to move a car both on land and in the sea. Engineers developed a vehicle that is capable of moving on both land and water with an experience of their experience of bi-terrestrial requirements. According to Börekçi, Kaygan, and Hasdoan (2016), AVs are the kind of vehicles that can travel over both land and sea.

2.5 Possibility of Applications of AVs for Recreational Purposes

Recreational activity is perhaps the largest sector in AV. In the 1950s, this vehicle came in a variety of forms. Different types of the ferry that could go on highways were produced by DUKW of Boston (Tovey, Porter, & Newman, 2003). The information on several types of amphibious vehicles can be found on websites(Siddaiah, & Menezes, 2016).

2.6 Types of Amphibious Vehicles

Many military vehicles have been transformed into AVs in order to meet the demands of the field. Several kinds of amphibious trucks with 6X6 wheels carrying soldiers and weapons through coastal areas were deployed during World War II by the German company DUKW. About DUKW (Amphibian Truck) Amphibian trucks with 6x6 wheels were developed by Alvis Stalwart for use in military and cargo transportation in the United Kingdom. Alvis Stalwart Amphibian Truck looks like a truck in Hull.

2.6.1 Amphibian Bus

Another historical example of a leisure vehicle is the Amphibian Bus. In Rotterdam, The Netherlands, a popular tourist destination is the splash tour. It seems to be a standard bus and has a high floor. Water and roads function differently internally. On water, the vehicle travels at a speed of 8 knots and can accommodate 25 passengers. For a bus that can swim as described in website Wikipedia `Alvis Stalwart' on 7th Feb 2023, which is utilized in Rotterdam, Netherlands (Hajare, 2015).

2.6.2 Amphibian Car

This style of prehistoric Amphibian vehicle is fairly common in the USA and Europe. One German corporation produced and distributed its goods; although it possessed a 4x4 drive and watertight construction, it had a car-like appearance. It had a Porche 356 transmission, a BMW control system, and a 43 HP engine. It might cross a road as well as a river. It was popular because of how much the design resembled a car, as described in `Amphicar' on the website (Classic Traders, 1965). The Amphicar had a low first-gear ratio and had better ground clearance than a jeep: large tires and power steering. The Amphi vehicle is depicted in Fig. 2.1. the user-centric approach is not well-established for AV design, despite the literature detailing numerous different AV design methods. This study tries to provide a user-centric vehicle (Majumder, Choudhury 2021).

2.6.3 Amphibian Cycle

This particular bicycle model can travel both on land and in water. The Discovery Channel and BBC News provided the first coverage of the Amphibian cycle. It's referred to as Saidullah's Bicycle. It used four rectangular air-filled tanks to provide

buoyancy. A tricycle frame and a fan blade drove it. The manually pedaled bike could go at a speed of 1.12 meters per second on the water. This was effective in urban settings like floods and the leisure industry.

2.6.4 Amphibious Bike

Gibbs of the United States produces the most well-known amphibious bike. It has a twin-cylinder engine with 55 HP. This travels at a 35 mph water speed and 80 mph on land. The two-wheeled AV is 502 pounds heavy.

2..6.5 Amphi Jeep

The Amphibian Jeep, which resembles a jeep almost exactly but travels on water at a speed of 44 mph, is the most widely used type of AV. It is now the fastest boat available. The most well-known business is "Water Craft" from California, USA. Its 3.7-lt V6 engine goes by the name "panther," and it is for sale for an amphibian quadbike and an amphibian jeep, respectively.

2.6.6 Amphi- Submarine

In 2011, the Scubster team in the USA used a model of an amphibian submarine called Scubster for adventure and enjoyment. It participated in the world championship of naval racing. There are two seats in this electric version of the car. It is driven by two electric motors, and its top underwater speed is 8 kmph. For the Mini Subs model, Similar to the aforementioned, there are numerous additional types of recreation vehicles, mostly used for adventure and water sports.

2.6.7 Amphibious trucks and artillery vehicles

In addition, other innovative amphibian military-based carrier designs were used throughout the 1955–1975 Vietnam War. In the 1960s, the British created the 6X6 cargo ship Alvis Stalwart, which used water-jet power at 6 knots. German engineers created the M3 Amphibious Rig, which can transport numerous soldiers and large vehicles and goods.

The Sherman, a post-World War II British vehicle with a rubberized screen that the soldiers opened before entering the water to provide extra buoyancy, was named for the Civil War leader William Sherman and was also known as the "Duplex Drive." It used propellers as part of its propulsion system. The screen concealed the cannons, making them unusable while afloat, which was a flaw in the design (Lin et al., 2016).

2.6.8 Hovercraft based vehicles:

These air-cushioned cars are also recreated for the big screen in movies like the James Bond film Die Another Day 2002. It is based on levitation, where a low-pressure air cushion separates the ground and the vehicle's base. They can quickly switch from land to water or vice versa and can even travel at speeds of up to 150 mph while on the water. It undoubtedly has disadvantages, such as the need for level ground and excessive fuel consumption.

2.6.9 Commercial Amphibious vehicles

Many AV designs are based on WWII amphibious vehicles that are still used as amusement and tourism attractions today (Sitek & Yang, 2011). They are employed in locations like Venice's waterways and other similar ones. Many concepts and prototypes, such as the Rinspeed Squaba and Gibbs Aquada, have been created for a limited consumer market as described on the website (Amphibious Splash Tour Slashburg, 2016). Numerous individuals have attempted to alter and adapt their wagons into fun, family-friendly amphibious automobiles (Stamov, 1990). Bert Sandlin of New Orleans created an inexpensive, 40 mph capable homemade AV in his garage. For added buoyancy, it incorporates fiberglass and Styrofoam reinforcing (Bo et al, 2014).

2.7 Design Philosophy of Existing Amphibian Vehicle

All of the current Amphibian vehicles need-based modifications of land vehicles. As shown by a look at their design philosophy (Mayyas, Qattawi, Omar & Shan, 2012), for vehicles that are amphibious vehicle, land vehicle shapes like bike, Jeep, or automobile shapes are available (Weber, 2009). When we perform a job analysis on an AV that is not a land vehicle, we find the shape and structure unsuitable for a water vehicle. Human desires are not considered when designing an AV (Edwards, Bhamra, & Rahimifard, 2006). Because the Amphibian recreational vehicle has unique characteristics and operations, a user wants a survey undertaken for its design. (Awasthi, 2017).

The study of existing amphibious vehicles shows that a large portion of the vehicle was in military applications, where it resembles too much of a war machine.

After a long while, the occasional use of amphibious vehicles is found in some countries for tourist attractions. Customized vehicles are made in small numbers for tourist attractions. The road vehicle shapes are taken to convert into amphibious vehicles like Buses, jeeps, Scooters, etc. AV can be treated as a particular segment of the vehicle and can be designed keeping its user requirements and aesthetic requirements into consideration. The framework may focus on Requirement Analysis, Concept Design, Interior & Exterior Design, and design evaluations. This chapter suggests a framework for an amphibious vehicle that can be useful for any AV design for different kinds of applications.

2.8 Current Design Strategies

A literature review demonstrates that all amphibian designs turn land vehicles into watercraft. For example, the Amphibian Jeep and Amphibian Car maintain their current appearance. Compared to a land vehicle, a boat's hull design and ergonomic entry and evacuation concerns differ. The aesthetics of amphibian vehicles should be distinct from those of boats or other land vehicles because of their unique qualities. For instance, the Amphibian Bus resembles a bus in appearance and construction. Although the spectators' amazement that a bus can run on water is also considered, it still does not last long. (Burchard, Ayers, Frey, & Sapidis, 1994).

Based on studies, many types of AVs were developed over time for specific uses. AVs were typically sold for defense use, but a minimal number of specially designed editions are now made available to the public (De Pauw et al., 2010). As a result, AV design has a user-centric standard and procedure. It is acknowledged that the complete spectrum of human emotions affects purchasing decisions. Design elements that affect the senses should match how the product looks. It might be challenging to define boundaries that are meaningful to human perception (Gawande and Mali, 2016). A helpful technique for

coordinating visual perception with the vehicle's form is the Kansei Engineering process. This procedure enables the vehicle to be styled to meet the sensory requirements of the user. (Nagamachi, Lokman, 2016).

2.9 Design Process developed from different Study

A framework represents product designers' choices and actions when developing it (Kalhari et al., 2020). The process's depth depends on careful evaluations of factors that affect the ultimate design outcome. A holistic design approach also considers the actual situation and possible relevant factors (Börekçi, Kaygan, Hasdoan, 2016).

Compared to a terrestrial vehicle, an amphibian vehicle will have different formal notions. Moving on to water presents unique challenges for stability and buoyancy. Since it must float on water and move through water, the propulsion requirement is also different. Amphibious vehicles differ from land vehicles and boats in areas like how high-speed boats calculate drag on the water (Koler, 2007).

Amphibian vehicles have various user considerations than cars or any other land vehicle, such as egress and egress from the vehicle. The water-bouncing properties and speed characteristics show that the seating arrangement can be adjusted to the proper configuration needed for AV for recreation (Tovey, Owen, 2000). Figure 2.10 depicts the design framework for the amphibious vehicle.

2.10 Different steps in framework design of an amphibious vehicle

Following chart shows different steps towards design of amphibious Vehicle.

Design Process followed for designing amphibious vehicle

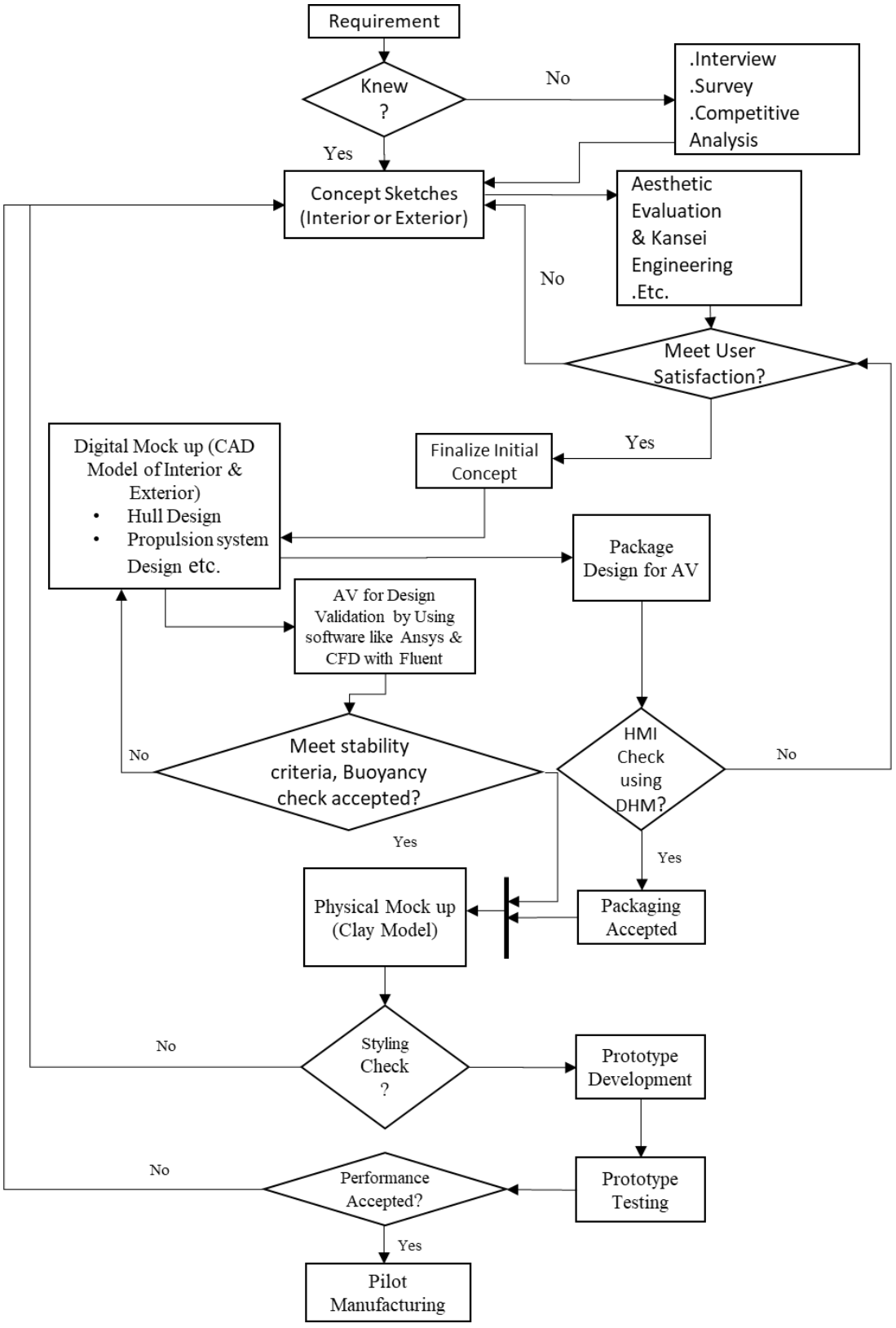


Figure 2.2. Design process suggested for design of amphibian vehicle (AV) design.

2.10.1 Requirement Analysis

A "User Survey" is carried out to obtain detailed information about user requirements and goals. User desires and keyword surveys are carried out following the Kansei Method (Wycoff, 1991). A questionnaire, direct interviews, and secondary research techniques are used to perform this survey. The present situation exposes a two-seater vehicle that can go on land, water, and undersea (Wycoff, 1991).

2.10.2 Conceptualization

AV design starts with ideation and sketching. According to the user survey, the primary aim and mood board are formed as "Safety." The vehicle's forms are entirely distinct from those now on the road (Tovey, Porter, Newman, 2003).

"Helmet" was the initial source of inspiration for the energetic, secure, and elegant elements. The primary form used to generate the forms was Helmet, which was then changed into Amphibian Vehicle.

2.10.3 Interior & Exterior Sketching

Throughout the detailed sketching, ergonomic concerns and packaging ideas are considered. Here, the Hull Design, Propulsion Method Selection, Stability, and Buoyancy Criteria are considered (Sanjog, Karmakar, Patel, Chowdhury, 2015).

2.10.4 Design Evaluation

It is challenging to evaluate the finished design. Regarding the use of AV, design processes involve emotional factors, which strengthen product identification. Amphibian vehicles must adhere to aesthetic standards (Mugge & Dahl, 2013). It

should not be combined with cars or boats. Unlike automobiles or boats, airplanes have different operating and comfort requirements. As a result, the vehicle's design must consider this application.

The framework includes the Kansei engineering (KE) approach, which may be used to build an amphibian vehicle (AV) methodically while considering all relevant elements. A user survey is used for this. The success of the product depends mainly on its appearance and personality evaluation. The KE approach collects and applies consumer feedback on vehicle aesthetics. (Yuhazri, et, al, 2018).

2.10.5 Preparation of Digital Mockup

Software such as CATIA, SolidWorks, Fusion 360, etc., turns car conceptions into digital mockups. A vehicle's scaling and material distribution are also done simultaneously. All vehicle engineering factors are considered at this phase, and specific vehicle parts are also subjected to Finite Element Analysis depending on vehicle design. The digital mockup also addresses adjustments needed due to aesthetics and FEA results. The assemblies are created using both existing and freshly developed elements. At this point, engineering and aesthetics converge. The use of digital human models allows for ergonomic considerations to be tested (Riascos, Levy, Stjepandić & Fröhlich, 2015).

2.10.6 Finalizing CAD Design

Packaging internal AV for entertainment system components is part of the CAD design. The choice of the battery and the motor is the main task of an electric AV. Choosing between the two is followed by considerations about the propeller, water jet motor, shaft, chassis, and body measurements. The digital mockup replicates the real

AV for ergonomics assessment using digital human models (Chaffin, 2001).

Other factors, like materials and procedure, might be considered when building the digital AV mockup. For the purpose of calculating buoyancy during AV construction, the lightweight and volume of water that is displaced by the "Hull" is taken into account. Sturdy and lightweight carbon steel could be used for the frame. Expanded polyurethane can be used as a filler material in the AV's body design to make it more lightweight. A Hover Fan is available and is utilized for both beach and sea excursions. A vital component of this AV's design is how the Hover fan is packaged, and its frame is attached to the body.

When building the AV design, styling and aesthetics are crucial. The original concept sketches are a reference for building the AV design's digital mockup. Preliminary calculations for efficiency can be made manually. Advanced Design validation may be done by utilizing this program. The first phase of design finalization is package finalization. Another standard for determining when a design is finished is the optimization of the materials and processes.

2.10.7 Human Machine Interface (HMI) Check Applying DHM

This capability is necessary for the tool's user to produce objective and repeatable simulation results or outcomes unrelated to the DHM tool user's presumptions on the postures and behaviors of drivers in particular circumstances. Such prediction abilities may be based on optimization techniques, enabling the human model to automatically generate an appropriate sitting position or motion within the existing constraints.

An AV cannot be considered designed if HMI Check is not performed. In this case, the overall measurements, panel dimensions, door dimensions, etc., of a digital mockup of the vehicle concept digital model. The concepts are developed through

sketches and verified using digital mockups (Sanjog, Karmakar, Patel, Chowdhury, 2015). The Digital Human model aims to represent the human body with the ability to apply any attribute, including height and gender, as necessary. A software model determines the dimensions dependent on postures like sitting, standing, and contact area in sitting, clutching, etc. DHM is necessary to develop AV for leisure—the inside (Chang & Wang, 2007). Industrial shop floor layouts are now created using digital human models. DHM can be used to illustrate and address the assembly line's ergonomic and man-machine compatibility issues (Sanjog, Chowdhury & Karmakar, 2012). Human elements are more effectively incorporated in the design phase using CAD and DHM. By including this, the balance between desired performance and user comfort may be guaranteed (Sanjog, Chowdhury & Karmakar. 2010).

2.10.8 Final Styling Check and Modification

Since the design is developed with a specific theme in mind from the start, it endures even after numerous changes are made for various factors, such as engineering packing. (Zhang, Zhao, Zou, 2009). After every change, the styling check is carried out to restore the original visual design's essence. Additionally, styling changes have been made to the CAD models. To polish the incredibly minute features of visual design, 1:1 scale clay modeling is finally used after making multiple dummy models—the requirements for alteration related to style. The other adjustment was the positioning of the rotor, wheels, and fan. (Stamov,1990).

2.10.9 Prototype Construction

The amphibian vehicle's full-scale prototype has to be ready for concept testing. This document currently needs to cover it. Engineering characteristics are tested to ensure

that the concept is sound. When the test results are satisfied, precise drawings will be produced for pilot manufacturing (Du Plessis et al., 2019). Innovative construction methods and materials that are lightweight and float in water were used to construct the vehicle's body. Roto-molded plastic foam components can be used for simple and straightforward forms (Babapour, 2012).

2.10.10 Prototype Testing

The last stage for result confirmation is prototype testing in real-world settings. At this point, design adjustment is still dependent on improving results. After the prototype has been built, testing can be carried out. Prototype testing is often how the reliability of AV is determined. There are three forms of prototype testing. 1) Testing of virtual prototypes 2) In-depth testing of the prototype in lab 3) Field testing of prototypes. Analysis software and a digital mock-up are typically used for virtual prototype testing. Static and dynamic stress assessments are carried out for chassis validation. Software like Ansys, LS Dyna, and Abacus are just a few examples of what is utilized for crash investigation. Software for fluid analysis, such as Fluent, Star CD, etc., can be used to compute the drag on the AV body. Attaching instruments and running the AV in simulated conditions are two ways to evaluate the actual prototype of an AV. The measured and observed reading may be utilized to do additional life prediction analysis. The final testing type involves running the AV on the ocean and a beach multiple times while subjected to various load situations. All functional parameters are susceptible to observation.

2.11 Research Gaps

1. There are reports addressing the technology and development aspects of an amphibious vehicle. However, significantly fewer studies have focused on an amphibious vehicle's aesthetics, emotion, and human-centered design.
2. Minimal studies have focused on designing amphibious vehicles for amusement purposes.
3. No study reported on an amphibious vehicle that considered Indian human anthropometric body dimensions and their applications for amphibious vehicle design.

2.12 Research Questions

1. Can we conduct studies on aesthetics, affect, and HMI aspects of AV that might be useful for amusement purposes, such as children's parks, science parks, etc., in the Indian context?
2. Can we analyze the requirements of Indian users for designing amphibious vehicles inspired by the morphology of biological organisms such as amphibian animals?
3. What are the methods and strategies designers should follow for amphibious vehicle design in the context of the amusement of the Indian audience?
4. Does the designed amphibious vehicle suitable in terms of Indian anthropometric body dimensions and fitting to the aesthetics and affective requirements of Indian occupants?

2.13 Aim

To design amphibian animal-inspired amphibious vehicles considering aesthetics, affect, and HMI aspects in the Indian context for amusement purposes

2.14 Objectives

1. To analyze aesthetic and affective requirements of the amphibious vehicle which helps to satisfy Indian occupants in the context of amusement
2. To design (bio-inspired) and check human anthropometric fitment and HMI

aspects of the amphibious vehicle in the Indian context

3. To determine the vehicle dimensions and manufacturing feasibility of an amphibious vehicle as an e-vehicle with limited speed for amusement purposes

2.15 Research Hypotheses

1. It could be reasonable to assume that if the amphibious vehicle is designed from the inspiration of the morphology of amphibian animals, the design might be acceptable from the point of view of aesthetics and affective requirement by Indian users for amusement purposes.
2. It is reasonable to assume that the amphibious vehicle would be feasible to develop if stress and strain parameters are within the acceptable range in the structural design of AV.

It is reasonable to assume that if AV fits the body dimensions of the Indian population, it would be comfortable.

CHAPTER 3

Design and Evaluation of Speed Forms for the Design of an Amphibious Vehicle for Amusement Purpose

Abstract

Speed Forms are abstract forms generated from various inspirations. They convey various moods and meanings. Bio-inspired speed-forms are generated to bring innovative forms of the vehicle. It is not found in the case of AV design. Various inspiration has been taken from natural amphibious organisms like frogs, fish, and Birds. The abstract forms were created from morphologies of these animals. The abstractions are modified to generate forms which convey AV characteristics. Automotive clay is used to make three-dimensional models in abstract forms. Twenty-two prospective users have been surveyed to get feedback on three possible speed forms. A total of 8 adjectives were selected, which are prospective for AV design. On a scale of 1 to 7, users were asked to rate the speed forms according to their preferences. ANOVA was used to assess the user replies statistically, and SPSS was used to analyze the results (Statistical package for social sciences). The Wilcoxon test and Friedman ANOVA were performed as part of a planned within-subjects investigation (wherein the same group of participants reacted to three different speed forms for varied factors). Three keywords had varying responses and having selected for maximum score. They were Attractive, Beautiful, Dynamic, Fluidic, etc. The impact of these four keywords varies in models 1, 2, and 3. After the Wilcoxon test, Form 1 was found to be the most acceptable. Form 1 was inspired by the frog. Out of various speed forms from different sources, the designed form which is inspired from the frog is most appropriate for designing an amphibious vehicle.

Keywords: Amphibious organism, ANOVA, Speed Forms, SPSS, Wilcoxon

Key Findings:

- The aesthetics of AV is judged by users whereas bio-inspired organisms can be a design source.
- Speed Forms reflect the aesthetics and dynamic characteristics of AV design. People's decision of selection is more influenced by aesthetics than dynamics in the case of AV design.

3.1 Introduction

When creating vehicle exteriors, automotive design and styling are essential (Lai, Zhang, Mao, Liu, & Chen, 2021). The designer employs intuitive techniques to create intriguing forms that can be applied to the design of vehicles. Many studies are being done in this area to develop accurate and intriguing types of vehicle design, including market experience, consumer preferences, sales, etc. (Hamid, Hanifa, Abidin, & Abdullah, 2013).

All vehicle parts easily visible to the buyer are included in the automobile design. Examples include metal, glass, wheels, lights, mirrors, grilles, and emblems. The radio, console, steering wheel, switches, soft trim, seats, door trims, instrument panels, controls, and other interior components (Clements, porter, 2008). This section aims to create and evaluate a speed form for designing amphibious vehicles. The goal is to make amphibious vehicles more appealing and stylish for entertainment (Eves & Hewitt, 2009). to monitor customer response to their selections and to quantify the numerous aesthetic components (Ward, Rezadad, Fearday & Viyapuri, 2015). To determine the optimal options for the user, apply statistical techniques. The basics of vehicle shape development and other literature on amphibious vehicles are

investigated. Here are descriptions of the case studies (Chen[1], Kang[1] & Hung, 2007).

3.2 Amphibious Vehicle form generation strategies

The current automotive business places great importance on vehicle style and design strategy. It works effectively for specialized areas of mobility design and upcoming automobile designs. Additionally, the AV's aesthetic is crucial for selling the AV (Kim et al., 2009). It is an effective communication tool. Users' preferences and psycho-social factors should be considered while designing the vehicle's shape, proportion, and surfaces. This medium enhances the product's user interface and overall user experience. (Mezghani, Zayani, Amous, & Gargouri, 2012). This topic is discussed and referred to as emotive design. Engineering Styling is one of the more specialist parts of vehicle development; without it, vehicle design would lack a critical component (Liem, Abidin, Warell, 2009). Numerous authors emphasized the value of styling as a crucial task. The individual vision of the designer largely influences the creative process. It mainly comprises graphic language and form creation (Chen, Kang & Hung, 2007). Both pragmatic and semantic usage is considered when creating form and graphic language. This medium is dependent on the facts and product usage. This internship strikes me as comic relief. It is up for contention whether this process is reflective within a specific context or a planned procedure instead of a structured problem-solving approach. Numerous studies are being conducted in this area to provide methodologies for vehicle design because form development affects the product's visual appeal (Koler, 2007). It is challenging to standardize an all-inclusive approach in contemporary design practice. However, character development and interpretation of the character involve a lot of gestalt application (Liem, Abidin, & Warell, 2009). They are concrete, abstract, and semi-concrete (Abidin, 2012). Most of the tools used in this process are pencil and paper. Physical models are frequently

created using foam, industrial clay, and physical clay. The designer will reflect on the circumstances, the materials, the price, and the production techniques throughout this process. The utilization of CAD and morphing in this project was highly effective. (Seitz & Dyer, 1996).

3.3 Speed Form and Aerodynamics

Aerodynamics is a crucial component of the design process for vehicles. Automotive aerodynamics is the study of the aerodynamic features of vehicle design that lessen drag and wind noise and prevent unwanted lift forces from generating instability at high speeds to use technical language. Designers imitate quick animals, birds, or other natural objects to produce aerodynamic forms (Hamid, Hanifa, Zainal Abidin, & Abdullah, 2013). There are many similarities between the design of an airplane and that of a flying bird. Figure 3.1 illustrates how leopards' aerodynamic shapes and forms are commonly replicated in the design of cars and bicycles (Benyus, 2020).

Fig.3.1. Speed forms in nature are adapted for aerodynamics.

According to a recent study, the aerodynamic qualities of speed forms inspired by certain high-speed animals or creatures are substantially better than those of traditional designs. This medium also gives the design a fresh aesthetic language (Lurie-Luke, 2014).

3.4 Speed Form and Vehicle Design

Designers create speed forms in order to create one idea from multiple ideas. The design is transformed through sketching and understanding. Transforming sketches laterally and vertically is used (Pathak, 2019). Vertical transformations alter one thought into a variation of the same notion, but lateral transformations change one idea into a distinct idea. In general, sketching is the first step in creating a quick form to identify characteristics or traits (Peters, 2011).

Newness and creativity in form design are predominant in the styling and design of automobiles (Fan, 2012). By incorporating character into the form, newness can be brought about. An inspiration board is used to study the character. A collage of like-minded character objects or creatures is called an inspiration board. Character lines from the mood board are first incorporated into the 2D designs. 3D entities are sketched from 2D sketches. Sketches are frequently used to generate the 3D model. The speed of the design process has a significant impact on both the outside and interior of vehicles (Christian, Potts, Burnett & Lacher, 1996).

3.5 Importance of visual appeal and usability

The primary five sensory modalities on which human perception depends are as follows. Due to these five sensory modalities, it is possible to interact with a product.

Visual, aural, and kinesthetic are the most active sense channels for experiencing and engaging with items in everyday life (Robinson-Riegler & Robinson-Riegler, 2008).

A product's visual appeal and interaction style are primary indicators of its use, safety, and comfort. These three ergonomic factors influence consumer perceptions of product value and selection (Creusen & Schoormans, 2005). These three characteristics should be taken into account by designers when creating new products. However, historical marketing research has shown this is different for anthropomorphic product design. Because of this reality, designed products might not last very long on the market.

3.6 Methodology

Despite speed shapes being created to demonstrate personality and creativity in form, they represent the designer's personal interpretation. The precision and accuracy come through years of repetition of a similar practice. The three-speed forms, in this case, were produced by nature. Frogs, fish, and birds are a few examples of bio-inspired species.

Sketching produces abstractions and vehicle clay modeling (Krause, Bock, 1999). Twenty-two users rate the 3-speed forms against seven keywords relevant to the amphibious vehicle on a scale of 1 to 7. The terms in vogue were dynamic, fluid, attractive, lovely, delightful to the eye, bionic, and cute. Statistical analysis is used to examine the findings (Ungerer & Schmid, 2013).

3.7 Participants

In this instance, we rated the various features in the clay models using the user survey approach. We rated items on a scale of 1 to 7. Between 1 and 7 represent "lowest characteristic identified in model" and "extremely high characteristics found,"

respectively. The sample size was 22 users, which is a fair number. Males made up 70% of the 18- to 35-year-old user base, while females made up 30%. After examining the three clay models separately, they were asked to rank various characters: Bionic, Dynamic, Fluid, attractive, Beautiful, Visual Delight, and Cute. The points were taken note of, and an analysis using statistics was done on them (Mezghani, Zayani, Amous, & Gargouri, 2012).

3.8 Speed Form Development for Amphibious Vehicle and Clay Modeling

Amphibious vehicles are those that can go both on land and in water. The AV should have a different appearance from land vehicles and watercraft. Three-speed forms were created using relevant keywords to find a new form. The three final forms were chosen after the sketches were approved. 1:10 size clay models were created. Models are not correlated with either (Rafeeq, Ahmad & Razib, 2021). They have utterly different appearances from one another. Creating mood boards is the initial step in the speed form-generating process. Choose a Bio item or inert substance to represent the character. To arrive at a form ideal for the design of the antagonistic vehicle, identify its essential visual character and sketch variations. Refer to Figure 3.2. (Verlinden, Kooijman, Edelenbos, & Go, 2005).

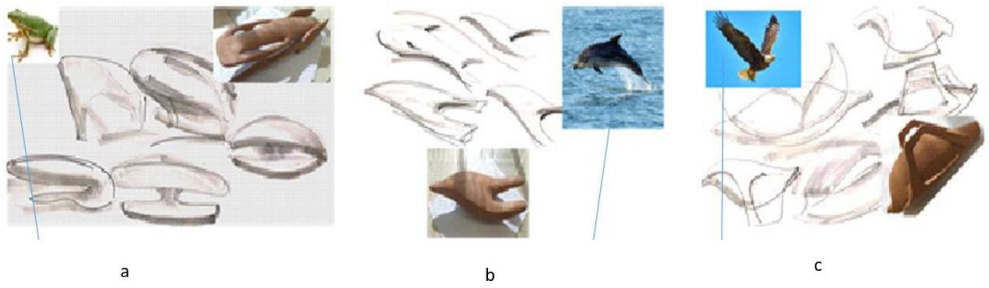


Figure 3.2. Bio-inspired form transition for AV: a) Speed form model concept from frog as an inspiration; b) speed form model creation from dolphin as an inspiration; c) speed form model creation from eagle as an inspiration.

This medium also reflects user psychology and AV comprehension. This approach gives the customer preference for personality and aesthetics for a novel product like AV and a novel market (Wang, Li, Cao, Dey, Ashour & Shi, 2018). The following characteristics are taken into account when developing a speed form for the amphibious vehicle design.

Speed Form 1:

A frog served as the form's inspiration. The experiment examines the aesthetics and dynamism of speed form's visual attributes. This form has characteristics of the word "Frog" in it. It is "Dynamic" as well. It indicates a particular feature of the movement. Other characteristics of speed form, such as attractiveness and fluidity, are also displayed on a range of scales (Wang, 1995).

Speed Form 2:

Dolphins served as the form's inspiration. This medium demonstrates the traits of dolphins with speed form. A wave-like structure with an attribute like "Fluidic" mimics the dolphin's fin-like anatomy. The second model illustrates the fluidic component of the amphibious vehicle.

Speed Form 3:

The "Eagle" structure served as the model for this speed form. The Eagle flies swiftly, smoothly, and high. A wing-like structure balances the body's structure. The amphibious vehicle's characteristics, such as its rapid speed and fluid movement, are similar to Eagle. It could also be considered dynamic (Ward, Rezadad, Fearday & Viyapuri, 2015).

3.9 Aesthetics and Perceptual Evaluation of Speed forms

These seven qualities cannot have one source of inspiration. Various natural items elicit a certain kind of perceptual language (Kwong, Jiang, & Luo, 2016). The design of a speed form combines all of these characteristics into a single form. There are various techniques for producing multiple forms with different ratios of these properties in a single model. The capacity of the designer to combine many perceptual languages to maximize communication efficacy is necessary for the production of speed forms. For the same perceptual form, the effects of cross-cultural, gender, and age produce different findings. Therefore, it is crucial to conduct a user perception mapping survey for these speed forms (Kozlov, Chowdhury, Mustary, Loganathan, & Alam, 2015). Please consult Figure 3.3 to view the speed forms taken into consideration for this investigation.

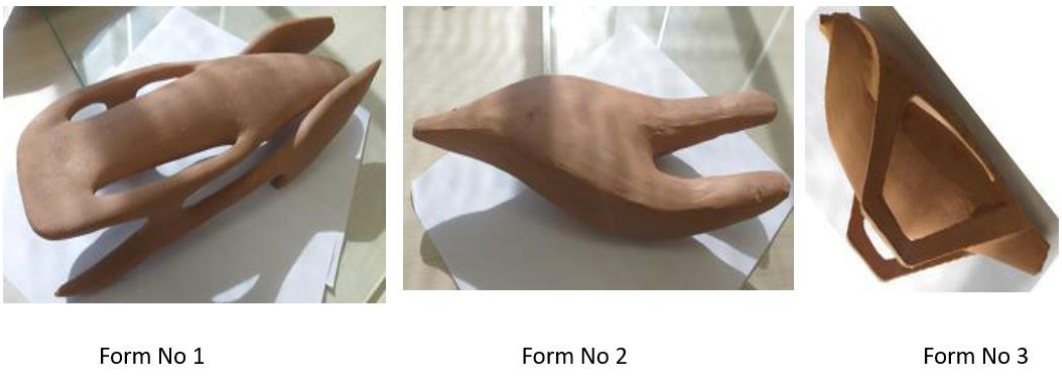


Figure 3.3. Clay Models of Speed Form used for Amphibious Vehicle Design.

3.10 Selection of Keywords

Seven keywords were chosen for this exercise's speed form evaluation. They were cute, gorgeous, attractive, dynamic, fluid, and bionic (Lai, Zhang, Mao, Liu & Chen, 2021). Based on significant scores, four keywords were taken for analysis (Chen & Chuan, 2011).

Dynamic:

This character's ability to travel equally well on land and in water makes it an excellent fit for the concept of AV. People prefer dynamism and quickness in the design of their AVs. Various birds in nature or fast animals like cheetahs or deer might be visual examples of dynamic qualities. They may serve as inspiration (Helander, Peng & Khalid, 2007).

Fluid:

This medium fits how AV is built because it moves on water and makes ripples. The performance of forms with streamlined bodies when moving in the water is more remarkable. For instance, a fish's physical structure makes it very effective in the water. The nature of the fluid is regarded as an attribute in the design of AV (Hartono & Raharjo, 2015).

Attractive:

Being appealing is a necessary quality of the metaphor of speed form since the AV will be an object of desire. This medium is a crucial consideration when making a purchase.

Beautiful:

This medium is a broad term that is used to refer to all types of people who have options. Being attractive is necessary while creating the metaphorical speed form for AV because this design is inclusive (Kyffin, Feijs, Young, 2010). The speed shapes are assessed in order to transform them into amphibious vehicles. The user considers the technical aspects of the form when evaluating it. They begin equating "Form" and

"Function." (Kwon, Ahn, Kim & Yun, 2021,44). Users evaluate the form's aesthetics by contrasting it with other AVs currently on the market. They consider whether it will appear better than the current AV (Chen, Hoyle & Wassenaar, 2013). The acceptance criteria are the combination of all the elements and the relative dominance of each. It differs from person to person based on the individual's background (Kwong, Jiang & Luo, 2016).

3.11 Questionnaire for User Survey

The purpose of the survey questionnaire is to get access to the physical model and assess their acceptance criteria. Users were asked to rate the 3-speed forms using a Google survey Form. They each received a demonstration of the speed using tangible models created with automobile clay. At the conclusion, they were asked to choose from a list of three-speed forms what they thought was the best (Please refer to Figure.3.4).

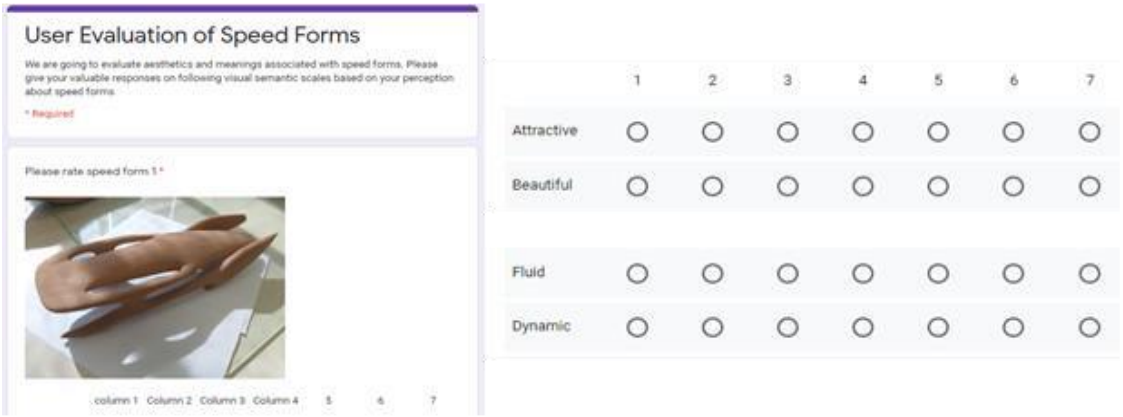
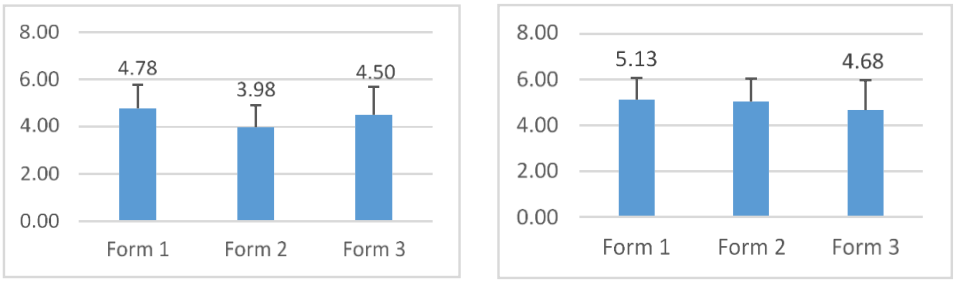


Fig.3.4. Tools for Questionnaire Survey Statistical Analysis of Speed Form Data

The SPSS application was used to analyze the data (Statistical package for social sciences). Nonparametric statistics were employed since the sample data distribution does not follow a typical distribution pattern (bell curve) (Ferreira, Furini, Silva, 2007). The Friedman ANOVA and Wilcoxon tests were intended to be used in the within-subjects study (where the same group of participants responded to different parameters on three distinct speed forms) (Haas, 1991), (Andreasen, 2003).

3.12 Results and Discussion

The results of the feedback from the user survey are shown below. The speed forms were mainly judged on Aesthetic parameters and Dynamic parameters. The individual feedback is shown below in **Figure.3.5.**



(a) **(b)**

Figure 3.5. Variations of Aesthetics; (a) Dynamism; (b) Perception.

3.12.1 Aesthetic Perception

The Model survey asked about four different features. Attractive, Beautiful, Dynamic, and Fluidic were the words. The typical response for "Visual Delight" and "Attractive."

to be an "Attractive Response." A "Dynamic" reaction is the average of "Dynamic" and "Fluidic" responses. According to the research above, Form 1 has more "Aesthetic Traits" than "Dynamic" characteristics (Hekkert, 2006).

3.12.2 Statistical interpretation for aesthetic variations

There is a substantial variance in the aesthetic value of speed shape in the Friedman test since the p-value is less than 0.05 [Z (2) = 8.720; p=0.01]. No significant difference was found between speed form 1 and speed form 2 when aesthetic values were compared using multiple comparison tests, except the mean aesthetic values for each speed form, where *p* - values are over 0.05. [Z (2) = -2.567. *p* = 0.01] (Worcester, 1966).

3.12.3 Dynamism Perception

All of the forms have dynamic properties. Compared to Forms 1 and 3, Form 2 has a more "dynamic" nature. Except for "Dynamism," Form 3 has the second-highest percentage of all characters. Please refer to Fig.3.6 (Taylor, 1958).

3.12.4 Statistical interpretation for variation of Dynamism values

Since the Friedman test's *p* - value is more than 0.05 [X^2(2) = 2.564; *p* = 0.28], there is no discernible difference in the dynamism value of the speed variant. There was no noticeable difference in the mean dynamism values for the various speed forms in multiple comparison tests because *p* - values are over 0.05 compared to the dynamism values in different combinations for three variations of speed forms. The research above using SPSS software also reveals that users prefer "Aesthetics" and "Dynamic." The speed form's characteristics determined their decision of the final chosen model. Below is a breakdown of each keyword's score on the three-speed form models in Figure. 3.6 (Chen, Kang, & Hung, 2007; Firat & Kocabicak, 2004).

3.12.5 Speed Form Selection Based on the Perception of Users

Figure.3.6 displays the unique variations in features among the three models. The three models' Chi-Square Test values are 0.035, less than 0.05, which supports the null hypothesis. The two characters differ significantly from one another. In contrast to the dynamic character, which does not influence how users choose their Form, the aesthetic character is in charge of how users choose their Form.

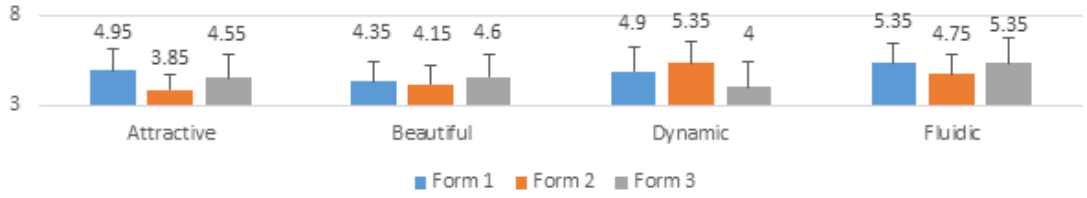


Fig.3.6. Speed form evaluation for performance (individual variations in aesthetics and dynamics related parameters).

The user survey results also demonstrate that most users choose Form 1 as their preferred final Form. (Kim et., al., 2016). The final Model selection as per user Choice is shown below in Figure.3.7. Form 1 is selected by a majority of users as the Final choice.

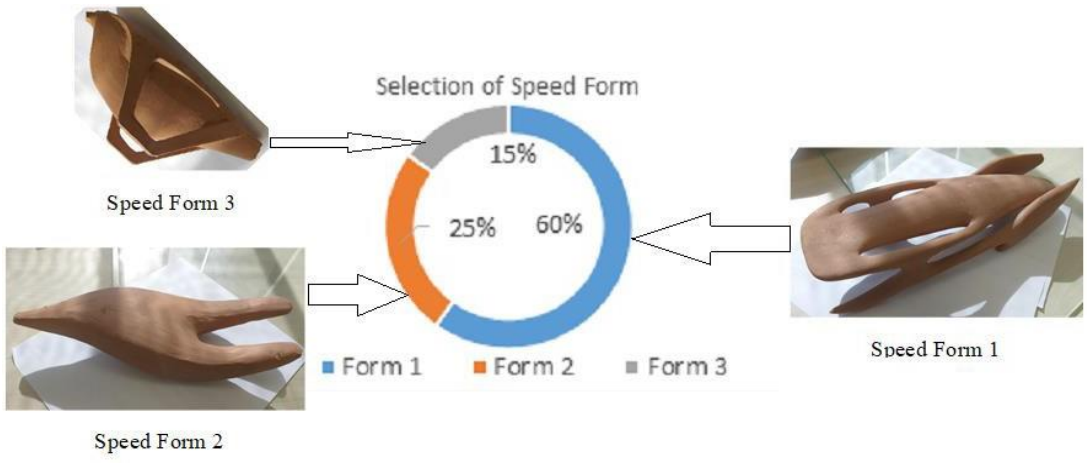


Fig.3.7. Form Selection Rates

3.13 Conclusion

Analyzing speed from aesthetic languages was the purpose of this assignment. The qualities of the speed forms varied in their degree of "attractiveness," "dynamics," "beauty," and "fluidity." According to the user survey, users chose the preferred speed variants due to good aesthetic scores. Aesthetic tastes heavily influence their selection choices. Users preferred Form 1 over the other two forms the most. According to the statistical study, there was no discernible difference between the 'Dynamic,' 'Beautiful,' and 'Fluid' form character scores. However, the 'Aesthetic' character revealed a notable distinction (Cai et al, 2015).

As a consequence, users have chosen the final set of forms. We can deduce that people preferred aesthetic qualities over dynamic and other factors while choosing speed forms. It was also demonstrated that user preferences might vary even when an object is made from natural materials. The speed form derived from the frog was preferred more in the amphibious vehicle concept. Form 1 can be expanded upon to create the outside shape of the AV. This medium is a preliminary investigation, so the intricate mechanics and ergonomics are not considered. Future design work for the development of AV can take ergonomics and actual mechanics into account.

This method can be applied to the creative AV form design. Currently, this element is absent from AV design. Designing AV for some purposes may leverage this. In this chapter's experiment on speed forms, we discovered that an aquatic animal, like a frog, was the best candidate for a speed form. Three diverse bio-organisms in nature were our inspirations, one of which was an amphibious animal like a frog. Others included non-amphibious animals like dolphins and eagles. We assigned the seven keywords "bionic," "dynamic," "fluid," "attractive," "beautiful," and "cute."

Users are limited to three marks per keyword. The basic terms for differentiation were dynamic, fluid, and attractive. Based on statistical analyses (Friedman ANOVA and Wilcoxon signed test), it was discovered that people preferred the Speed form 1, which was modeled after a frog, as their amusing amphibious vehicle. The following chapter will compare two CAD-based designs of AV created from two amphibious creatures to determine which is best for the user.

CHAPTER 4

Affective design analysis of the interior and exterior of the amphibious vehicle for amusement purposes

Abstract

Aesthetics is a strong determinant of vehicle choice and contributes to human pleasure. Hence, it is very relevant to study the aesthetics of an amphibious vehicle (AV) (which runs on both land and water), primarily when targeted for amusement purposes. The aesthetics of an amphibious vehicle depends on its design elements (exterior and interior). This study aims to design AV exterior and interior by applying practical design principles to meet users' psychological expectations. Earlier, it was found in the literature that the bio-inspired concepts which are generated from amphibious animals had better user acceptability. In this study, one set of concepts was designed from the inspiration of the duck beak. For the other set of concepts, the body form of the frog was taken as a base for inspiration. Final concepts were presented to 81 users, and their feedback was collected on a 1-7 scale using relevant keywords suitable for AV exterior design and interior design. The AV Exterior design is associated with the perception of three keywords that were critically identified for exterior design: Engaging, Adventurous, and Luxurious, which are more associated with AV concept 1. Similarly, AV interior concept 1 had significantly more mean values for keywords. The interior design keywords with more significant values were Dynamic, Beautiful, Engaging, Cheerful, Wonderful, Surprising, Adventurous, Splendid, Graceful, Luxurious, Concurrent and exciting, etc. Therefore, the exterior and interior design concepts, which are linked with the amphibious creature `frog' as an inspiration, were better than the concept inspired by the duck beak.

Keywords: Affective Design, Amphibious Vehicle, Analysis of variances, Bio-inspired Design.

Key Findings:

- The designer can generate concepts by considering Attractive, Engaging, Adventurous, and Luxurious keywords for the exterior design of the AV
- Designers can explore concepts by considering Fluid, Delightful, Relaxed, and

Graceful keywords for the interior design of AV.

- The applied effective design process can be followed to design amphibious vehicles for amusement purposes.

4.1. Introduction

The exterior and interior design of Amphibious Vehicles are mostly dominated by land vehicles and military vehicles (Helander, Peng & Khalid, 2007). The AV has immense potential to be used as a commercially mass-produced vehicle for entertainment, expedition, nature tour, border patrolling, and flood relief purposes (Khalid, Opperud, Radha, Xu, & Helander, 2012). This study aims to design the exterior and interior of AV for amusement purposes with a practical design approach to meet user expectations. The methodology involves digging out users' latent choices through the affective keyword-based survey from target users and determining the fruitful affective expressions for AV (interior and exterior) using advanced statistical techniques (Factor Analysis and ANOVA) (Akay & Kurt, 2009) (Schütte, Krus, & Eklund, 2008, December). A total of 81 target users participated in this study. Two interior and exterior design variations were created and compared per target users' affective requirements (20 and 12 affective keywords were selected to study exterior and interior appearances, respectively) (Schütte, 2002).

Exterior design concept-2 is significantly more engaging, adventurous, and luxurious than design concept-1. For interior design concept-2, average fluidic, relaxed, and graceful values were significantly higher than concept-1. This medium shows that amphibious vehicles for amusement purposes can be designed to keep these visual attributes in mind to be more acceptable to users (Suzianti, Apriliandary, & Poetry, 2016).

4.2. Biological Design Principles

AV's design functions are sometimes very similar to some biological organisms (Wang, 1995). It may match some aspects of creatures or birds or any other animal. AV functions by nature are synonymous with creatures like ducks, frogs, etc., which are amphibious, as shown in **Figure** 4.1. Here concepts are generated from frogs as an inspiration. Compare both concepts for user reactions. The final model was taken for further detailing, as shown in **Figure** 4.2.

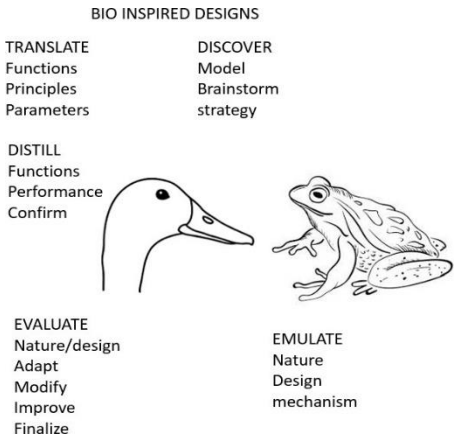


Figure 4.1. Nature-Based design process.

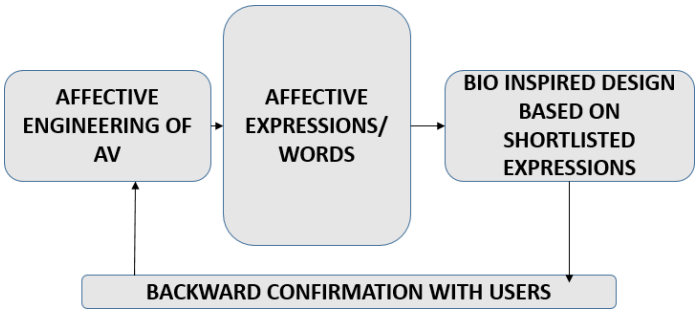


Figure 4.2. Affective Design of AV.

4.3. Methodology

A few AVs' need-based conceptual designs were developed and linked with the vehicle's aesthetic features for recreational use. For this concept, inspiration was taken from the duck, as it is an amphibious bird. The body structure, especially the beak, has a specialty in form and function. After preliminary sketches and models, a CAD model was made, as shown in **Figure.**4.3

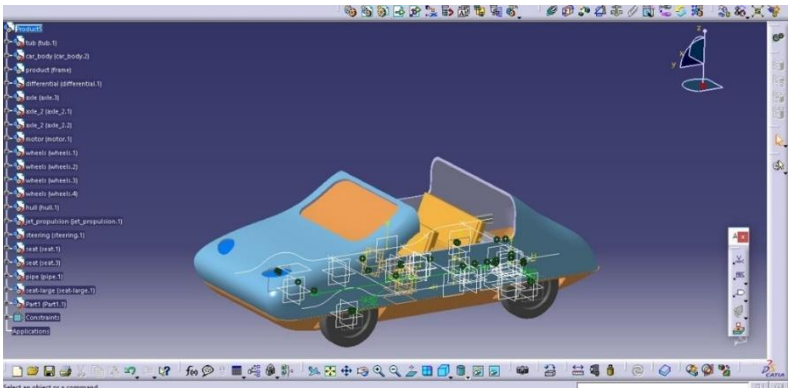


Fig. 4.3 CAD model from the inspiration of a duck

The structural features were produced in a CAD model. ANSYS software was used to analyze structural strength. Drag and surface shear stress was calculated using the CFD analysis. It was determined how buoyant the CAD model of the AV was. As a result, it offers a valuable method for building an amphibious vehicle for outdoor leisure (Rieuf, Bouchard, Meyrueis, & Omhover, 2017).

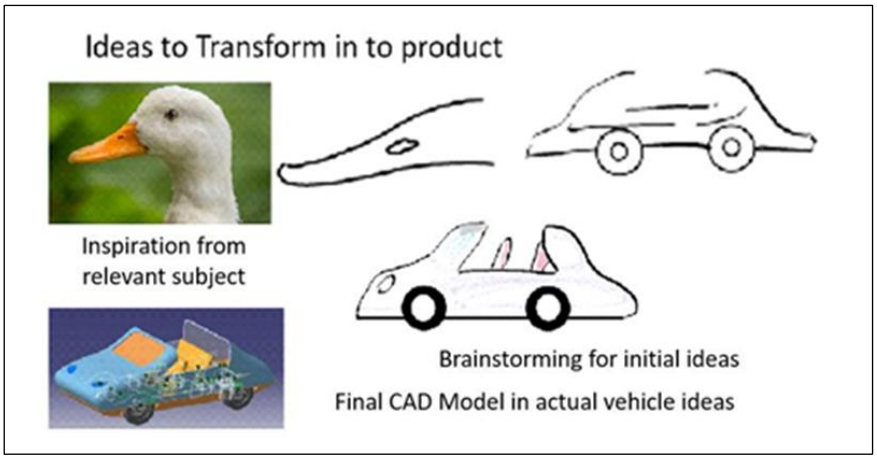


Figure 4.4. Concept generation from Mood Board considering Bioinspiration (Duck). Initial 3D concepts were done by taking inspiration from the duck.

The features are cross-checked with users for their opinions and modifications. As we designed and detailed the AV with the necessary engineering details, we surveyed this concept with experienced designers and prospective users. Even though a duck inspired it, there was a requirement for improving the aesthetics of body design. The practical design of AV was divided into two parts—exterior and Interior design. Since the user interaction with AV is both in terms of appreciating and owning AV, it is essential to have a design visually and psychologically connected with users (Nagamachi, 2010). The methodology followed was known user reaction for two concepts derived from Bio-inspired design. A Duck beak inspired one design, and Frog inspired the other design. Both are amphibious creatures, but their designs had varying amounts of design elements required for AV design (Baldovino & Garcia, 2016).

Users were given 30 keywords and asked to ratify on a 1-7 scale, depending on their choice. Eighty-one target users (male and female) in the age group of 17-35 were considered. (Wang et al., 2018). Initially, brainstorming on effective keywords related to AV was done. Since nature-based or contextual design is considered here as a base, words (Park, Jung & Im, 2019) related to the context of AV for recreation were considered a base. A keyword interview is generally done to get user feedback on a practical design. Since words do not give qualitative feedback, the visual design of a based user survey was done (Nagamachi, Lokman, 2016). Two possible designs were made based on the effective keywords. The creative designs were made based on inspiration from nature. The finalized designs were tested against the effective keywords. Prospective users, including males and females of the age group 18 to 50 years, were considered. They presented their reactions in Google Forms, and the observation was analyzed by a statistical method using SPSS software (Bo, W, 2008), (Frejek, Michael and Scott, 2008).

4.4 Comparison of two concepts of AV (exterior & interior)

The detail detailed for AV, which includes interior & exterior design, was made for two sets of concepts. A duck inspired one, and a frog inspired the other. The visual aesthetics of both are different. These concepts were ratified on a 1-7 scale by a group of 38 users, including both genders in an age group of 18-55. The users were given 30 appropriate attributes or keywords. Users were asked to reflect on them on a scale of 1-7, giving a particular number suitable to the concept. These numbers were then taken for statistical analysis and ANOVA. By suppressing less significant components, the comparison is made, which is explained below (Västfjäll, Gulbol, Kleiner & Gärling & 2002).

Figure 4.5. Concept 1 of AV Exterior & Interior.

Figure 4.6. Concept 2 of AV.

4.4.1 Results of Exterior Design Analysis

The Varimax rotation matrix was applied, and a component having a coefficient less than 0.8 was suppressed. A Maximum iteration of 25 was applied (Chen, Hoyle, & Wassenaar, 2013). Through Factor Analysis and ANOVA, three parameters had significant high values and were found in **concept 2** (De Pauw, Kandachar, Karana, Peck & Wever, 2010)(Lurie-Luke, 2014)(Tovey, Porter & Newman, 2003)(Wijegunawardana & de Mel, 2021)(Vincent, 2001), as shown in Table 4. 1.

The 30 keywords related to exterior design had choices given by 43 users, consisting of males and females of preferred age groups. The factor analysis was done by SPSS software, and the ANOVA test was done on the feedback (Benyus,

2020)(Pathak, 2019)(Wijegunawardana & de Mel, 2021)(Fan, Wang, Duan, Xia & Wang, 2012).

After conducting of Principal Component Analysis (PCA), it has been found that component 1 is the principal component composed of splendid, ecstasy, cheerful, wonderful, graceful, luxurious, concurrent, exciting, honest, addictive, nomadic, and amazing. These parameters can explain 78.89% of AV design needs variations. In addition, it is possible to explain 82.74% of design needs if component 2 is considered. Therefore, both components 1 & component 2 have been considered to compare proposed exterior design concepts (Lin, Chao, Hsieh, Tsai, 2016).

Table 4.1. Factor Analysis of Exterior Design.

ROTATED COMPONENT MATRIX FOR EXTERIOR DESIGN DATA		
Keywords	**Component1**	**Component 2**
Dynamic		0.748
Beautiful		0.723
Relaxed		0.798
Leaser		0.812
Refreshing		0.715
Hilarious		0.795
Cheerful		0.768
Wonderful		0.747
Surprising		0.742
Exploration		0.737
Splendid	0.773	
Ecstasy	0.707	
Graceful	0.782	
Luxurious	0.780	
Concurrent	0.84	
Exciting	0.83	
Honest	0.776	
Addictive	0.781	
Nomadic	0.811	
Amazing	0.904	
Eigen Values	23.666	1.155
% Variance	78.888	82.738

4.4.2 Results of Interior Design Analysis

The two interior concepts are shown below in **Figures 4.9 & 4.10**.

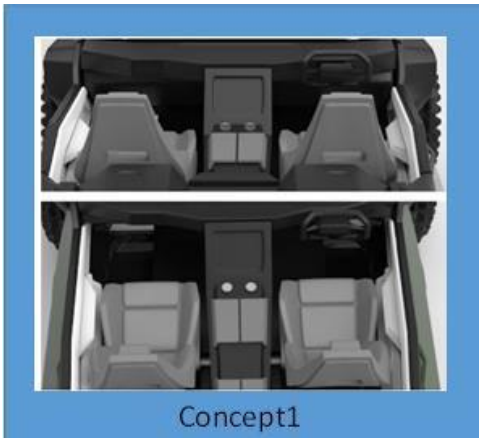


Fig. 4.7. Interior concept 1.

Fig.4.8. Interior Concept 2.

A set of 36 users' (Male=86%, Female=14%) opinions on two given concepts were checked by a user survey. The concepts were derived from biological organisms (Bordegoni & Caruso, 2012).

The CAD models were developed from the initial concepts. The users presented the two concepts and were asked to show their preferences against given keywords. They were measured on a 1-7 scale, with one being the least preferred and seven being the most preferred. The user feedback was analyzed in statistical software named SPSS. The Factor Analysis and ANOVA tests were done on the given feedback on interior concepts (Peters, 2011)(Senoz, Daughton, Gosavi & Cudney,2008)(Siddaiah & Menezes, 2016).

A user survey checked a set of 38 users' opinions on two given concepts. The concepts were derived from biological organisms like ducks and frogs. The CAD models were developed from the initial concepts. The users presented the two concepts and were asked to show their preferences against given keywords. They were measured on a 1-7 scale, with one being the least preferred and seven being the most

preferred. The user feedback was analyzed in statistical software named SPSS. The Factor Analysis and ANOVA tests were done on feedback on interior concepts (Novak, 2012).

Table 4.2 Factor Analysis of Interior Design Data.

ROTATED COMPONENT MATRIX FOR INTERIOR DESIGN DATA		
Keywords	**Component1**	**Component 2**
Fluid	0.920	
Relaxed	0.901	
Pleasant	0.887	
Luxurious	0.840	
Hilarious	0.823	
Graceful	0.822	
Leaser	0.822	
Delightful	0.814	
Cheerful	0.811	
Wonderful		
Beautiful		
Fun		
Ecstasy		
Nomadic		
Enjoyable		
Refreshing		
Beautiful		
Addictive		
Surprising		
Dynamic		
Exploration		0.955
Adventurous		0.949
Gypsy		0.822
Interesting		0.810
Amazing		
Splendid		
Engaging		
Concurrent		
Honest		
Eigen Values	22.833	2.369
% Variance	76.109	84.005

The component is fluid, relaxed, pleasant, luxurious, hilarious, graceful, leaser, and delightful. These parameters can explain 76.11% of AV design needs variations. In addition, it is possible to explain 84.00% of design needs if component 2 is considered. Therefore, both components 1 & component 2 have been considered to compare proposed interior design concepts (Vilau, Stoica, Constantinescu & Suci, 2019).

The Varimax rotation matrix was applied, and components having a coefficient less than 0.8 were suppressed. Maximum iteration of 25 applied. Through Factor analysis and ANOVA, eight parameters had significantly high values and were found in concept 1, and 4 parameters had significantly high values and were found in concept 2. They were – 1) Fluid, 2) Relaxed, 3) Pleasant, 4) Luxurious, 5) Hilarious, 6) Graceful, 7) Leisure and 8) Delightful. Component 2 has four attributes such as 1) Exploration, 2) Adventurous, 3) Jeepsy, and 12) Interesting.

4.5 Results and discussion

The judging system is generally referred to as affect, whereas emotion is the conscious experience of affect. Human behavior, though, is frequently unconscious. The emotional system quickly and effectively assesses if the design is appealing and practical and affective design, which takes into account human impressions when developing, is beneficial for the interior and outside design characteristics of the AV (Kwon, Ahn, Kim, & Yun, 2021)(Lin, Su, Chao, Hsieh & Tsai, 2016). Participants in this research rated their emotional responses (how nice I feel), preferences for these affective reactions (how much I enjoy how I feel), and affective evaluations on a range of scales (how good the experience is). It also demonstrates how to incorporate emotional design elements during the design stage to make the AV design more palatable and improve the overall experience. Additionally, this guarantees that customers' needs are taken into account during the practical design process (Ishihara,

Nagamachi, Schutte, & Eklund, 2008)(Nagamachi, 2010).

4.6 Comparison of Exterior Design Data

Here the statistical data from the experiments are represented in Graphical form. Based on the maximum F value and minimum *p*-value, the final differentiator for Exterior designs is 4 (star marked). They are attractive, engaging, exploring, and luxurious. These factors are responsible for user appreciation and selection. These are very high in Design concept 2. Hence Design concept 2 is better than Design concept 1 in the above experiment, as shown in Figure. 4.9.

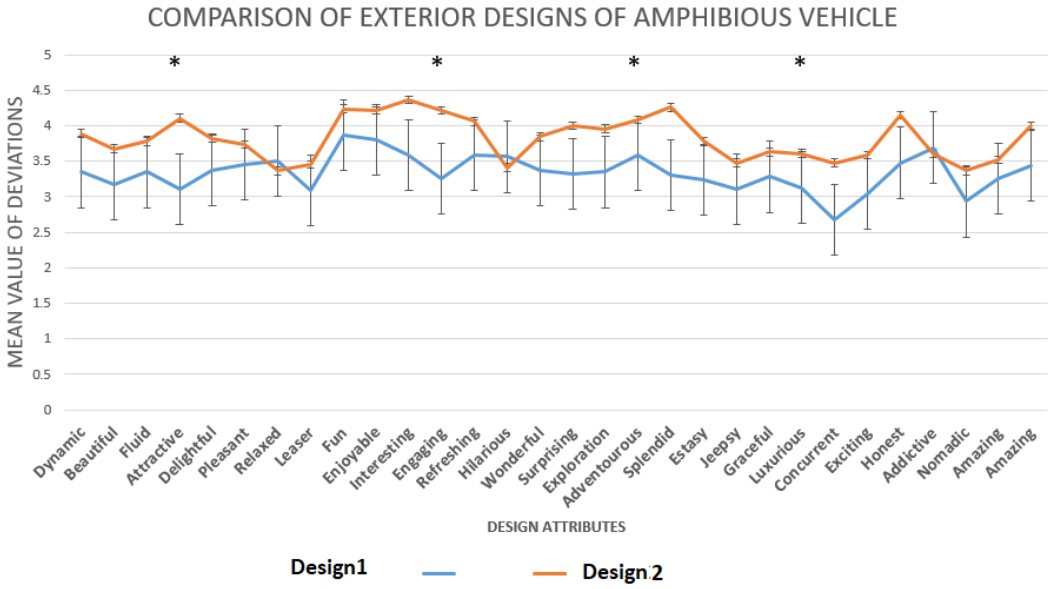


Figure 4.9: Comparison of AV Exterior Design concepts.

The above graph illustrates the interaction of various factors in the exterior design of the amphibious vehicle. A significant difference is observed in the case of 1. Attractive, 2. Engaging, 3. Adventurous, and 4) Luxurious attributes as shown in Figure. 4.9. The F and *p* values are as under- Attractive [F (1, 44) = 6.037 and p = 0.016], Engaging [F (1, 44) = 6.471, p = 0.013], Adventurous [F (1, 44) =6.02, p = 0.016], Luxurious [F (1, 44) = 4.063, p = 0.047] (You, Ryu, Yun, & Kim, 2006)(Mayyas, Qattawi, Omar, & Shan, 2012)(Attridge, Williams, & Tennant, 2007)(Lai,

Zhang, Mao, Liu, & Chen, 2021).

4.7 Comparison of Interior Design Data

The below graph illustrates the interaction of various factors in the interior design of amphibious vehicles in Figure. 4.10. From the principal component analysis (PCA), factors having a maximum difference in F-values (F=5.005) and fewer p-values are identified and plotted. The above experiment shows four components responsible for the user's preferences and selection.

Fluid [F (1 , 33) =10.056, p=0.002], delightful [F (1 , 33) = 5.051, p=0.026], relaxed [F (1 , 33) =5.946, p=0.017], Graceful [F (1 , 33) =5.929, p=0.017].

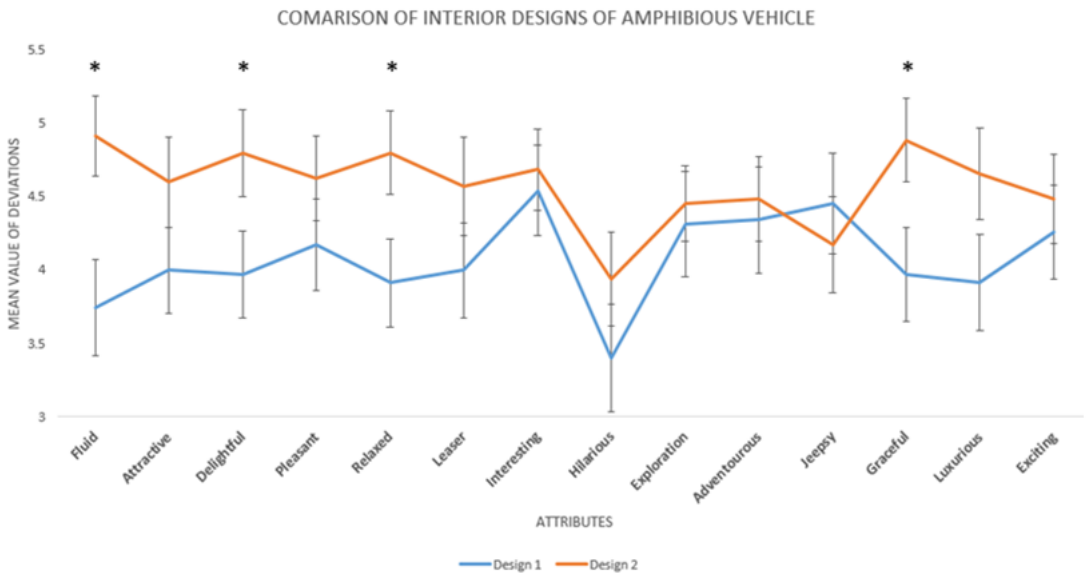


Figure 4.10 Comparison of AV Interior Design Concepts.

Users' behavior shows that they give maximum preference to aspects like Fluid, delightful, relaxed, and graceful in the case of AV interior design concepts. These attributes have higher values in Design concept 2. So, they liked and selected Design 2 as a better interior design concept.

These aspects of affective design apply to the amphibious vehicle's design for amusement purposes. The methodology is based on a visual design approach and also includes inspiration from features of amphibious animals like ducks and frogs. The design concepts are explored with inspiration from the body structures of frogs and duck beaks. The creative process of form design for engineering products like an amphibious vehicle can make it look softer and more acceptable. The design of AV has a variety of applications and diversities. The above exercise can make AV suitable for individual application and acceptable to society.

4.8 Conclusions

In this paper, we experimented with a bio-inspired design process to create amphibious vehicles, and designs were evaluated using the affective design technique. The affective keywords and nature-based contextual design concepts were used to determine the user's inclination towards form, shape, color, and other elements of AV design. The visual design approach makes it easy to react precisely and get accurate responses for AV exterior and AV interiors. We have seen that visual style expectations for AV exteriors are different from AV interiors.

The above method successfully measured users' expectations using feedback for affective keywords based on visual and illustrated options where they could imagine the end product and rank more judiciously. The User's affective survey of AV design successfully helped authors to shortlist affective parameters responsible for the user's selection of the design of AV.

The process reported in this study can be taken forward for the detailed design of AV based on the affective design method. The subject of amphibious creatures and their body construction was used as inspiration for concept development, which users

liked more. The different vehicle parts like body, lights, front view, and rear views are coordinated to achieve the inherent theme. It also can be called styling language, which establishes a link between the user's psychological profile and vehicle form. The affective design methodology can be used for detailed design and design modifications for amphibious vehicle design. This is also equally effective for any other amphibious vehicle design.

4.9 Practitioner's Summary

The Designer can generate concepts by considering attractive, engaging, exploration, and luxurious keywords for the exterior design of AV and can explore concepts by considering fluid, delightful, relaxed, and graceful keywords for the interior design of AV. The applied affective design process can be followed to design amphibious vehicles for amusement.

CHAPTER 5

The CAD-based Analysis for Feasibility of Design of an Amphibious Vehicle for Recreation

Abstract

This chapter deals with the feasibility of implementation for the better concept described in the previous chapter. In the Design Framework, CAD-based design and analysis come after concepts are finalized with users. During CAD design, many changes come due to the fitment of actual parts in the concept. The concept is divided into different parts due to assembly and manufacturing constraints. The CAD details are worked out, which is more towards the realization of actual AV design, Keeping the essence of the concepts. The package and engineering specifications of primary aggregates are found, and the CAD model represents the basic package. The Hull Design and Frame design were analyzed for static stress analysis through ANSYS software. The stress due to self-weight and water pressure was within the permissible limit. The submerged hull volume was calculated using the hull's CAD model and the weight of the AV. The planned materials and body part designs were within acceptable limits; hence, the body chassis and hull could be useful for implementation of AV for amusement purpose.

Keywords: AV Package, CAD model, hull volume, Powertrain, Submerged Static Stress Analysis.

Key Findings:

- The digital mockup of the virtual prototype is presented and described.

- The specifications of major components of electric amphibious vehicles are finalized. The basic confirmation of concept approval is done.

5.1 Introduction

An amphibious vehicle can go across both land and water. Because an amphibious vehicle must have the ability to function on both land and water, the vehicle design should not compromise the requirements for a good boat and a promising land vehicle. Even if amphibious vehicles were utilized for military operations, there is still no mention of their use for leisure activities like visiting nature parks, eco-parks, and science parks. In addition, due to the depletion of fossil fuels and all the adverse effects on marine life, an effort is being made to create an electric amphibious vehicle for leisure purposes and to use it for transportation within Science & Technology Parks, Eco-Parks, and tourism purposes. A conceptual design was created, and it is in keeping with the aesthetic traits of an amphibious creature that resembles a duck. The structural features were produced in a CAD model. ANSYS software was used to analyze structural strength. In order to determine buoyancy and surface shear stress, a CFD analysis was performed. As a result, it offers a valuable method for building an amphibious vehicle for leisure. The findings of the CAD study demonstrate that the buoyancy requirements are satisfied and that the stress on the Frame was within the permitted range.

Additionally, it predicts a 40kmph top speed on the water. The vehicle's appearance and feel, which were inspired by the duck beak, reflect amphibian traits in addition to its sporting appearance. In Science & Technology Park, the prototype car may thus be used on land and in water.

5.2 About Amphibious Vehicle Design

In AV design, affective design can also be done by considering the user's views (Kwon, Kim, Yun, 2021). Minute detail choices on vehicle interiors and exteriors are made using this method. This will make it more acceptable and user-friendly to customers (Khalid, H.M et al., 2012). This is done by using various user survey methods and questionnaires (Rafeeq, Toha, Ahmad, Razib, 2021). Customer needs can be grouped into different categories on different levels. In 1980 the Kano Model was discovered (Kano et al., 1984), where product properties are considered, and different functional characteristics can be obtained, shown in Figure 5.1. (Tovey, Bull, & Osmond, 2010).

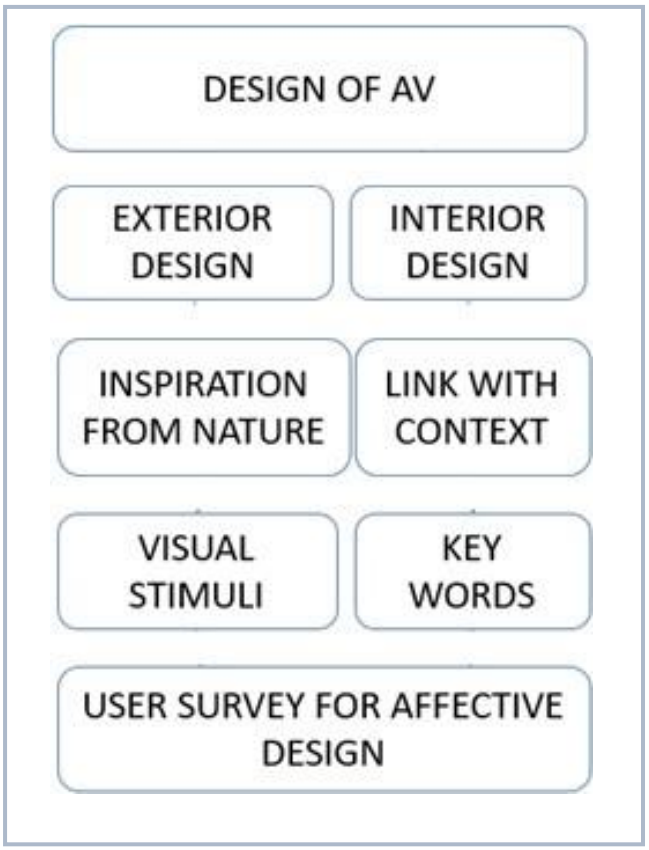


Figure 5.1. The affective Design process for AV design.

5.3 Different Amphibious Vehicle Body Structures

AV has been mainly used in military applications where consumer aspects were absent, as shown in Figure 5.2. Here we are discussing making AV a social and adventurous vehicle for the common mass. Here, it is essential to bring affective design aspects to it as users will drive themselves. The visual form and features of the vehicle contribute to understanding applications and their performance (Ranscombe, 2012). Aesthetic choices influence the decision of appreciation and acceptance (Wijegunawardana & Mel, 2021).

Figure 5.2. Interior and Exteriors aspects of AV.

There are more than 150 amusement parks in India. Many more are coming up as it is growing in demand (Roach, 1960). Most of the parks have water amusement facilities. It is in terms of Boats in lakes or Water Park or any other (Suzianti, Apriliandary, & Poetri, 2016). Experiencing water and land travel in the exact vehicle is not there. This is a new activity where tourists and fun-loving people will explore freedom and excitement (Ouellette, 2012). The vehicle form and style should be inviting and not have a mechanical look or look like a gadget. The slow-moving and safe vehicle for any terrain and water surfing is an exciting idea checked by many

users. An experiment was conducted to arrive at a user-friendly look and comfortable features. The numerical analyses were done using statistical methods and SPSS software. The results are shown in this paper (Nagamachi, 1999).

5.4 Steps of the Design Process

5.4.1 Ideation

5.4.2 User Survey (Secondary Research)

5.4.3 Inspiration / Mood Board creation

5.4.4 Conceptual Design

5.4.5 CAD Model Preparation in CATIA V5

5.4.6 Validation of body Design

5.4.7 Component selection

5.4.8 Weight finalization

5.4.9 Dimension Finalization

5.4.10 Buoyancy Calculation

5.4.11 Chassis design by FE Analysis

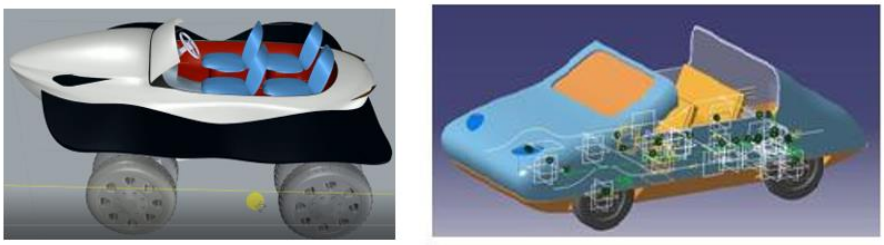


Figure.5.3 CAD models of AV.

5.5 Development of CAD Model.

A CAD model was created, and thorough prototyping was carried out based on a Bio-inspired concept. Figure 5.3 contains the CAD model of the AV for personal amusement. The vehicle's dimensions were chosen by drawing design cues from existing electric land vehicles like the Nissan Leaf and Chevrolet Bolt. The mechanical components such as the suspension, differential, motors, seats, and body are modeled after the ladder-type chassis as the following steps (See Table 5.1) (Tovey & Owen, 2000).

Table 5.1: Dimensions for AV CAD prototype

Part Name	Dimension (mm)
Wheelbase	2700
Total height of the car	1900
Ground Clearance	200
Body length	5200
Body width	2200
Wheel diameter	550
Hull beam	2240
Hull LOA	5350

5.6 Development of Parts for amphibious Vehicle

Research has been done on designing AVs for leisure activities. Here, CAD software has been used to examine, optimize, and improve the material and feasibility. Software were used to make the model and analysis. Catia and Fusion were used for modeling, while FE analysis tools such as Ansys were used to assess stress on the chassis and fluid flow pressure on the body. This has improved the design aspect considerably. Other AVs that are intended for recreational usage could be designed using a similar methodology. (Hajare, et al.2015), (Ragi et al. (2013).

The followings are the major elements of the Amphibious Vehicle:

a) The Hull

The hull of a wheeled amphibian is the container that holds the crew compartment, cargo compartment, engine compartment, and several other vehicle components. The amphibian hull is essentially different from the body of other military car assemblies in that it must adhere to particular marine design criteria. It must, in particular, have the essential buoyancy, stability, and configuration qualities to provide an appropriate speed-power relationship for aquatic operations. In summary, the amphibian hull may serve as both a truck body and a boat hull (Zahir, Razali, and Halid, 2013). The body and hull can be assembled using an inboard flange, and the hull is sealed by dousing it in epoxy resin (Wenshan, Zheng, 2010).

b) The Propulsion System

Amphibious vehicles are divided into two groups based on how they are propelled on land and in the water. Here, both continue to share the majority of the system. It includes a technology that allows it to move over various surfaces, including water. The mechanics of this kind of vehicle can include tracks, screw mechanisms, water jet propulsion, or even regular propellers (Millward, 1987).

The propulsion system now employed for tiny electric automobiles in other applications served as the foundation for the propulsion technology used in this investigation. A jet-based propulsion technology will propel the Watercraft. However, depending on economic constraints, the design may alter in the future to include jet and other rotor-based hybrid propulsion or a conventional rotor-based propulsion system (Frejek, Nokleby, 2008).

c) Power Train (Electric Vehicle)

Electric technology offers a broader range of torque, quieter operation, reduced running costs, and minimum maintenance compared to internal combustion engines. Electric technology is also ecologically friendly and has a rapidly increasing infrastructure. Most hobbyists concur that controlling the vehicle and putting it in and out of the water are complex tasks (Hay et al., 2017). It also provides green technology to save the environment. As the fossil fuels pass through the sea, they have an effect on aquatic life (Atienza et al., 2015).

d) Electrical components of AV

Electrical components were chosen after considering the General Motors electric car, the `Bolt.' For information and specs on the electrical components, please see Table 2. (Garud, & Pandey, 2018). The vehicle's powertrain was chosen following land-based electric vehicles like the Nissan Leaf or Chevrolet Bolt (Zahir, Razali, and Halid, 2013). The project consists of an electric vehicle (EV) with all necessary modules mounted on board and a complete motors assembly powered by a primary battery pack. (Dubey, & Dwivedi, 2003) (Hassan, Razali & Halid 2013).

e) Component Finalization

Table 5.2: Tentative components and initial specifications of electric AV

Component selected	Specification	Remarks
Battery	LG 40 Battery module pack, 60KWh	Same as GM Bolt
Motor for wheels	100 KW synchronous motor by Siemens (model SIVETEC MRS)	Also used in Volvo S60 Hybrid
Hull	Flat-bottomed glass fiber reinforced plastic hull	
Frame	Ladder-type frame made by Carbon steel	
Body	Body made out of 5052 Aluminum alloy	5052 is an Aluminum alloy, primarily alloyed with magnesium and chromium.
Tires	20in Michelin tires	
Water jet propulsion system	Berkeley Jet Drive Model 12JC	Made out of high-strength aluminum alloy
Rigid expanded polyurethane	CORAFOAM®	comes as two liquids to be mixed and poured in

5.7 The submerged hull volume

Volume is calculated using Fusion 360 software, shown in Figure 5.4.

The buoyancy of the amphibious hybrid vehicle depends on the parameter of the bottom hull body to keep it afloat every time. Based on the Archimedes Principle, the weight of the floating object is equal to the volume of water displaced (McCauley. 2018).

To calculate the appropriate water line length of our hull, we used the following approach:

Slicing the hull an arbitrary LWL and calculating the lower part's volume (Tran, 2010). The obtained value is inserted in the formula:

Fb = pw g V (Buoyancy Formula)

Fb = 997 kg/m³ * 9.81 kg m/s2 * 0.205 m3 (using Fusion 360 software) Fb=19.2 KN

* pw value at 25o C was considered

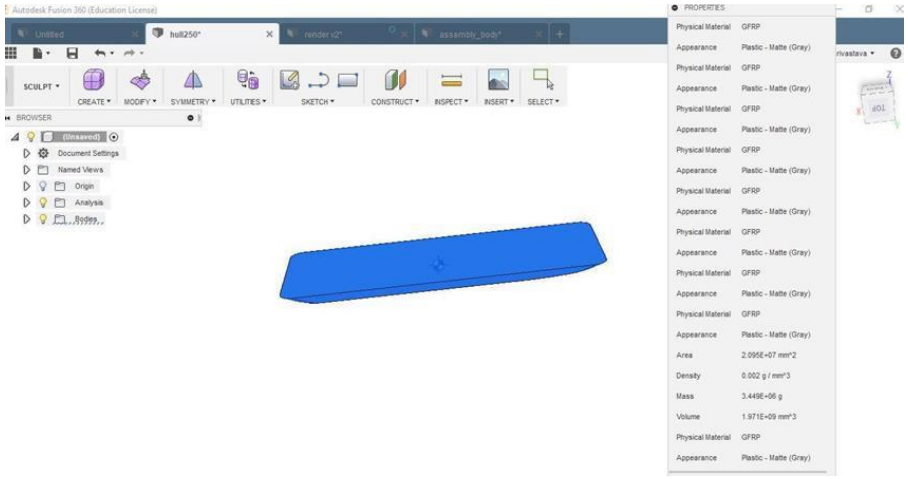


Figure 5.4. The floating Hull design was done using Fusion 360.

The submerged hull volume is calculated using Fusion 360 software. The obtained values should be close to the values of mog as pwVg = mog. Necessary changes to the hull dimensions are made if the values differ for the Floating condition.

Waterline length = 5141mm Hull draft = 250mm

5.8 Static Stress Calculation on Frame

New boundary conditions were used in the stress analysis of the Frame, and the findings were deemed to be safe and within bounds. Here, a conventional ladder frame chassis is taken into account in the static analysis (Huang et al., 2007). For analysis, various load considerations are used (land and water). An analytical beam with a rectangular cross-section is used to design the chassis (Baldovino & Garcia, 2016).

The process of structurally assessing a component involves a number of processes. Here, the body's gross weight is estimated to be 862.5 kg. Since von Misses stress is within the allowed range, and factor safety is considered 4, the design is acceptable (Colton, Ouellette, 1994).

The main steps are -

1. Geometric model design
2. Mesh generation
3. Fixed supports
4. Application of loads
5. Evaluating result

The stress plots are shown in Figure. 5.5, 5.6, 5.7, 5.8

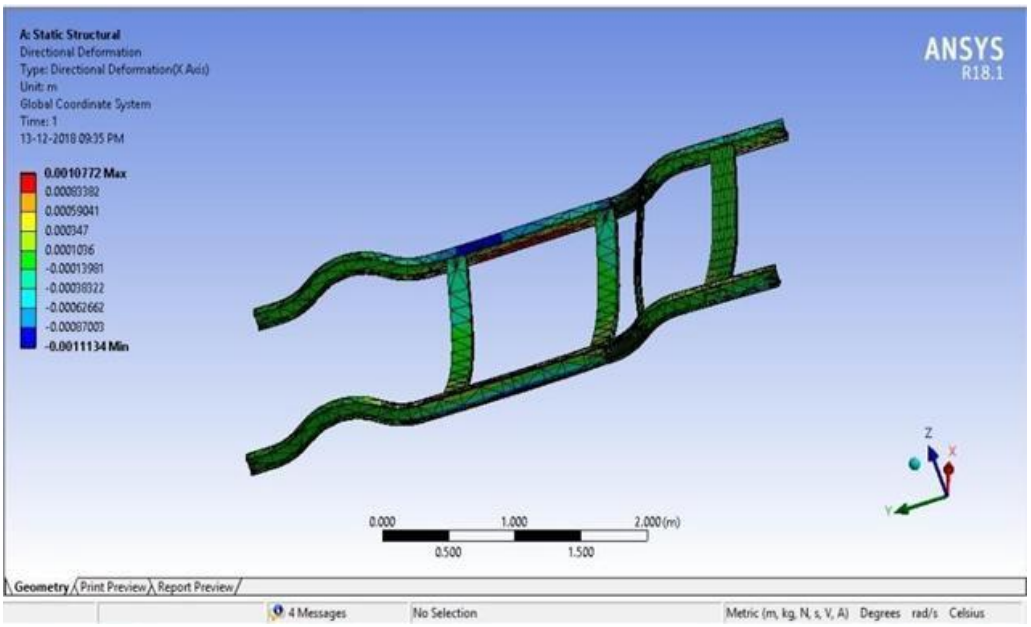


Figure. 5.5. Stress Analysis of Frame Deformation 0.8 m. m. (distribution of load in water).

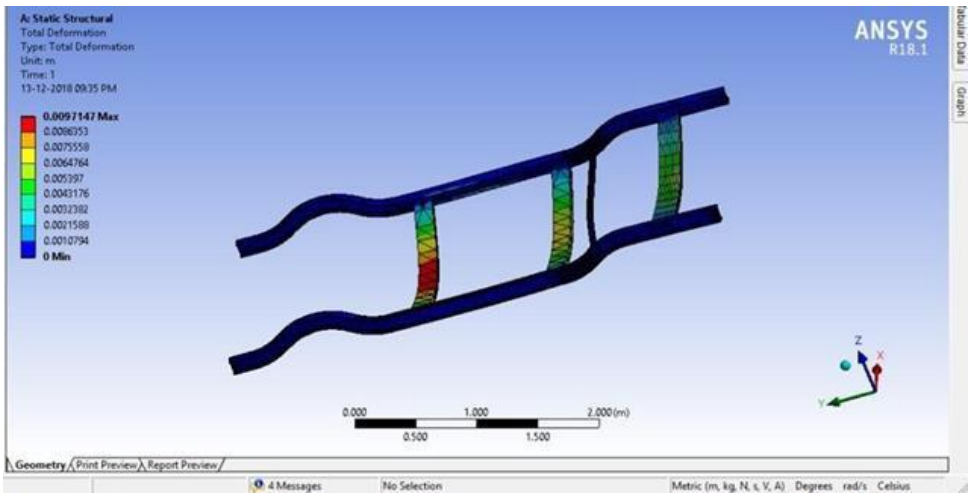


Figure 5.6. Total Deformation 8.6 millimeters (distribution of load in land).

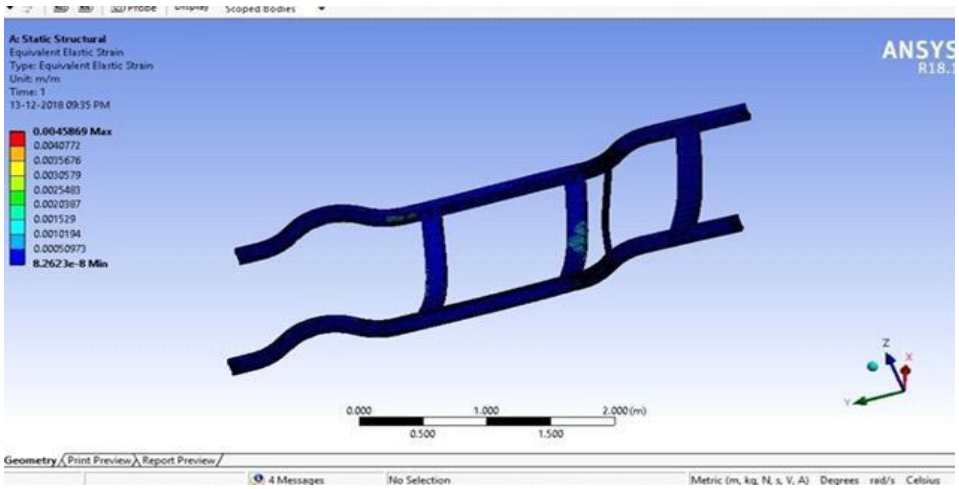


Figure 5.7. The equivalent Elastic strain of the frame is 0.00050973.

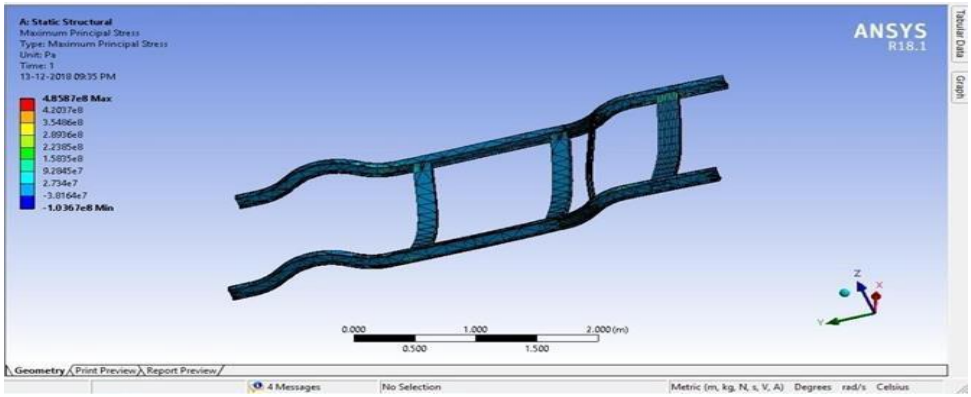


Figure 5.8. Maximum Principal Stress 485.87 MPa.

Table 5.3. Properties of Material.

Property	HSLA Steel
Mass density (Kg/m3)	7850
Yield strength (Mpa)	552
Ultimate tensile strength (Mpa)	630
Poisons ratio	0.3
Shear Modulus (Gpa)	76.9
Young's Modulus (Gpa)	200

Yield strengths of HSLA steels are more than 550 MPa (Ritchie, 1973).

Acicular ferrite (low-carbon bainite) steels are low-carbon (less than 0.05% C) steels that have a great mix of high yield strengths, weldability, formability, and strong toughness (as high as 690 MPa, or 100 Ksi) (Hofheins, et al., 1944).

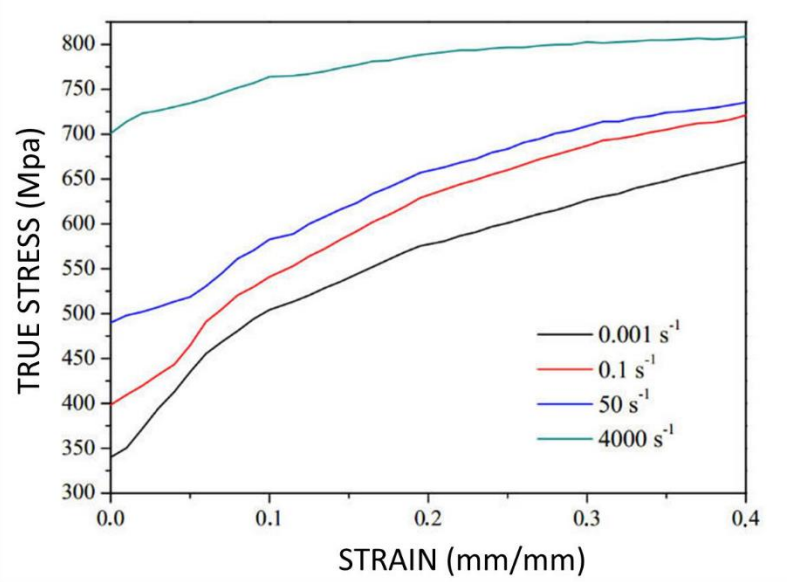


Figure 5.9. HSLA Steel Stress-Strain Curve (This graph is a modified version of the one that can be seen at

5.9 Range calculation

For calculating the range in which the battery can work is calculated by using the following approach (Cai, Chen, He, & Huang, 2015).

No. of modules= 40

Voltage of each module= 3V, Total battery voltage=120 V, Current drawn= 60 Amp at 40 kmph, the formula used here is:

I*V/Speed= Range at 40kmph= 360 Wh/m.

Also, Range= Total battery capacity/ (Wh per mile usage); therefore, at 20 mph Range=155.67 miles = 270Km Similarly, at 50mph range=255 Km

It must be noted that the actual value may be up to 55% to 79% of the ideal value in the case of a Lithium-ion battery (Tovey, 1997) (Gao, Pan, Cai & Yang, 2010).

5.10 Conclusions

It was investigated to design an amphibious vehicle conceptually for modern recreational activities. Technical feasibility and many user interface aspects were researched, and the design concept took into account the psychological side of the user's thinking.

The possibility of creating an amphibious vehicle using the concept above is tested in this study, and its actual manufacturing limitations are taken into account. Engineering

calculations are made for structural strength, fluid dynamics, buoyancy, and the creative and aesthetically pleasing design process. The body's strength allows for both on-land and underwater movement. The intended vehicle can be used for recreational activities in an "Eco-Park," where it can move both on land and in water and is appropriate for recreation by the water. Additionally, it does not harm the environment. So, it will be perfectly acceptable in various locations, such as jungles and nature parks.

CHAPTER 6

Human Machine Interface (HMI) and Digital Human Model (DHM) based Analysis of Amphibious Vehicle (AV)

Abstract

This chapter deals with the realization of a design into an actual prototype. Apart from the CAD model, the validation is done using digital human modeling (DHM). The ergonomic considerations (postural and anthropometric considerations) are taken into account. The initial Design faced some issues as part of the analysis. Necessary modifications are undertaken to make the AV design meet the design considerations. The Vehicle interior and dashboard operations are evaluated using RULA technique. The neck position for visibility of the instrument panel needed modification. The height of the instrument panel was increased, and the bend in the neck was reduced. The space requirement for two persons in AV was less as the arm-to-arm space was interfering. The width of the AV and the space of the seat were increased to make it comfortable. The ingress step was at a height that was causing leg muscle stress. An additional step was suggested to get into the AV. Additionally, a handle is provided at the time of ingress into the vehicle. With all this modification, a scaled-down (1:10) model was 3D-printed to get the look and feel of the AV for adventure park.

Keywords: Digital Human Modeling (DHM), Egress, Human Machine Interface (HMI), Ingress, R U L A , REBA.

Key Findings:

- AV design when analyzed with digital human models, accurate judgment can be taken.

- Regarding human interface in design and modifications, a digital model can be used.
- Regarding human interface also RULA and REBA can be performed.

6.1 Introduction

Digital human models are a digital representation of the human body, which helps create a virtual environment per actual needs. Space, safety, and human body movements can be judged in operating conditions (Demirel & Duff, 2007). Here the AV is a new vehicle designed for four people to travel on water and land. The operation is similar to driving a car but not exactly the same. There are different operations and different ingress and egress heights. The front portion of an AV is extended, and the seat height is different from that of a car (Martin, 1978). In the design stage, when the CAD model is done, the operation by humans also can be judged by using digital human models (Rangaraj & Raghuram, 2007).

The society of Automotive Engineers and many other similar bodies in the world do practice the use of DHM in designing automotive and product designs at the design stage. The Human Factors and Ergonomics Society (HFFS) was formed as an international body, and they do annual conferences on this matter to improve the design aspects of products. HCI (Human-Computer International Society also does annual conferences on DHM. Exhaustive research is being done to make it advanced and reduce hazards and improve safety. DHM is more required in the areas where more interactivity is observed (Lavie, Gilad, & Meyer, 2011). It is finally resolved in an actual prototype where humans drive or operate the product. In the preliminary design stage, DHM gives the opportunity to check human parameters, both physical and cognitive-based on the software used (Karmakar, 2011), (Gkikas, 2016).

6.2 Packaging of AV

The cad model of AV was analyzed with the components that will go into realizing the product of AV physically. A list of components was worked out, and the model of each was made to be installed in AV. The schematic diagram below shows the layout of the component that goes into AV (Ouma, Hayombe, & Agong, 2014), (Thaneswer, Sanjog, Chowdhury, Karmakar, 2013).

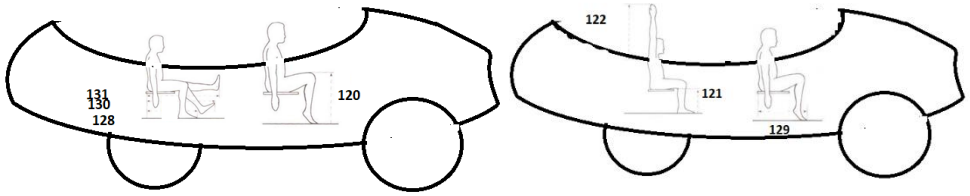
6.3 HMI Considerations in AV Design

Human-centered design approaches have replaced technology-centered and feature-driven approaches in developing human-machine interfaces (i.e., applying human factors and usability Knowledge). Considering the users' perspective to create a useable system, User-centered design has emerged as the industry standard for automobile HMI design among human-centered methodologies. The HMI of AV considers users' and drivers' participation in AV operations into account (Bekker, Long, 2000). This has various advantages, including sustaining physical ergonomics and information systems and enhancing user comfort. In contrast to previous approaches, the participatory design strategy used by the HMI designers might allow access to users' mental models and preferences (Spinuzzi, 2005). According to participatory design, users should actively participate in all process stages, including concept design activities (Moraes, Padovani, 1998). Several internal and external factors can impact healthy interactions (Leplat, 1981). Driver characteristics are internal variables (e.g., experience level, motivation, age, emotional status, time pressure, etc.). The context (such as the degree of emergency, task implications, lighting conditions, etc.) is seen as an external component, together with the characteristics of the interface itself. (For instance, speech recognition, colors, menus,

the mode of operation, etc.). Driver and context components are primarily outside the control of human-machine interface designers. However, by designing interface elements, HMI designers can directly influence how a user interacts with a device and completes the primary task. To develop interfaces that are in line with human capabilities and limitations, HMI designers use cognitive ergonomic principles as design principles and assessment criteria (Cannan & Hu 2011).

6.4 DHM method in AV Design

The ergonomic data for the required postures were taken for consultation for `Indian Anthropometric Data' (Chakrabarti, 1997) depending on various human postures in the AV as shown in **Figures** 6.1 & 6.2. The Human model was constructed in CATIA software (Ergonomics Module)for DHM analysis.

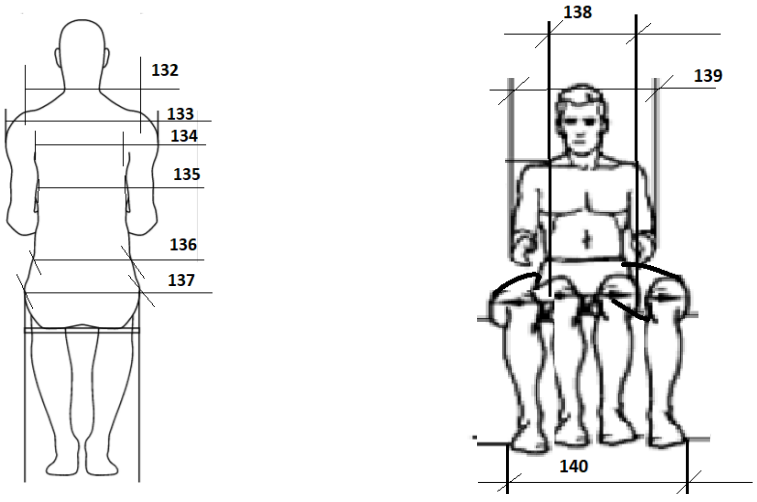


A) B)

Figure 6.1 Postures and Dimensions for AV Interiors: A) Knee Reach of Human Figure in AV B) Arm Reach of Human Figure in AV.

Table 6.1. Human Anthropometric Dimensions Considered to Build DHM in CATIA.

Nos	Parameters		Min	Percentile					Max	Mean
				5th	25th	50th	75th	95th		
120	Thigh clearance Ht.	Male	479	530	564	587	610	644	710	588
	With raised knee	Female	480	500	525	540	555	596	622	542
121	Popliteal	Male	335	380	406	425	443	471	540	426
		Female	305	365	386	399	417	441	455	399
122	Vertical arm	Male	484	623	675	701	736	774	854	704
		Female	476	576	613	638	670	740	772	639
128	Buttock to Leg	Male	639	640	654	719	779	779	780	699
129	Same with Raised Toe	Male	520	569	599	659	699	769	960	658
130	Extended	Male	685	758	869	923	989	1086	1210	926
		Female	660	719	809	851	904	979	1086	852
131	Buttock to Leg	Male	870	971	1039	1088	1133	1209	1350	1088
		Female	865	910	964	999	1035	1106	1230	1071



A B

Figure 6.2. Indian anthropometric Dimensions considered for AV Design: A) Posterior View B) Anterior View

Table 6.2 Indian anthropometric Dimensions for AV Design

Nos	Parameters		Min	Percentile					Max	Mean
				5th	25th	50th	75th	95th		
132	Bi-acromion	Male	307	341	364	380	394	422	455	380
		Female	225	298	322	334	355	378	442	338
133	Bi-deltoid	Male	350	379	407	426	449	482	672	430
		Female	276	319	352	369	394	449	490	376
134	Chest (on bust)	Male	241	259	282	298	319	356	596	303
		Female	203	217	255	277	293	313	355	274
135	Abdomen	Male	205	227	244	260	283	327	428	268
		Female	182	201	215	234	253	270	334	236
136	Waist	Male	150	216	241	259	279	317	453	264
		Female	192	197	216	231	247	289	470	237
137	Hip	Male	209	272	309	331	355	405	550	334
		Female	220	259	296	314	341	429	520	323
138	Thigh Extd M	Male	82	99	116	129	142	164	204	131
		Female	53	75	96	105	116	136	145	107
139	Mid Thigh to Thigh	Male	285	289	339	369	399	449	490	373
		Female	273	274	309	379	394	529	530	363
140	Elbw to Elbow	Male	296	346	375	409	435	489	746	411
		Female	257	282	325	364	399	435	510	363

The CAD model of AV and the DHM of Indian male 95th percentile value was selected for analyzing the dimensional check of interiors. Design development using a digital human model (DHM) can be done for AV design. The interaction between driver and passengers inside the AV can be observed concerning the ingress and egress of the AV. The clear line of sight for the driver can be decided accurately by using DHM. This technique allows the driving wheel and control pedals to be reached comfortably. Using the ergonomic module in the CATIA program, one can also assess the strain placed on the muscles during extended driving. Virtual techniques like Digital Human Modelling (DHM) are frequently employed for these verifications. A DHM tool is

important to be able to represent the postures and motions that varied persons are most likely to adopt under specific circumstances when validating that design supports the variety of users and tasks. In order to accomplish our objectives and generate reliable simulation results, we require this functionality. The DHM and theories involving drivers' postures and movements under specific conditions did not impact the result. Such prediction abilities may be based on applying optimization techniques, enabling the human model to automatically generate an appropriate sitting position or motion within the existing constraints.

6.5 DHM Analysis of AV

6.5.1 Dashboard

The digital human model on a 1: 10 scale is implanted in AV and all the critical operations were analyzed in CATIA software (Chang, & Wang, 2007).

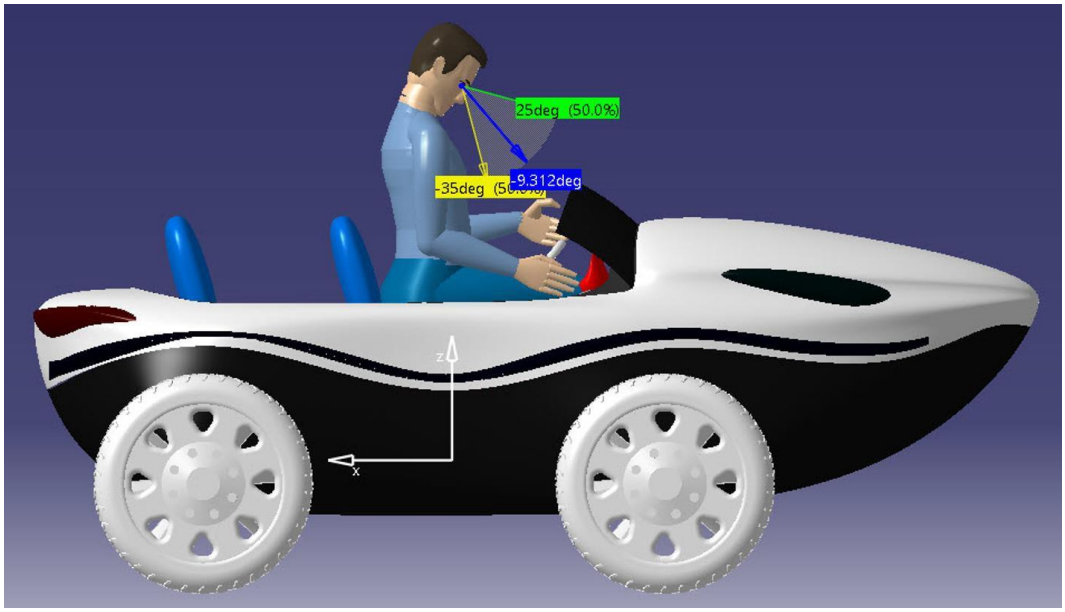
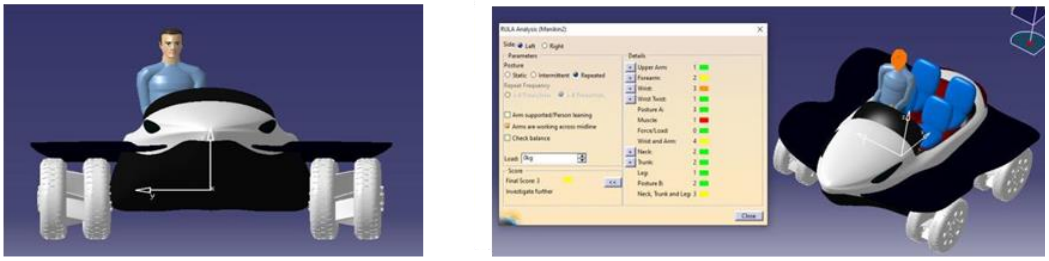


Figure 6.3. DHM Analysis of the dashboard.

The position of the dashboard and instrument panel was lower and causing neck movement of 9.3 degrees which can result in fatigue (see **Figures 6.3, 6.4, and 6.5**). This aspect was rectified by improving the height of the IP and reducing the neck angle (Burchard, Ayers, Frey, & Sapidis, 1994).



A B

Figure 6.4. The Modified CAD model after DHM analysis: A) Front View B) Isometric View with RULA results.

6.5.2 The Ingress and egress of AV

The ingress and egress of AV were analyzed with the DHM model in CAD. Due to more height of the AV, a step and Handle were provided to relax the leg muscle during that (Kozlov, Chowdhury, Mustary, Loganathan, & Alam, 2015).

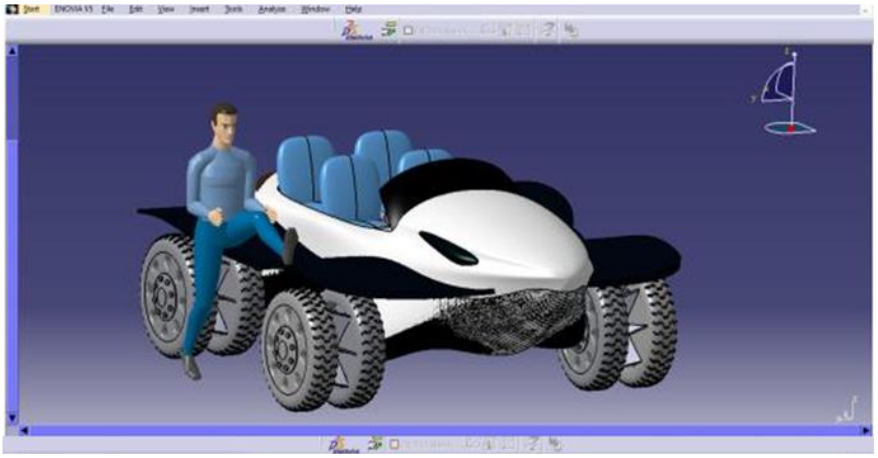


Figure 6.5. Ergonomic evaluation of CAD model using DHM method (Ingress-egress analysis).

6.5.3 Elbow space modification

The elbow space for two side passengers was falling short. This is taken care of by increasing the space for seating (Bhise, 2016).

The DHM method was useful in validating the AV design concerning user-friendliness and comfort. This led to the next process of making scaled-down models in actual material (Senoz, Daughton, Gosavi, & Cudney, 2011). 3D printing was used to make a physical AV Model to get the Product's actual look and feel (Liem, Abidin, Warell, 2009).

6.6 Scaled Down Model of AV for Aesthetics Judgment

The scaled-down model is made in specific colors and graphics to give the look and feel of AV. This was to give the actual color and finish of the product and get feedback. It is shown in **Figure 6.6. and 6.7**.

Figure 6.6. Final Model of AV for amusement parks.

Figure 6.7 Final finished model of AV for Eco Parks.

6.7 Discussions

Högberg, Castro, Mördberg, Delfs, Nurbo, Fragoso, and Hanson (2018) claim that it is quick and affordable to construct a digital human modeling (DHM) based test method concept for evaluating physical ergonomics conditions in virtual phases of the automotive interior design process. This is in line with lean product development (LPD), and ergonomics are taken into account proactively. As a result, it ensures that three factors—the product (amphibious vehicle), the users, and the task (functioning of the amphibious vehicle)—interact appropriately. AV Högberg, Castro, Mördberg, Delfs, Nurbo, Fragoso, and Hanson (2018) claim that it is quick and affordable to construct a digital human modeling (DHM) based test method concept for evaluating physical ergonomics conditions in virtual phases of the automotive interior design process. Ergonomics are actively considered, which is in line with the lean product development (LPD) concepts. As a result, it ensures that three factors—the product (amphibious vehicle), the users, and the task—interact appropriately (Jung, Cho, Roh, & Lee 2009).

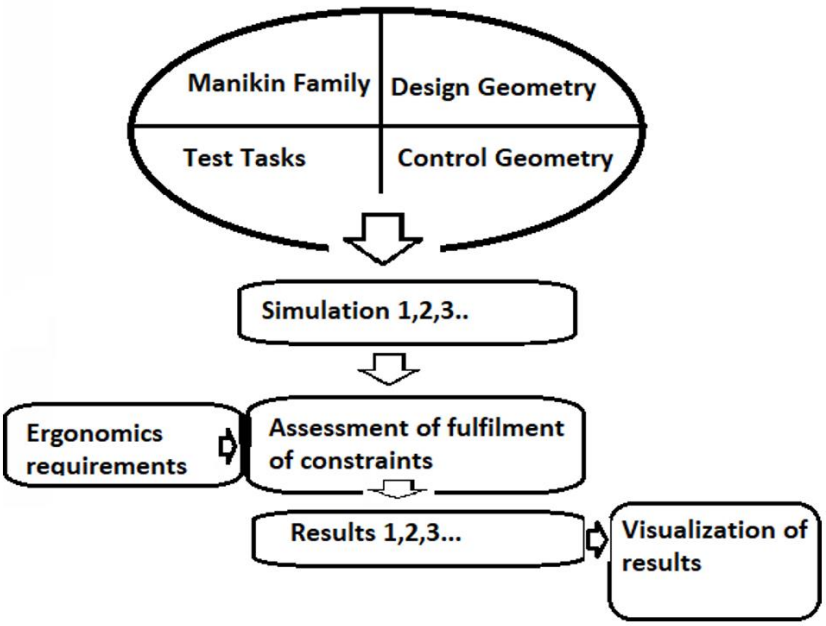


Figure. 6.8 Structure of procedure of DHM Process.

Figure.6.8 depicts the procedure. Comparing the test procedure to current methods of employing DHM in the AV interior design process, the main goal is to improve the quality, efficiency, and objectivity of ergonomics assessments. The desire to run simulations using various thoughtful digital human models is related to the quality goal and will improve user diversity consideration. It also has obvious advantages in simplicity and cost-effectiveness to iteratively adapt and test various design options in the virtual world instead of the real world. Another quality-related goal is to replicate more frequently performed actions like a natural person would carry out such tasks, i.e., by including the anticipated human motions needed to carry out those jobs. This will make it easier to examine new design suggestions and ensure that all crucial activities, including related motions and force exertions, are considered. It will also help us better understand these tasks' aggregate and combinatorial impacts, lowering the likelihood of suboptimizations. The DHM-based conceptual test technique must also be able to quickly evaluate and contrast various design suggestions to promote quality and efficiency. The DHM-based conceptual test technique must produce the same or very similar results regardless of who conducts the tests to achieve

the objective goal of objectivity (Von, 2021).

Additionally, if tests are repeated, the test technique should produce identical or reasonably similar results. The DHM-based test procedure concept's supporting reasons are consistent with LPD's goal of having stable processes. Acquiring consistent simulation results during design processes, independent of who uses the tool or when, and comparing findings when comparing various design ideas is supported by reliable procedures for using DHM tools. The primary parts of the DHM-based test technique are shown in Figure 6.8, where each part can be swapped out to reflect other simulation and evaluation scenarios.

6.8 Conclusions

The present Thesis work focuses on scoping the new amphibious vehicle in the Indian context for various unique and exciting applications. The inspiration-based design work for the amphibious vehicle is carried out, resulting in multiple options varying in aesthetics. Aesthetic evaluation is carried out through a user survey. The CAD model and DHM analysis are carried out for validation. The engineering analysis is done for structural members. The details for the working prototype and specifications are worked out for making a prototype for testing.

CHAPTER 7

Conclusions, Final Design Recommendations, and Guidelines

Abstract

The electric amphibious vehicle for amusement will have the added advantages of environmental friendliness and soundlessness in a quiet environment. The Hull design has two options in terms of materials. A steel frame with a sheet metal body is recommended. It can be a steel frame with an FRP body also. The power source is the battery. Options can be both, Lithium-ion or dry batteries of 750 AH. The prime mover is a centrally located 5KWH BLDC motor connected to 4 wheels by belt drive. The motor is also alternately connected to the propeller when it requires to move on water. These are the proposals for making an 1:1 prototype for testing. The suggested design is recommended for amusement purposes. However, actual validation can be done after making a prototype and testing with real users. In addition, the diversification of amphibious vehicles can be done for various other applications in India. Design of AV can be done considering the context and user's psychological preferences. User-based design of AV can make the application easier and more acceptable for general people. Adopting technical configuration and electrical power for AV applications can make them environment-friendly and sustainable.

Keywords: FRP body, Hull Design, Prototype, Technical Configuration, User-based design.

Key Findings:

- The final technical specifications for the components and prototype are reported in this chapter.
- However, it requires validation and testing after making the actual prototype.

7.1 Introduction

India is mainly a rural area-based country. About 70% of India's population stays in rural India. About 70% of roads in India are kutcha roads. There are 15000 water bodies like lakes, reservoirs, and more than 400 rivers in India (Chaudhary, Kumar, Pramanik, & Negi, 2021). There are many natural disasters like floods and earthquakes where the amphibious vehicle can be used in many situations better than a regular vehicle. Research is being taken place for Amphibious Ambulance and Amphibious Cycle in India. In this thesis, the effort is made to design amphibious vehicles for amusement and Eco-parks in India. Many other applications, like National Border Patrolling vehicles in watery areas, can be considered for new vehicle design. Integration of AV characteristics provides a unique usability factor to the regular vehicle in India. The design characteristics of AV and design can be used in the design of special-purpose vehicles for rural applications and areas where watery applications are needed. In states like Kerala, Bihar, UP, and West Bengal, where the usage of boats is typical for daily passengers, the design of AV can add value to regular vehicles and be a unique advantage for the people living there.

The requirement of the amphibious vehicle in India and its interpretation as an amusement vehicle was done as an exercise in this paper. The framework of AV design and Bio-Inspired design approach was applied to create a design for Eco-Parks in India. Evaluation is done for its interior & exterior to complete the exercise. It is recommended for new applications, and benefits are shown. New applications and special purpose applications can be found with amphibious characteristics to provide an upper edge for applications in rural India (Farr, 2011).

7.2 Establishment of Hypotheses

From the first study (reported in chapter 3) of aesthetics and speed forms generated from inspiration of various animals (Bird, Fish, and Frog), it is clear that the aesthetically favorable speed form was derived from amphibian (Frog). Hence, hypothesis 1 is supported by this study result. On the other side, when scholars tried to implement the amphibious vehicle design inspired from morphology of a duck (another amphibious animal as reported in Chapter 4), they have realized that it might not be aesthetically favorable as much as it is favorable in case of amphibious vehicle inspired from morphology of a frog (as reported in chapter 4). Therefore, it could be argued that morphology of all kinds of amphibian animals are not suitable for design inspiration and implementation of amphibious vehicle. This kind of results partially supports hypothesis 1.

Stress strain parameters were studied in chapter 5, and it was evident that HSLA Steel is suitable for development of amphibious vehicle as all stress-strain parameters were with acceptable limit. Hence, hypothesis 2 is supported by these results.

The Indian anthropometric considered for the design of cad model of amphibious vehicle. When we tested the cad model with digital human model in simulated environment using CATIA ergonomics module, it was evident that the seating arrangement and car interior space are suitable for seating of four Indian occupants including the driver. However, as there is no step to raise on the vehicle, the awkward and uncomfortable leg posture was observed for ingress procedure in to the vehicle. Hence, a pedal to ride up to the vehicle has to be implemented in near future, in real life scenario, highlighted as recommendation by scholars. Therefore, hypothesis 3 is mostly supported by DHM simulation results as reported in chapter 6. Please refer to Table 7.1. to see claims related to this thesis work and Table 7.2 for

overview of establishment of hypotheses.

7.3 7.3 Claims Related to this Thesis Work

Table 7.1. Claims related to this thesis work.

No	Experiments/User Survey	Findings	Claims	Contributions
1	Requirement of Amphibious Vehicle for amusement purpose (Chapter 1)	People do like the idea of the amphibious vehicle and want to use it for specific purposes like recreation, adventure, and general-purpose vehicle	An amphibious vehicle with recreational use is novel in the Indian context. The planned vehicles are designed with inspiration from Bio forms. This is aesthetically good and comfortable to use.	User requirements were analyzed using survey method, generally used for user need analysis. Hence, Amphibious Vehicle can be designed to suit Indian user needs in the context of Recreation.
2	Aesthetic speed Form Generation for amphibious vehicle (Chapter 3)	The best and most basic aesthetic speed form of AV has been identified out of all explorations by subjective rating by target users using a 7-point semantic differential scheme.	The identified basic speed form is unique to the context of amphibious vehicle design.	The process of evaluation of aesthetics and speed form for AV.
3	Design of amphibious vehicle inspired by Duck Beak (Chapter 5).	The speed form was fitting to the context but it was not aesthetically up to the mark and there was scope for improvement.	Although, this contextual design is based on bio-inspired objects and is functional in nature, it is not necessary that it gives more acceptability to the user, because of poor aesthetics.	Functional requirements of Electric AV are determined. Aesthetics is identified as one of the important criteria for designing of AV.
4	Design of amphibious vehicle inspired by Frog (Chapter 4).	The AV Form inspired by Frog is more acceptable as it has aesthetic look along with speed form.	If the AV has improved aesthetics and is inspired by Frog, is more acceptable for recreational usage.	The bio-inspired aesthetic design process for AV.
5	Evaluation of AVs using Digital Human Modeling software to check vehicle packaging in simulated environment (Chapter 6).	Anthropometric fit and comfort were more in the case of the AV design inspired by Frog than the AV design which is inspired by Duck Beak.	The AV design which is inspired by Frog Is more comfortable for occupants as well as aesthetic in nature.	The way of application of DHM for packaging of AV to optimize the comfort of occupants.
6	Comparative study on aesthetics of the interior of AV	Design 2 is aesthetically better than other designs and meets user requirements.	Interior Design 2 can be implemented along with the AV design which is inspired by Frog to get a better chance of acceptance.	Car interior design has an overall acceptance of the vehicle. The method of aesthetic design and implementation of interiors in designing AV has been demonstrated.

Table 7.2. Status of Establishment of Hypotheses.

Serial No	Hypothesis	Status
1	It could be reasonable to assume that if the amphibious vehicle is designed from the inspiration of the morphology of amphibian animals, the design might be acceptable from the point of view of aesthetics and affective requirement by Indian users for amusement purposes.	Partially Established
2	It is reasonable to assume that the amphibious vehicle would be feasible to develop if stress and strain parameters are within the acceptable range in the structural design of AV.	Established
3	It is reasonable to assume that if AV fits the body dimensions of the Indian population, it would be comfortable.	Nearly Established

7.4 Final Design Recommendations

The AV for Eco-Park is lightweight and for four persons. Since, it is a recreation vehicle, the speed limit in water and land is kept low for safety. Here people enjoy freedom and experience. The current design is without a canopy. We can also modify the design with a canopy without increasing much of the vehicle weight. The wheels of AV are selected for an off-highway drive. Tyre of 255/70 R18 size is selected. The driveline is of 4X4 type, which helps travel in soft soil. The body is designed as a type of hull of a boat. The shafts come out of the body with flanges that are tightly fitted with a gasket for leak-proof ness. The suspension is fixed with the body from the outside. All the controls and batteries are packed in watertight plastic boxes. The driving operation is with steering and few controls. A Brushless DC motor operates the main drive shaft. The detail of the circuits and specifications are out of the scope of this document. In the future, it will be worked out for prototype development, as shown in Figure 7.1.

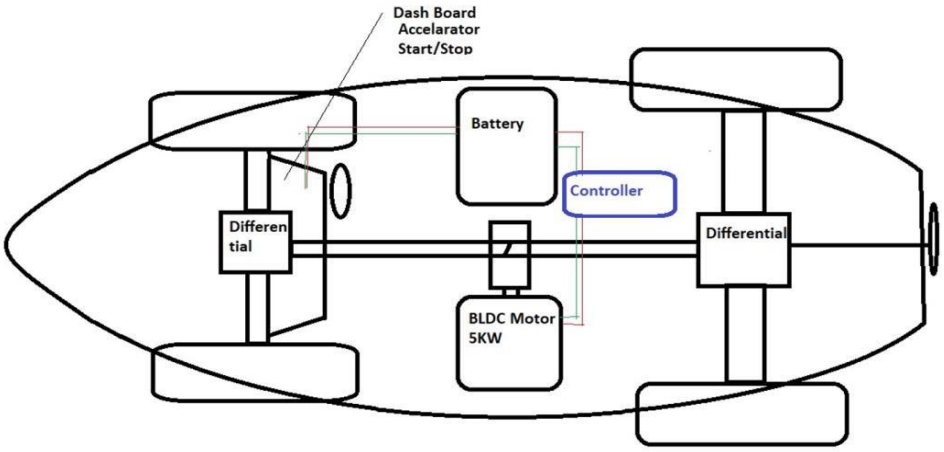


Figure 7.1. Schematic diagram of components of Electric AV.

List proposed Components for Prototype

a. Battery: 130 AH, 5 Nos
b. Motor: 5 KW BLDC 72V, 3000rpm, Class F,
c. Differential: Hypoid gear differential, 2 Nos. Marine Propeller shaft: 1 No
d. Tire: 235/75 R15, Universal Joint, Ackerman Steering, and leaf & spring suspensions.

7.5 CAD Model of AV

From the previous analysis done on various concepts, one final model was shortlisted and the CAD model was done to show the vehicle exterior and interiors (Lavie, Oron-Gilad, & Meyer, 2011).

Figure 7.2. CAD model of AV.

7.6 Design guidelines for amphibious vehicles in India for the amusement sector

Indian amusement sector is in its starting stage of developing amusement parks and water parks. The response is excellent for going ahead to bring innovation and diversity. They can think of amphibious vehicles in amusement parks. The landscaping and water bodies can be natural or artificial. The form and shape design of an amphibious vehicle depends on the geography and nature of the people. The design and construction of materials can be brought in, depending on the cost structure suitable to the places in India. Primarily it is designed for Electric operated AV; however, depending on speed and terrain, design changes can be brought in. The AV is high torque and low-speed vehicle where the drive train can be selected for the 4-wheel drive, which can be suitable for uneven terrain and soft soil.

7.7 Relevance of present research work

The present research set a context and deep dive into the amusement sector for applying the amphibious vehicle. A user study has been carried out for user reactions. Perceptions of the amphibious vehicle and possible variations of form and shape have been worked out to get the psychological acceptance factors. The speed form exercise has been carried out to explore and incorporate bio-organism-oriented form structures for the AV and evaluate their preference for one. The details of CAD designs were worked out, and vehicle structural analysis was done to see the feasibility of making a prototype for a working amphibious vehicle. A scaled-down model with a mannequin was presented to get the look and feel of the final amphibious vehicle. The DHM analysis was done for ergonomic evaluations and fine-tuning certain assembly designs. However, detailed technical specifications are outside the scope of the present thesis. It is left to be done in the future.

7.8 Recommendations for the AV in India

India is a country full of natural resources and plenty of water bodies are there which include lakes, reservoirs, rivers, seas, lagoons, etc. Owing to people's habitation and natural calamities, there are plenty of applications of AV that could be taken up for development. To start with tourism sector is a big area of development where AV can be used to upgrade the quality of nature-based tourism. Flood relief vehicle is a particular requirement where AV ambulance is a special requirements that can be done for some rural sectors in India. Border protection vehicle is another application where the border falls on water or rivers. AV can be developed for patrolling the border. There are states like Kerala and West Bengal where people have to cross rivers for daily commutes.

AV can find applications there to create a vehicle which is convenient for land and water applications. There are other researches carried out for other potential areas also. It has a bigger and wider application in India if it is designed suitably for the application considering people's affective design considerations. The affective design considerations for an amphibious vehicle for amusement purpose are derived here to systematically consider the necessary steps for designing an AV for that purpose.

7.9 Conclusions

The amphibious vehicle for amusement purpose and its form design requirement and ergonomic design requirements are experimentally derived in the above thesis. This is done considering an innovative process of bio-inspired amphibious creatures. The validation of the process is done considering Indian prospective users. Different inspiration-based designs were tried out from birds, fishes and amphibious creatures. The designs that could get maximum people acceptance was from amphibious creatures.

The ergonomic evaluations were done by using DHM methods. Digital human models were used in designing interiors and space design for AV for Eco-Park. Material and operational feasibility were worked out for AV for Eco-Park. The same process can be followed for other applications also.

The practical feasibility for prototype were checked by making a CAD model and a scaled down model in actual material. Battery as a power source was taken for Eco-Park. However, hybrid power also can be taken into consideration. Battery-operated AV for Eco-Park will be suitable as it will not pollute the environment and noiselessly it can work in reserve forests. A prototype was proposed to be made in fiber-reinforced plastics (FRP) with metal inserts For the necessary speed and floatability, necessary calculations were done for AV for Eco-Park (Tahera, Earl, & Claudia, 2014).

This establishes the need to realize amphibious vehicle requirement for Indian society. The water-based amusement sector was taken as a area of application to start with. The thesis deals with a affective design process applicable for amphibious vehicle. The affective design process considering Indian customers considers their choices of forms for amphibious vehicle. The form-based analysis was done considering bio-inspired process. The CAD based modeling and DHM process ensures the ergonomics considerations are evaluated for particular application. The construction of model and prototype further reconfirm structural and engineering confirmations towards realization.

7.10 Limitations of the Present Research Work

The present thesis did not extend it till prototype creation and working model creation. The exact specifications of the battery and electrical components. However, the buoyancy and speed calculations including structural finite element analysis are done. The prototyping and testing are kept for the future scope of work from the present thesis work. Proposals are sent to DRDO for prototype creation for AV for Border Patrolling. Below is the form for that.

Since it is not a land vehicle or a boat, the design considerations are different from the existing vehicle. The specific design depends on the amount of travel on land and water and also the number of occupants. Apart from the land and water consideration, it has soft soil, mud, and grassy area applications attached to it. The design of wheels and the number of wheels will be done based on application (Mezghani, Zayani, Amous, Gargouri, 2012).

7.11 Future Scope of the Vehicle

The amphibious vehicle has a wide range of cutting-edge uses in modern culture. The potential uses are endless. The current vehicle, however, might require additional visual enhancements and suitable placing in the market. The real creation and testing of the vehicle will support the viability of mass production and cost containment. To facilitate mass production, detail manufacturing and material selection can be done in the future. (Wright, 2003).

REFERENCES

Abidin, S. Z., Sigurjonsson, J., Liem, A., & Keitsch, M. (2008). On the role of formgiving in design. In DS 46: Proceedings of E&PDE 2008, the *10th International Conference on Engineering and Product Design Education*, Barcelona, Spain, 04.-05.09. 2008 (pp. 365-370). The Design Society, Scotland, number SC 031694.

Akner Koler, C. (2007). *Form & Formlessness: Questioning aesthetic abstractions through art projects, cross-disciplinary studies and product design education* (Doctoral dissertation, Axl books). University of Arts, Crafts and Design, The Department of Design, Crafts and Art (DKK), Industrial design. Chalmers, Sweden.

Andreasen T. (2003). An approach to knowledge-based query evaluation. *Fuzzy Sets and Systems*, 140 (1), pp3939-3948

Atienza, D. K. D., Bulanadi, E. C. C., Enriquez, M. A. S., Peralta, S. M. C., Sabado, A. L. R., Baldovino, R. G., & Garcia, G. R. (2015, December). Conceptual design of an amphibious E-tricycle. In *2015 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)* (pp. 1-4). IEEE.

Awasthi, S. (2017). Design & Fabrication of Amphibious Bicycle. *International Journal of Applied Engineering Research*. SSRN, Volume 14, Number 2, pp128-132

Babapour, M., Rehammar, B., & Rahe, U. (2012). A comparison of diary method variations for enlightening form generation in the design process, DRS, pp 49-60: *https://dl.designresearchsociety.org/drs-conference-papers*

Baldovino, R. G., & Garcia, G. R. (2016). Amphibious electric tricycle: mechanical design, simulation and dynamic analysis. *Advanced Science Letters, 22(9), 2141-2144.*

Benyus, J. M. (1997). Biomimicry: Innovation inspired by nature. *International Journal of New Technology and Research* 5(6), DOI:10.31871/IJNTR.5.6.17; ISSN: 2454-4116, Volume-5, Issue-6, June 2019 Pages 34-38

Bhise, Vivek D. (2016) *Ergonomics in the automotive design process. CRC Press,* Taylor & Francis Group

Bo, W., Bao-Jun, L., Ping, H., & Ming-Liang, S. (2014, November). Semantic-oriented shape exploration for car styling. In *2014 5th International Conference on Digital Home* (pp. 368-373). IEEE.

Bordegoni, M. O. N. I. C. A., & Caruso, G. I. A. N. D. O. M. E. N. I. C. O. (2012). Mixed reality distributed platform for collaborative design review of automotive interiors: This paper presents how mixed reality technologies allow a closer collaboration among designers, final users and engineers and hence reduce the time for reviewing and validating car interior designs. *Virtual and Physical Prototyping*, *7*(4), 243-259.

Börekçi, N. A., Kaygan, P., & Hasdoğan, G. (2016). Concept development for vehicle design education projects carried out in collaboration with industry. *Procedia CIRP*, *50*, 751-758.

Bouchard, C., Kim, J., & Aoussat, A. (2009). Kansei information processing in design. In *Proceedings of IASDR conference* (pp. 3327-3337).

Benyus, J. M. (1997). Biomimicry: innovation inspired by nature. William Morrow and Co. *Inc., NY*.

Cai, W., Chen, L., He, J., & Huang, G. (2015). Establishment and Analysis of a Comprehensive Economic Speed Model for Multi-purpose Marine Working Boats. In *The Twenty-fifth International Ocean and Polar Engineering Conference*. *Twenty-fifth International Ocean and Polar Engineering Conference. One Petro*. ISOPE OnePetro. ISBN: 978-1-880653-89-0

Ceballos-Lascurain, H. (1996). *Tourism, ecotourism, and protected areas: The state of nature-based tourism around the world and guidelines for its development*. Iucn.SCILIT Switzerland. http://dx.doi.org/10.2305/iucn.ch.1996.7.en; Journal of Environmental Protection, Vol.6 No.9, September 15, 2015

Chaffin, D. B. (2001). *Digital human modeling for vehicle and workplace design*. SAE International. *Society of Automotive Engineers Inc. Warrendale PA*, USA; ISBN: 0768006872. Warrendale, Pa.,Society of Automotive Engineers

Chang, S. W., & Wang, M. J. J. (2007). Digital human modeling and workplace evaluation: Using an automobile assembly task as an example. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *17*(5), 445-455.

Cannan, J., & Hu, H. (2011). Human-machine interaction (HMI): A survey. *University of Essex*, 27. Biomedical Science and Engineering. 2015, Vol. 3 No. 3, 46-64,

DOI: 10.12691/bse-3-3-1

Chakrabarti, D. (1997). *Indian Anthropometric Dimensions for Ergonomic Design Practice. India: National Institute of Design*. ISBN 81-86199-15-0. First published online July 21, 2016.

Chaudhary, S., Kumar, A., Pramanik, M., & Negi, M. S. (2022). Land evaluation and sustainable development of ecotourism in the Garhwal Himalayan region using geospatial technology and analytical hierarchy process. *Environment, Development and Sustainability*, 1-42. https://doi.org/10.1007/s10668-021-01528-4; 10 July 2021

Chen, C. C., & Chuan, M. C. (2011). A design decision-making support model for prioritizing affective qualities of product. In *Advances in Neural Networks–ISNN 2011: 8th International Symposium on Neural Networks, ISNN 2011, Guilin, China, May 29–June 1, 2011, Proceedings, Part III 8* (pp. 21-30). Springer Berlin Heidelberg.

Chen, W., Hoyle, C., & Wassenaar, H. J. (2013). *Decision-based design: Integrating consumer preferences into engineering design* (pp. 79-92). London: Springer.

Chen, Hung, Kang and Chiu (2006) Computer Aided Concept Design by Image Morphing, Proceedings of Wonder ground: 2006 DRS International Conference, Lisbon, Portugal, November 1-4.

Christian, C., Potts, T., Burnett, G., & Lacher Jr, T. (1996). Parrot conservation and ecotourism in the Windward Islands. *Journal of Biogeography, 23(3), 387-393*. Wiley-Blackwell Publishing Ltd Volume23, Issue3, May 1996, Pages 387-393

CLEMENTS C, PORTER S. Automotive design. Design Council, UK. 2008.

Colton, J. S., & Ouellette, M. P. (1994). A form verification system for the conceptual design of complex mechanical systems. *Engineering with Computers*, *10*, 33-44.

Creusen, M. E., & Schoormans, J. P. (2005). The different roles of product appearance in consumer choice. *Journal of product innovation management*, *22*(1), 63-81.

Davis, L. S. (Ed.). (2012). *Foundations of image understanding* (Vol. 628). Springer Science & Business Media. Springer Publications

De Pauw, Ingrid, Prabhu Kandachar, Elvin Karana, David Peck, and Renee Wever, (2010). "Nature inspired design: Strategies towards sustainability."

Researchgate, October 2010.
https://www.researchgate.net/publication/254906399

Du Plessis, A., Broeckhoven, C., Yadroitsava, I., Yadroitsev, I., Hands, C. H., Kunju, R., & Bhate, D. (2019). Beautiful and functional: a review of biomimetic design in additive manufacturing. *Additive Manufacturing*, *27*, pp408-427.

Dubey, A., & Dwivedi, V. (2003, December). Vehicle chassis analysis: load cases & boundary conditions for stress analysis. In *11th National Conference on Machines and Mechanisms. IIT, Delhi, India*.

Edwards, C., Bhamra, T., & Rahimifard, S. (2006, May). A design framework for end-of-life vehicle recovery. In *Proceedings of the 13th CIRP International Conference on Life Cycle Engineering, Leuven, Belgium* (pp. 365-370).

Eves, B., & Hewitt, J. (2009). Style-branding, aesthetic design DNA. In *DS 59: Proceedings of E&PDE 2009, the 11th Engineering and Product Design Education Conference-Creating a Better World, Brighton, UK, 10.-11.09. 2009* (pp. 478-482).

Fan, X. M., Wang, J. F., Duan, C. J., Xia, X. X., & Wang, Z. H. (2012). Study on automobile body performance of honeycomb sandwich composite material. In *Advanced Materials Research* (Vol. 567, pp. 146-149). Trans Tech Publications Ltd.

Farr, D. (2011). *Sustainable urbanism: Urban design with nature*. John Wiley & Sons.

Ferreira, J., Furini, F., & Silva, N. (2007, February). Framework for an advanced design vehicle process development. In *Proceedings of IASTED international conference on modelling, identification, and control (MIC 2007)* (pp. 12-14).

Feijs, L., Kyffin, S., & Young, B. (2007). *Design and semantics of form and movement* (Doctoral dissertation, Northumbria University, Newcastle).

Firat, M., & Kocabicak, U. (2004). Analytical durability modeling and evaluation—complementary techniques for physical testing of automotive components. *Engineering Failure Analysis*, *11*(4), 655-674.

Frejek, M., & Nokleby, S. (2008, May). Design of a small-scale autonomous amphibious vehicle. In *2008 Canadian Conference on Electrical and Computer Engineering* (pp. 000781-000786). IEEE.

Garud, R. Y., & Pandey, A. (2018). Structural analysis of automotive chassis, design modification and optimization. *Int. J. Appl. Eng. Res*, *13*(11), 9887-9892.

Gawande, M., & Mali, P. (2016). Amphibious vehicle. *International Research Journal*

of Engineering and Technology (IRJET), 137-138.

Gkikas, Nikolaos. (2016) Automotive Ergonomics: driver-vehicle interaction. CRC Press,

Hajare, P. M. S., et al. (2015). "a review on design and analysis of amphibious vehicle." *International Journal of Science, Technology & Management,* ISSN (Online) 2394-1537 ISSN (Print) 2394-1529.

Hartono, M., & Raharjo, H. (2015). Exploring the mediating role of affective and cognitive satisfaction on the effect of service quality on loyalty. *Total Quality Management & Business Excellence*, *26*(9-10), 971-985.

Hassan, M. Z., Razali, M. R., & Halid, M. S. (2013). Design and Development of Amphibious Hybrid Vehicle Body Structure. *International Journal of Science and Research (IJSR)*, *2*(5), 220-223.

Hay, L., McTeague, C., Duffy, A. H., Pidgeon, L. M., Vuletic, T., & Grealy, M. (2017). A systematic review of protocol studies on conceptual design cognition. Design Computing and Cognition'16, 135-153.

Hekkert, P. (2006). Design aesthetics: principles of pleasure in design. *Psychology science*, *48*(2), 157.

Helander, M. G., Peng, H., & Khalid, H. M. (2007, December). Citarasa engineering model for affective design of vehicles. In *2007 IEEE International Conference on Industrial Engineering and Engineering Management* (pp. 1282-1286). IEEE.

Huang, T., Kong, C. W., Guo, H., Baldwin, A., & Li, H. (2007). A virtual prototyping system for simulating construction processes. *Automation in construction*, *16*(5), 576-585.

Jaiswal, B., & Bisht, M. (2017). Tourism sector in Uttarakhand: A brief overview after the state formation. *International Journal of Research in Economics and Social Sciences (IJRESS)*, *7*(7), 277-295.

Jones, K. D., Bradshaw, C. J., Papadopoulos, J., & Platzer, M. F. (2005). Bio-inspired design of flapping-wing micro air vehicles. *The Aeronautical Journal*, *109*(1098), 385-393.

Kala, C. P. (2013). Ecotourism and sustainable development of mountain communities: A study of Dhanolti Ecopark in Uttarakhand state of India. *Applied Ecology and Environmental Sciences*, *1*(5), 98-103.

Kalhari, A., Wickramarathna, N., Yapa, L., Nandasena, D., & Kalansooriya, L. P. (2020). Development of Automated Aquatic Taxi for Sri Lanka using Kansei Engineering Concept, *13th International Research Conference*, General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka; https://www.researchgate.net/publication/348154818

Karmakar, M. (2011). Ecotourism and its impact on the regional economy–A study of North Bengal (India). *Tourismos*, *6*(1), 251-270.

Khalid, H. M., & Helander, M. G. (2004). A framework for affective customer needs in product design. *Theoretical Issues in Ergonomics Science*, *5*(1), 27-42.

Khalid, H. M., Opperud, A., Radha, J. K., Xu, Q., & Helander, M. G. (2012). Elicitation and analysis of affective needs in vehicle design. *Theoretical Issues in Ergonomics Science*, *13*(3), 318-334.

Kim, J. H., Kwon, O. Y., Hwang, U. J., Jung, S. H., Ahn, S. H., & Kim, H. A. (2021). Comparison of the shoulder external rotator strength and asymmetry ratio between workers with and without shoulder impingement syndrome. *The Journal of Strength & Conditioning Research*, *35*(12), 3364-3369. NSCA

Kim, S. M., Lee, Y. J., Kim, D. H., Kim, S. Y., Ahn, H. Y., & Yu, S. J. (2009). Perception, attitude, and knowledge about physical restraints among nursing personnel in long term care facilities. *The Journal of Korean Academic Society of Nursing Education, Korea 15*(1), 62-71.

Kim, W. J., Shin, G. W., Lee, J. H., Lee, Y. S., & Yun, M. H. (2016, December). Identifying the visual interference by design and tactile properties of leathers using automobile interior. In *2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 272-275). IEEE.

Kozlov, A., Chowdhury, H., Mustary, I., Loganathan, B., & Alam, F. (2015). Bio-inspired design: aerodynamics of boxfish. *Procedia engineering*, *105*, 323-328.

Krause, F. L., Bock, Y., & Dreher, S. (1999). Design evaluation of virtual clay models using selective laser sintering. In *Machining Impossible Shapes: IFIP TC5 WG5. 3 International Conference on Sculptured Surface Machining (SSM98) November 9–11, 1998 Chrysler Technology Center, Michigan, USA* (pp. 201-207). Springer US.

Kwon, S., Ahn, S. H., Kim, W., & Yun, M. H. (2021). Development of an affective model for the front visual quality during automobile driving. *Journal of Engineering Research*, *9*(3B). https://doi.org/10.36909/jer.v9i3B.8537

Kwong, C. K., Jiang, H., & Luo, X. G. (2016). AI-based methodology of integrating affective design, engineering, and marketing for defining design specifications of new products. *Engineering Applications of Artificial Intelligence*, *47*, 49-60.

Lavie, T., Oron-Gilad, T., & Meyer, J. (2011). Aesthetics and usability of in-vehicle navigation displays. *International Journal of Human-Computer Studies*, *69*(1-2), 80-99.

Liem, A., Abidin, S., & Warell, A. (2009, October). Designers' perceptions of typical characteristics of form treatment in automobile styling. In *5th International Workshop on Design & Semantics of Form and Movement, DesForm*. Taipei, 144-155

Lin, H. C. K., Su, S. H., Chao, C. J., Hsieh, C. Y., & Tsai, S. C. (2016). Construction of multi-mode affective learning system: taking affective design as an example. *Journal of Educational Technology & Society*, *19*(2), 132-147.

Lurie-Luke, E. (2014). Product and technology innovation: What can biomimicry inspire?. *Biotechnology advances*, *32*(8), 1494-1505. Elsevier Inc.

Martin, M. (1978). Theoretical determination of porpoising instability of high-speed planing boats. *Journal of ship research*, *22*(01), 32-53. SCImago

Mathieson, A., & Wall, G. (1982). *Tourism, economic, physical and social impacts*. UK, Longman.

Mayyas, A., Qattawi, A., Omar, M., & Shan, D. (2012). Design for sustainability in automotive industry: A comprehensive review. *Renewable and sustainable energy reviews*, *16*(4), 1845-1862.

McCauley, J. L. (2018). Hydrodynamic lift on boats. *arXiv preprint arXiv:1808.03313*.. Physics Dept. Univ. of Houston. Houston, Tx. 77204 https://doi.org/10.48550/arXiv.1808.03313

Millward, A. (1987). A study of the forces exerted by an oarsman and the effect on boat speed. *Journal of sports sciences*, *5*(2), 93-103, USA, David Publishing Company

Mugge, R., & Dahl, D. W. (2013). Seeking the ideal level of design newness: Consumer response to radical and incremental product design. *Journal of Product Innovation Management*, *30*, 34-47. John Wiley & Sons

Nagamachi, M. (1999). Kansei engineering: the implication and applications to product development. *IEEE International Conference on Systems, Man and Cybernatics, Vol. 6, pp. 273-278.*

Nagamachi, M. (2016). Methods of Kansei/Affective Engineering and Specific Cases of Kansei Products. In *Kansei/Affective Engineering* (pp. 27-44). CRC Press.

Nagamachi, M., & Lokman, A. M. (2016). *Innovations of Kansei engineering*. USA, CRC press.

Novak, M. (2012). COMPUTER AIDED DECISION SUPPORT IN PRODUCT DESIGN ENGINEERING. *Tehnicki vjesnik/Technical Gazette, 19*(4). MDPI; https://www.researchgate.net/journal/Tehnicki-Vjesnik-1330-3651

Ouellette, L. (2012). Branding the right: The affective economy of Sarah Palin. *Cinema Journal*, *51*(4), 185-191, *JSTOR Cinema Journal*, Vol. 51, No. 4 (Summer 2012), pp. 185-191 (7 pages) Published By: University of Texas Press

Ouma, O. J., Hayombe, P. O., & Agong, S. G. (2014). Assessing water-based recreational activities to project beach ecotourism potentials in Kisumu County. *IOSR Journal of Computer Engineering (IOSR-JCE)* e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 16, Issue 6, Ver. III (Nov – Dec. 2014), PP 27-36 www.iosrjournals.orgÖzcan,

Özcan, E., Cupchik, G. C., & Schifferstein, H. N. (2017). Auditory and visual contributions to affective product quality. *International Journal of Design*, 11(1), 35-50.

Park, K., Jung, E. S., & Im, Y. (2019). Affective Design of Automotive Center Fascia Display: Focused on Regional Preference. *Journal of the Ergonomics Society of Korea, 38(3).*Ergonomics Society of Korea

Peters, T. (2011). Nature as measure: The biomimicry guild. *Architectural Design*, *81*(6), 44-47, https://doi.org/10.1002/ad.1318

Rafeeq, M., Toha, S. F., Ahmad, S., & Razib, M. A. (2021). Locomotion Strategies for Amphibious Robots-A Review. *IEEE.* Digital Object Identifier 10.1109/ACCESS.2021.3057406

Rangaraj, N., & Raghuram, G. (2007). Viability of Inland water transport in India., SAGE Publications, Indian Institute of Technology, Bombay

Ranscombe, C., Hicks, B., Mullineux, G., & Singh, B. (2012). Visually decomposing vehicle images: Exploring the influence of different aesthetic features on consumer perception of the brand. *Design Studies*, 33(4), 319-341. Elsevier

Riascos, R., Levy, L., Stjepandić, J., & Fröhlich, A. (2015). Digital mock-up. In Concurrent engineering in the 21st century (pp. 355-388). *Springer, Cham.*

Ridden, P., Electric Scubster personal sub dives into crowdfunding pond from

https://newatlas.com/scubster-nemo/38827/ (Accessed on 12th April 2019) (2015)

Rieuf, V., Bouchard, C., Meyrueis, V., & Omhover, J. F. (2017). Emotional activity in early immersive design: Sketches and moodboards in virtual reality. *Design Studies*, *48*, 43-75. Elsevier

Roach, C. D. (1960). *Design of Wheeled Amphibians*. ARMY TRANSPORTATION RESEARCH COMMAND FORT EUSTIS VA. Defense Technical Information Center.Virginia, USA; https://Discover.DTIC.mil

Robinson-Riegler, G. L. (2008). *Cognitive Psychology+ My Searchlab Valuepack Access Card: Applying the Science of the Mind*. Prentice Hall.

Sanjog, J., Chowdhury, A., & Karmakar, S. (2012, May). Digital human modeling software in secondary manufacturing sector: A review. In *Proceedings of international conference on recent trends in computer science and engineering (ICRTCSE-2012)* (pp. 3-4).

Sanjog, J., Karmakar, S., Patel, T., & Chowdhury, A. (2015). Towards virtual ergonomics: aviation and aerospace. *Aircraft Engineering and Aerospace Technology: An International Journal*, *87*(3), 266-273.

Senoz, O., Daughton, W., Gosavi, A., & Cudney, E. (2011). An evaluation of professional quality measurement systems for the automotive industry. *International Journal of Engineering, Science and Technology*, *3*(7), 101-108.

Ragi, Shankarachary, et al. (2013): "Feasibility study of POMDP in autonomous amphibious vehicle guidance*." IFAC Proceedings Volumes 46.10, 85-90. Science Direct, Elsevier*

Sapidis, N. S. (Ed.). (1994). *Designing fair curves and surfaces: Shape quality in geometric modeling and computer-aided design*. Society for industrial and applied mathematics. (pp. 3-28).

Shirsath, P. S., Hajare, M. S., Sonawane, G. D., Kuwar, M. A., & Gunjal, M. S. (2015). A review on design and analysis of amphibious vehicle. *International Journal of Science, Technology & Management*, *4*(1), 43-56.

Siddaiah, A., Menezes, P.L. Advances in Bio-inspired Tribology for Engineering Applications. J Bio Tribo Corros 2, 23 (2016). https://doi.org/10.1007/s40735-016-0053-0

Sitek, B., & Yang, W. (2011). Conceptual design of an amphibious vehicle:

Vector. *ARPN J. Eng. Appl. Sci*, *6*(2), 1-6. VOL. 6, NO. 2, FEBRUARY 2011 www.arpnjournals.com. Islamabad, Pakistan

Stamov, T. On some principles of vehicle design and styling: character of the forms. *Int. J. Eng. Appl. Sci*, *4*(3).

Suzianti, A., Apriliandary, S., & Poetri, N. P. (2016). Affective design with kansei mining: An empirical study from automotive industry in indonesia. In *Design, User Experience, and Usability: Novel User Experiences: 5th International Conference, DUXU 2016, Held as Part of HCI International 2016, Toronto, Canada, July 17–22, 2016, Proceedings, Part II 5* (pp. 76-85). Springer International Publishing.

Tahera, K., Earl, C., & Claudia, E. (2014). Integrating virtual and physical testing to accelerate the engineering product development process. *International Journal of Information Technology and Management 9*, *13*(2-3), 154-175.

Ungerer, F., & Schmid, H. J. (2013). *An introduction to cognitive linguistics*. Routledge.

Thaneswer, P., Sanjog, J., Chowdhury, A., & Karmakar, S. (2013). Applications of DHM in agricultural engineering: a review. In *Advanced engineering forum* (Vol. 10, pp. 16-21). Trans Tech Publications Ltd.

Tovey, M., Porter, S., & Newman, R. (2003). Sketching, concept development and automotive design. *Design studies*, *24*(2), 135-153. *UK*

Tovey, M., Bull, K., & Osmond, J. (2010). Developing a pedagogic framework for product and automotive design. CEPAD UK

Tovey, M., & Owen, J. (2000). Sketching and direct CAD modelling in automotive design. *Design Studies*, *21*(6), 569-588.Elsevier

Tovey, M. (1997). Styling and design: intuition and analysis in industrial design. *Design studies*, *18*(1), 5-31. Elsevier

Tran, Y. (2010). Generating stylistic innovation: a process perspective. *Industry and Innovation*, *17*(2), 131-161.

Västfjäll, D., Gulbol, M. A., Kleiner, M., & Gärling, T. (2002). Affective evaluations of and reactions to exterior and interior vehicle auditory quality. *Journal of Sound and Vibration*, *255*(3), 501-518.Elsevier

Vilau, R., Stoica, A., Constantinescu, A., & Suci, D. (2019). Study of Stability on Water for a Special Amphibious Autovehicle. In *Proceedings of the 4th International Congress of Automotive and Transport Engineering (AMMA 2018)*

IV (pp. 136-143). Springer International Publishing.

Von Ellenrieder, K. D. (2021). *Control of marine vehicles*. Cham, Switzerland: Springer. (Nikolas I. Xiros). Electronic ISSN 2194-8453 Accessed on 10 Feb 2022.

Wang, C. H. (2015). Integrating Kansei engineering with conjoint analysis to fulfil market segmentation and product customization for digital cameras. *International Journal of Production Research*, *53*(8), 2427-2438.Taylor and Francis Ltd

Wang, D., He, T., Li, Z., Cao, L., Dey, N., Ashour, A. S., ... & Shi, F. (2018). Image feature-based affective retrieval employing improved parameter and structure identification of adaptive neuro-fuzzy inference system. *Neural Computing and Applications*, *29*, 1087-1102.Springer London

Wang, H. (1995). An approach to computer-aided styling. Design Studies, 16(1), 50-61. Elsevier Ltd

Ward, T. A., Rezadad, M., Fearday, C. J., & Viyapuri, R. (2015). A review of biomimetic air vehicle research: 1984-2014. *International Journal of Micro Air Vehicles*, *7*(3), 375-394.4. SAGE Publications Inc.

Weber, J. (2009). *Automotive development processes: Processes for successful customer-oriented vehicle development*. Springer Science & Business Media.Springer Nature *e-ISBN 978-3-642-01253-2*

Gao, F., Pan, C., Cai, W., & Yang, Z. (2010). Numerical analysis and validation of propeller open-water performance based on CFD. *Jixie Gongcheng Xuebao(Chinese Journal of Mechanical Engineering)*, *46*(8), 133-139.

Wijegunawardana, I. D., & de Mel, W. R. (2021). Biomimetic designs for automobile engineering: a review. *International Journal of Automotive and Mechanical Engineering*, *18*(3), 9029-9041.

Wilfred, S. D. (1964). *U.S. Patent No. 3,131,666*. Washington, DC: U.S. Patent and Trademark Office.

Woodside, A. G., Sood, S., & Miller, K. E. (2008). When consumers and brands talk: Storytelling theory and research in psychology and marketing. *Psychology & Marketing*, *25*(2), 97-145. Wiley Online Library

Wycoff, J. (1991). *Mindmapping: Your personal guide to exploring creativity and problem-solving*. Berkley.

Young, R., Feijs, L., & Kyffin, S. (2006). *Design and semantics of form and movement*

(DeSForM 2006). Koninklijke Philips Electronics NV.

Young, R., Feijs, L., & Kyffin, S. (2006). *Design and semantics of form and movement (DeSForM 2006)*. Koninklijke Philips Electronics NV.

Yuhazri, M. Y., Hidayah, W. N., Sihombing, H., Yahaya, S. H., Sulaiman, S., & Kamarul, A. M. (2018). Kansei engineering approach for the customers preferences of car design. In *Proceedings of the 7th International Conference on Kansei Engineering and Emotion Research 2018: KEER 2018, 19-22 March 2018, Kuching, Sarawak, Malaysia* (pp. 289-295). Springer Singapore.

Zainal Abidin, S., & Abdullah, M. H. (2013). The interaction of product noise and form design in evoking users' responses. In *DS 76: Proceedings of E&PDE 2013, the 15th International Conference on Engineering and Product Design Education, Dublin, Ireland, 05-06.09. 2013*.

Zhang, W., Zhao, J., & Zou, F. (2009). Semantic analysis of Chinese adjectives: a new approach to mapping the form-based metaphors in automobile styling. *Des. Rigor Relev*, 59-60.

Gibbs Sports Amphibian Quadski available at https://www.gibbssports.com/about/ (Accessed 30th Oct 2018)

Gibbs sports, Biski Sports Amphibian Bike, available at https://www.youtube.com/watch?v=6bvTlvjnGLI (Accessed 30th Oct 2018)

Alvis Stalwart , available at https://en.wikipedia.org/wiki/ (Accessed 30th Oct 2018)

DUKW: https://en.wikipedia.org/wiki/DUKW (Accessed 30th Oct 2018)

Research: https://niws.nic.in/ (Accessed 30th Oct 2018)

Alamy; https://www.alamy.com/stock-photo/london-amphibious-tour.html; (Accessed: 30 Oct 2018)

Amphibious Splash Tours Salzburg; https://www.amphibious-splash-tours.at/en/ (Accessed: 30 Oct 2018)

High-Strength Low-Alloy Steel; https://www.sciencedirect.com/topics/materials-science/high-strength-low-alloy-steel(Accessed 30th Oct 2018)

Water Car Panther - Amphibious Jeep; Subscribehttps://www.youtube.com/watch?v=m5xQy8MIuec (Accessed: 30 Oct 2018)

Amphibious bicycle3 and other technological contributions ; https://nif.org.in/upload/innovation/3rd/297-the-amphibious-bicycle-

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M. Des (Industrial Design-Product Design) from NID Ahmedabad, 1990-92. Strategic management **PG Dip** from **IIM Kashipur** 2017.

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Areas of Specialization: Teaching Transportation Design, Product Design, Furniture Design, Earthmoving & construction Vehicle design, Military Vehicle Design, Hydraulics operated vehicle Design, Model & Prototype construction, Digital mock-up & presentations, Project scheduling & management. Team management, technical training & competency development, design for manufacturing.

Design, Research & Publications:

1. Research Paper Publication at HWWE in Springer in 2018. Design of a Framework for Amphibian Vehicle Design.
2. Research Paper Published in Springer in 2019 in ICIPDIMS NIT Rourkela.
3. Best Research Paper award in ICIPDIMS NIT Rourkela.
4. Doctoral Colloquium in UPES Dehradun, Conceptual Design & manufacturing

aspects of an underwater vehicle.

5. Colloquium paper in 1989 for UCE Burla: Design of Swirl chamber in 2 stroke cycle engine for high-speed racing cars. Design Project in UCE Burla in 1988: Design of Hot & Cold chambers for Medical & pharmaceutical uses by using air run refrigeration system. Design of PSNG (portable Satellite News Gathering) Equipment for ISRO, Ahmedabad, 1993.
6. Design of Personal lighting system for Tulip Corporation, Mumbai, 1993. Done as an independent client project after passing out from NID.
7. Design of Kitchen Appliances system for Anjali Kitchenware, Mumbai,1993. Done as an independent client project.
8. Design of Water Purifier & Air Purifier; Client project s, Ahmedabad.1993. Done as an independent client project.
9. Design of Domestic office Furniture systems including modular desking & partitioning system for Godrej & Boyce Mfg. Co, Mumbai. 1994. Projects are done by individual ownership. Involved as an employee of Godrej & Boyce Mfg Co.
10. Design of modified low-cost version of Lista Open furniture systems for Allwyn voltas Ltd, Hyderabad, 1995. Executed as Design Manager in Allwyn Voltas Ltd, Hyderabad.
11. Design & manufacture of 20T Hydraulic Excavator for Telco Construction Equipment Company in collaboration with Hitachi Co. Japan.2000. Project executed as group in ownership of Telcon Design Department.
12. Design of 10T Hydraulic Crane for Telco Construction Equipment Co, Jamshedpur, 2002. Project executed as a group in ownership of Telcon Design Department.
13. Created center of excellence & offshore global design center for MNCs like Polaris Inc., Steelcase Inc., Delta, P&G USA, etc. (2003-2006). Involved in the Onsite USA for various MNCs for project initiation & management. Executed as DGM-projects in Infotech Enterprises Ltd.
14. Created global technical support Centre in EDS India, Pune, 2006. Involved as Centre Manager in EDS India, Pune.
15. Created a Design Automation center for global MNCs. Created customized user interface in cad software for reducing design effort & time. Involved as Centre Manage in Quest Global, Bangalore.
16. Design & launched a new model of P-N-C Crane 16 T capacity. Built prototype & tested. Extended range of lifting devices (Hydraulic Cranes) 8-14 Ton up to 30 Ton in Pick & carry segment. Involved as Design Head (2008-11)
17. Design & Execution of projects in Mahindra Defense Systems-
    i. Marksman modified, A bulletproof vehicle for military personnel.
    ii. Bulletproof roof Scorpio for VVIPs.
    iii. Mine protected Vehicle.

    These projects were executed as Design Head in Mahindra Defense Systems Ltd (2011-13).
18. Executed projects in L India Ltd-
    i. Redesign 40T Hydraulic Rough Terrain Cranes.

ii. Design of Operators cabin in 40 T RT Crane.
iii. Cabin Design for 75T Truck Crane
iv. Design & launch of 15T P-N-C Crane.

Showcased in India Design Mark and got awarded. Involved as Design Head in TIL Ltd.

19. Design of Dead Body Carrier vehicle: Coordinated students project while involved as Associate Professor in Product Design in United world Institute of Design, Gandhinagar(2015).

Work History:

- 30 Years of work experience in various MNCs and Design Education Universities.
- Domain Areas of Expertise: Industrial Design, Transportation Design, Computer Aided Design, Engineering, Styling, Prototyping, Teaching, Photography, Research & Development

Professional History:

- Worked as Professor of Industrial Design in UID (United world Institute of Design) Gandhinagar
- Worked as Design Head in TIL Kolkata
- Worked as GM in Mahindra Defense Systems, Prithla, Faridabad
- Worked as DGM Design in Escorts Ltd, Faridabad
- Worked as Center Head in Quest Global
- Worked as DGM in Cyient Technology, Hyderabad
- Worked in Design Dept. of Telco, Voltas & Godrej…etc.

Education:

- Executive Program from IIM Kashipur for 'Strategic Management' program in 2017.
- Certificate program in Project Management from ICFAI Hyderabad, 2004
- Masters: MDes –Industrial Design from National Institute of Design (NID), Ahmedabad, 1990- 93.
- Graduation: B.Tech –Mechanical Engineering from VSS University, Orissa. 1985-89.
- Certification course in Six Sigma.
- Certification course in ITIL, MSPP.

Nature of Responsibilities:

1. Teaching Transportation Design: Styling, Modeling, Design Methods, Technology etc..
2. Teaching Industrial Design: Form, Principles of Design, Design Projects etc.
3. Course Coordinator for final year & pre final year students
4. Job & Internship coordinator for final year students
5. Academic coordinator for Bachelor programs
6. Admissions & induction for fresh students
7. Support to NAAC audit for accreditations
8. Coordination for External & jury members
9. Organizing for special education programs
10. Helping vision, Mission & LRP

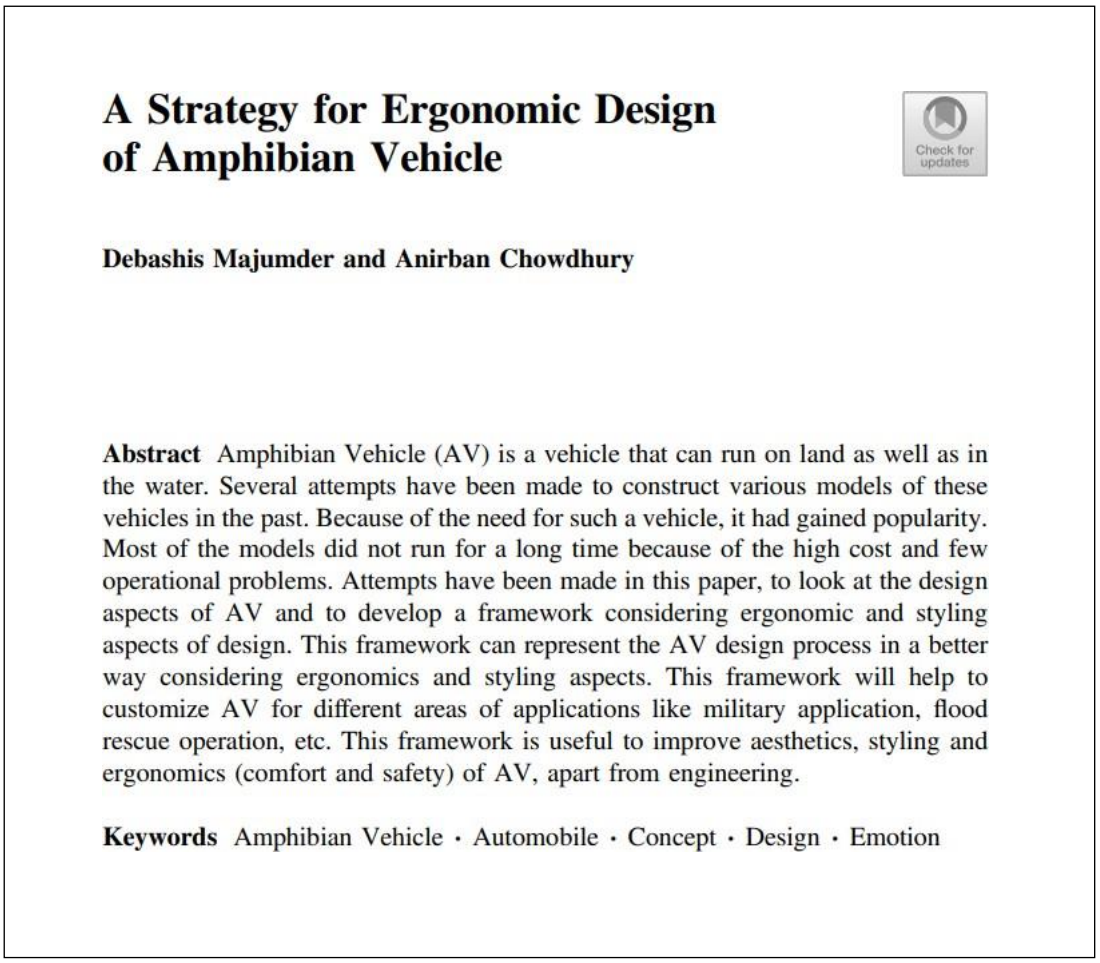
Domain Centric Involvement:

Teaching Transportation Design, Product Design, Furniture Design, Earth moving & construction Vehicle design, Military Vehicle Design, Hydraulics operated vehicle Design, Model & Prototype construction, Digital mock-up & presentations, Project scheduling & Management. Team management, technical training & competency development.

LIST OF THESIS RELATED PUBLICATIONS

1) ***Best Paper Awards & Published in Springer LNME 2021***

Majumder, D., & Chowdhury, A. (2020). A Strategy for Ergonomic Design of Amphibian Vehicle. In *Innovative Product Design and Intelligent Manufacturing Systems* (pp. 3-13). Springer, Singapore.



A Strategy for Ergonomic Design of Amphibian Vehicle

Debashis Majumder and Anirban Chowdhury

Abstract Amphibian Vehicle (AV) is a vehicle that can run on land as well as in the water. Several attempts have been made to construct various models of these vehicles in the past. Because of the need for such a vehicle, it had gained popularity. Most of the models did not run for a long time because of the high cost and few operational problems. Attempts have been made in this paper, to look at the design aspects of AV and to develop a framework considering ergonomic and styling aspects of design. This framework can represent the AV design process in a better way considering ergonomics and styling aspects. This framework will help to customize AV for different areas of applications like military application, flood rescue operation, etc. This framework is useful to improve aesthetics, styling and ergonomics (comfort and safety) of AV, apart from engineering.

Keywords Amphibian Vehicle · Automobile · Concept · Design · Emotion

2) ***Best Paper in IPDIMS, Published in Springer LNME***

Majumder, D., & Chowdhury, A. (2021). Design and Evaluation of Speed Forms for Design of an Amphibious Vehicle. In *Advanced Manufacturing Systems and Innovative Product*
Design (pp. 21-31). Springer, Singapore.

Design and Evaluation of Speed Forms for Design of an Amphibious Vehicle

Debashis Majumder & Anirban Chowdhury

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Part of the Lecture Notes in Mechanical Engineering book series (LNME)

Abstract

Amphibious vehicles (AV) are vehicles that can operate on land as well as on water. Historic evidences of different models of amphibious vehicles show that it has been lacking aestheti and styling aspects in its design. An effort has been made in this paper to derive bio-inspire speed forms considering aesthetic and dynamism characteristics to design the AV for amusement purpose. Aesthetics based on visual characteristics or expressions that are created in 2D and 3D by taking inspirations from biological organisms are called speed forms. Speed Forms for AV are evaluated to know the user choices. User survey was conducted for understanding aesthetic preferences, perception of dynamism and their selection criteria. A total of 22 users participated (age range: 18–35 years; 70% males, 30% females) in this study and they like to explore AV for amusement purpose. The data was analyzed by using SPSS software using descriptive and inferential statistics (Friedman ANOV and Wilcoxon signed test). It was observed that speed form 1 (inspired from frog) was most preferable among three speed forms explored in this study. The speed form 1 was aesthetically better than other speed forms; however, all the selected speed forms had dynamic characteristics. Hence, speed form 1 has the potential to be considered for designing amphibious vehicles used for amusement purpose.

3)

3) ***Journal Paper IJITEE International Journal of Innovative Technology and Exploring Engineering*** **International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278- 3075 (Online), Volume-10 Issue-10, August 2021**

International Journal of Innovative Technology and Exploring Engineering (I
ISSN: 2278-3075 (Online), Volume-X, Issue-X, Janua

CAD based Analysis for Feasibility of Desigr of an Amphibious Vehicle for Recreation

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Abstract: ***An amphibious vehicle is the vehicle that allows occupants to travel on both land and water. Since an amphibious vehicle must inherently possess both land and water capabilities, design of the vehicle should not compromise the requirements for a good boat as well as a good land vehicle. Although, amphibious vehicles were used for different purposes, still there is no mention of application of amphibious vehicle in recreational purposes such as beach riding and surfing on water. Market research shows that there is a growing trend for recreational vehicle for which all the big manufacturers are gearing up. With depletion of fossil fuel and for all the negative effect on marine life, attempt is made to design an electric amphibious vehicle for recreational sports. The literature review, pilot user survey reveal user aspirations and needs for such vehicle. Conceptual design of few options were worked out and matched with visual aspects of vehicle that match recreational sports. A CAD model was prepared with structural details. Structural strength was analyzed with Ansys software. CFD analysis was conducted for calculating drag and surface shear stress. Calculation for buoyancy was calculated. Thus it gives a practical approach to construction of an amphibious vehicle for recreational sports. Therefore, the aim of this study is to design an Amphibian vehicle that can be used for recreational purpose (for beach riding and surfing on water) at the same time, it is safe for passengers.The results of the CAD based analysis shows that the stress on the Frame was within acceptable limit and the buoyancy conditions are fulfilled. It also suggest for a maximum speed of 40kmph on water. Thus the conceptual vehicle is suitable for use on land and on water.In the next step this design can be taken up for building a prototype for testing in actual condition***

Keywords: Electric Amphibious Vehicle, CAD Model, CFD Analysis, Prototype, Conceptual Design

I. INTRODUCTION

There were occasional examples of use of amphibious nature of vehicle. Sometime it was bicycle some time it was car etc. These were very few in number and in a specific area. Vehicles such as Amphicar which was built by Quandt group in the 60s was a remarkable feat in amphibious vehicle production and an early inspiration. Although this rear wheeled wonder was soon out of production due to cost issues and several parts made of steel which was prone to rust and required high maintenance, it had various design aspects like high ground clearance for better maneuverability and traction control on land. Also a large bulge around the engine provided better hydrodynamic as well as ground effect [1].

Many films like Pontiac Moon and a 60s Pepsi Commercial featuring Amphibian vehicles at high speed on water also motivated us to build a similar recreational multi utility vehicle. Gibbs Aquada is also a prototype design which incorporates a thrust jet propulsion technology m speed mobility on water, an achievable feat. Its desi can be an employed in our amphibian vehicle for hi and speed allowances in water [2].

II. LITERATURE REVIEW

A. *Amphibious human powered cycles*

These are some independently made human powere having capability to move both on land and water. A primitive design of a human powered bicycle made Saidullah, an innovator from Bihar incorporates four floats for achieving buoyancy and propulsion is don fins attached to the spokes of the wheels. It was also documented by Discovery Channel.

B. *Amphibious trucks and artillery vehicles*

During the World War II, the US military used DUK which had a 6X6 wheel drive. Germany's Schwimm and Russia's GAZ 46 were also some similar primiti amphibious truck design used in the war [4].

The Vietnam war which spanned from 1955 to 19 saw many unique amphibian military-based carrier The British developed a 6X6 cargo carrier named A Stalwart in the 60s capable of achieving 6 knots with of water-jet propulsion technology. Germans develo M3 Amphibious rig capable of carrying multiple arr personnel along with heavy vehicles and cargos.

A very unique design was seen in the British desig the wake of World War II named Sherman (after the general William Sherman) which was also dubbed as Drive" due to the fact that it consisted of rubberized which was opened by the soldiers before entering the provide additional buoyancy. It had a propeller base propulsion system. The design was flawed as it was when afloat due to the covering of the guns by the s

C. *Hovercraft based vehicles*

These are air cushion based vehicles which reimagined on the big screen in the flicks such as James Bond flick Die Another Day. It is base principle of levitation based on an air cushion of low air between vehicle base and the They have an advantage of transition from land to water

1

Journal Paper Results in Engineering Submitted

AFFECTIVE DESIGN APPROACH FOR STRATEGISING INTERIOR AND EXTERIOR OF AMPHIBIOUS VEHICLE FOR AMUSEMENT PURPOSE

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Abstract

The exterior and interior design of Amphibious Vehicles are mostly dominated by land vehicles and military vehicles. The AV has immense potential to be used as a commercially mass-produced vehicle for entertainment, expedition, nature tour, border patrolling and flood relief purposes. This study aims to design the exterior and interior of AV for amusement purposes with an affective design approach to meet user expectations. The methodology involves digging out users' latent choices through the affective keyword-based survey from target users and determining the fruitful affective expressions for AV (interior and exterior) using advanced statistical techniques (Factor Analysis and ANOVA). A total of 81 target users have participated in this study. Two interior design variations and two exterior design variations were created and compared as per the affective requirements of target users (20 and 12 affective keywords were selected for the study of exterior and interior appearances respectively). Exterior design concept-2 is significantly more engaging, adventurous, and luxurious than design concept-1. For interior design concept-2, average values of fluidic, relaxed, and graceful were significantly high than concept-1. This sows that amphibious vehicle for amusement purpose can be designed keeping this visual attribute in mind so that it will be more acceptable to users.

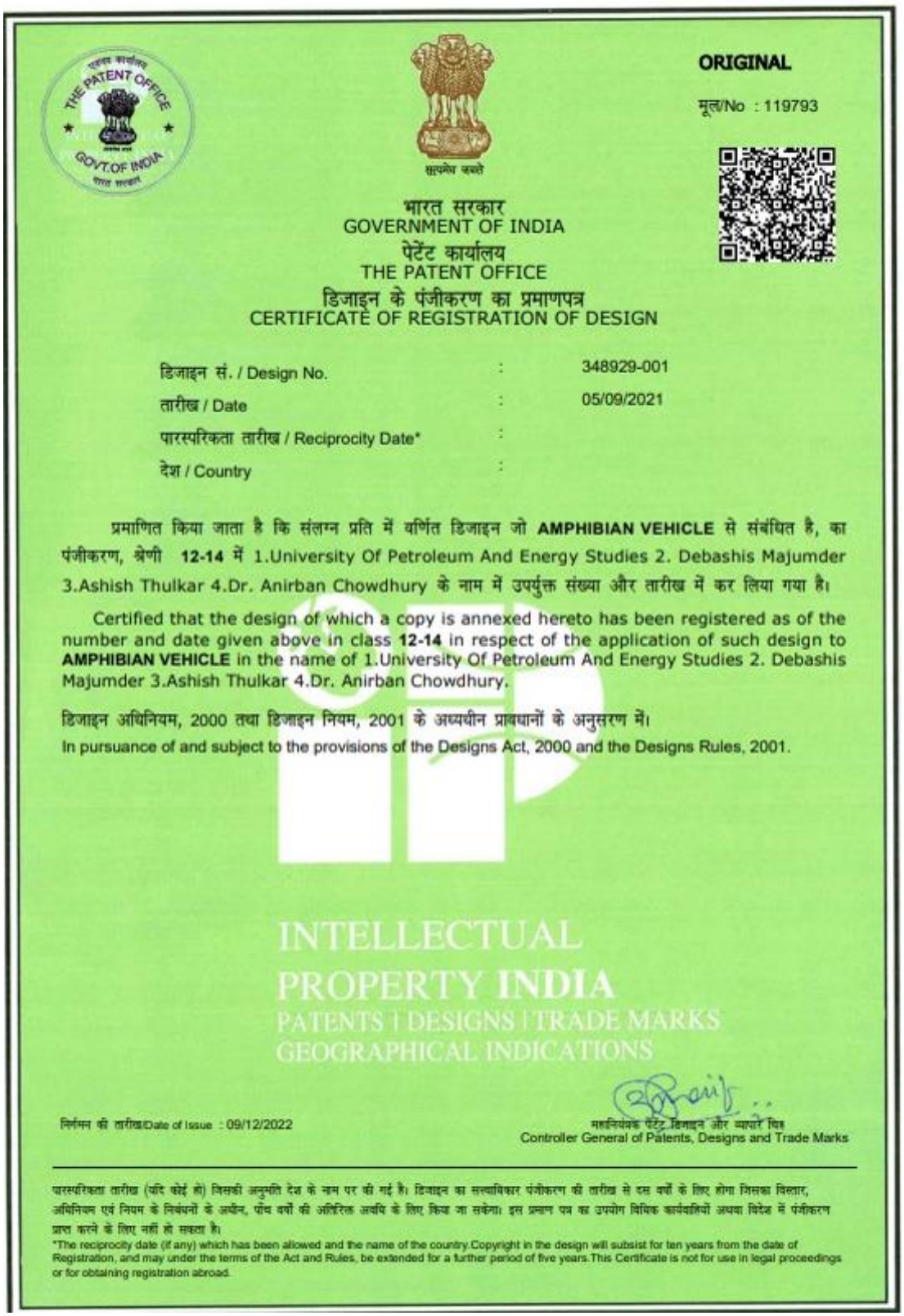
The significant difference is found based on the ANOVA test observed in Exterior and interior design. 12 out of 30 keywords have shown a significant difference. Similarly for AV interior out of 30 keywords only 3 keywords have shown significant difference based on customers' choices. The F value and P values are as below based on ANOVA. The attributes which had p value less than 0.05 were 12 in case of AV Exterior (Dynamic, Beautiful, Engaging, Cheerful, Wonderful, Surprising, Adventurous, Splendid, Graceful, Luxurious, Concurrent, and Exciting). Taking Maximum Mean value difference the 3 keywords were critically identified for exterior design. Engaging (P=0.000409), Adventurous (P= 0.001604) and Luxurious (P=0.008235). Similarly for AV interior design there were 3 key words which had been identified as having maximum mean value difference. The words were `Fluid' (P=0.002935), `Relaxed' (P=0.004991), `Graceful' (P=0.012817). This process shows that users liked these

attributes in the two concepts and the reason of selecting concept1 as final were these 3 attributes in exterior design and 3 keyword in case of interior design. Thus strategizing visual inputs for AV interior and AV exterior makes it more acceptable and selectable for buying by carrying out this exercise. This exercise can be applied for any other vehicle also especially when it is introduced for the first time.

Keywords: Affective Design, Amphibious Vehicle, Amusement

AWARDS & RECOGNITIONS

i. ***Design Registration of Amphibious Vehicle for Amusement purpose.***



ORIGINAL

मूल/No : 119793

सत्यमेव जयते

भारत सरकार
GOVERNMENT OF INDIA
पेटेंट कार्यालय
THE PATENT OFFICE

डिजाइन के पंजीकरण का प्रमाणपत्र
CERTIFICATE OF REGISTRATION OF DESIGN

डिजाइन सं. / Design No.	:	348929-001
तारीख / Date	:	05/09/2021
पारस्परिकता तारीख / Reciprocity Date*	:	
देश / Country	:	

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो **AMPHIBIAN VEHICLE** से संबंधित है, का पंजीकरण, श्रेणी **12-14** में 1.University Of Petroleum And Energy Studies 2. Debashis Majumder 3.Ashish Thulkar 4.Dr. Anirban Chowdhury के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

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In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

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V CONFERENCE PROCEEDING

1) HWWE 2018, 16th International Conference on Humanizing Work and Work Environment
   CET, Trivandrum, Kerala, 14-16 December 2018.

2) ICIPDIMS-19: 1st International Conference on
   Innovative Product Design and Intelligent, Manufacturing System, National Institute of Technology, Rourkela, Rourkela, India, May 17-18, 2019. Got Best Paper Award in industrial design.
3) Doctoral Colloquium- 2019, University of Petroleum and Energy Studies, 24TH May 2019. Got Best Paper Award in industrial design.

4) 17th **HWWE 2019,** NIT **Jalandhar**, Punjab.8-9 November 2019.
5) IPDIMS 2020, Innovative Product Design and Intelligent, Manufacturing System, National Institute of Technology, Rourkela, Rourkela, India, December 2-3, 2020. Got Best Paper Award in industrial design.

6) IPDIMS 2021, Innovative Product Design and Intelligent, Manufacturing System, National Institute of Technology, Rourkela, Rourkela, India, December 30-31, 2021. Got Best Paper Award in industrial design.

CERTIFICATES

IPDIMS 2020

2nd Innovative Product Design and Intelligent Manufacturing Systems

Certificate of Appreciation

This is to certify that the paper titled Design And Evaluation of Speed Forms for Design of An Amphibious Vehicle authored by *Debashis Majumder and Anirban Chowdhury* is selected as *Most Distinguished Paper* at the national conference on 2nd Innovative Product Design and Intelligent Manufacturing Systems (IPDIMS) during 12th & 13th February 2021, jointly organized by Department of Industrial Design and Department of Mechanical Engineering of NIT, Rourkela.

Director, NIT Rourkela | Dean (SRICCE), NIT Rourkela | Prof. D R K Parhi, Convener, IPDIMS'20 | Prof. B B V L Deepak, Chairman, IPDIMS'20

IPDIMS 2021

3rd Innovative Product Design and Intelligent Manufacturing Systems

Certificate of Appreciation

This is to certify that the paper titled Military Patrolling Amphibious Vehicle, A Design Concept authored by *Debashis Majumder, Rohit Kumar, Kushagra Dhall* is selected as *Most Distinguished Paper* at the international conference on 3rd Innovative Product Design and Intelligent Manufacturing Systems (IPDIMS) during 30th & 31st December 2021, jointly organized by Department of Industrial Design and Department of Mechanical Engineering of NIT, Rourkela.

Director, NIT Rourkela | Dean (SRICCE), NIT Rourkela | Prof. D R K Parhi, Chairman, IPDIMS'21 | Prof. B B V L Deepak, Convener, IPDIMS'21

International Conference on
Innovative Product Design and Intelligent Manufacturing Systems

Certificate of Excellence

This is to certify that the paper tiled A Strategy for Ergonomic Design of Amphibian Vehicle authored by Debashis Majumder, R. Anirban Chowdhury awarded with BEST PAPER at the International Conference on Innovative Product Design and Intelligent Manufacturing System (ICIPDMS) during 17-18 May 2019, jointly organized by Dept. of Industrial Design and Dept. of Mechanical Engineering of NIT, Rourkela.

Dr. B. B. V. L Deepak
Chairman, IC-IPDPMS, 2019
HOD, Department of Industrial Design
National Institute of Technology, Rourkela

Dr. Dayal R. Parhi
Convener, IC-IPDPMS, 2019
HOD, Department of Mechanical Engineering
National Institute of Technology, Rourkela

UPES
UNIVERSITY WITH A PURPOSE

2ND DOCTORAL COLLOQUIUM, 2019

May 24, 2019

Organised by University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India

Certificate of Excellence

Best Paper

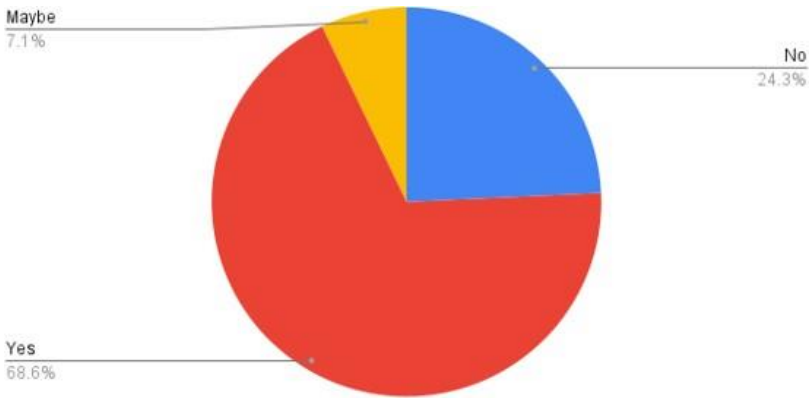
This is presented to Mr./Ms. Debashis Majumdar for being awarded "Best Paper" titled Design Analysis of Amphibian Vehical for recreational Use in the 2nd Doctoral Colloquium, 2019 held on 24th May.

Organising Secretary
Doctoral Colloquium, 2019

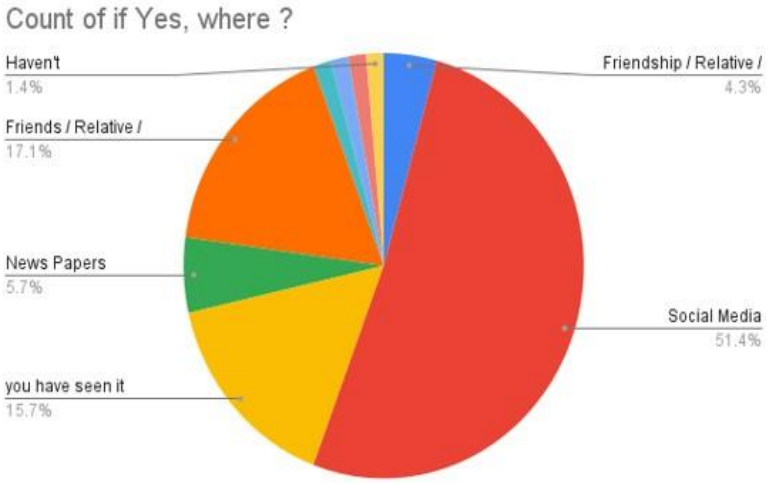
ANNEXURE 1

User Survey Results for Amphibious Vehicle

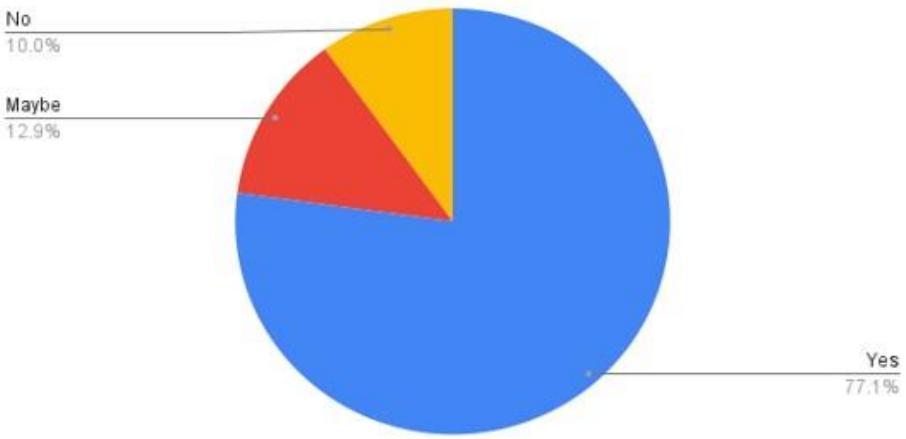
1) Have you ever heard about the term of AMPHIBIOUS VEHICLE before? 73 Respondents



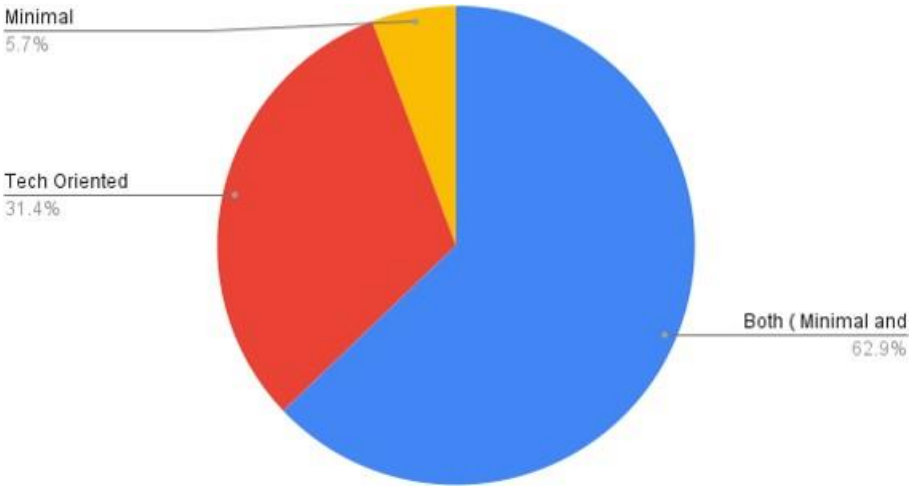
2) if yes, where?



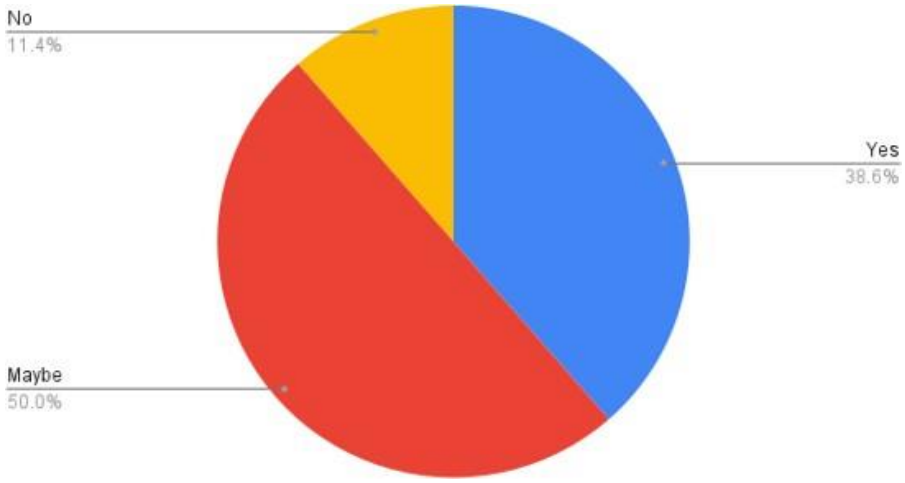
3) Would you like to see this kind of vehicle in near Future?



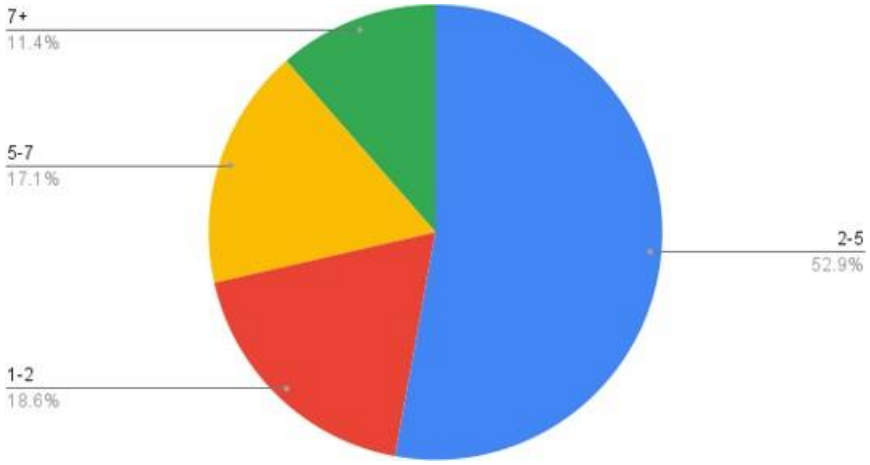
4) Should vehicle be.....



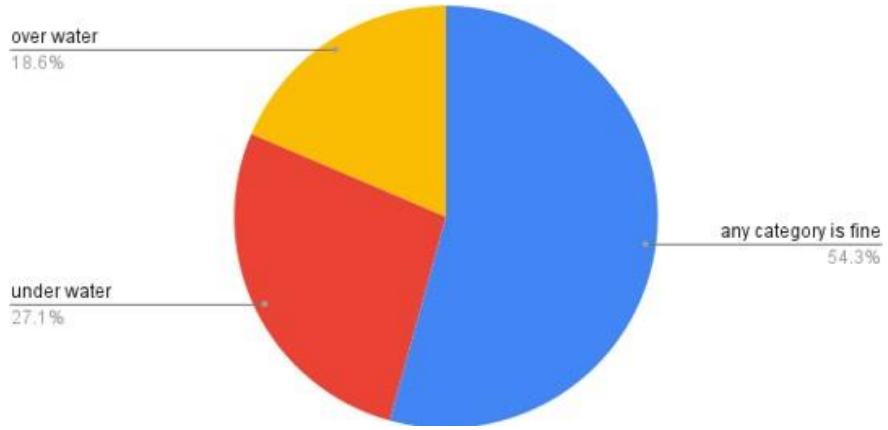
5) Does this kind of vehicle have a future in India?



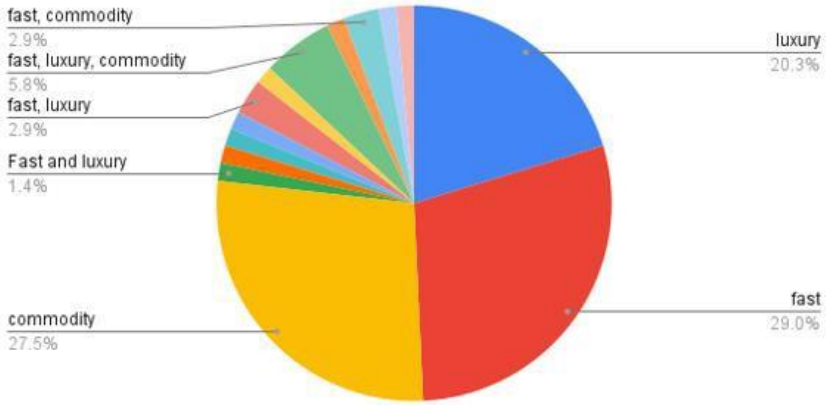
6) How many seater would this vehicle be??



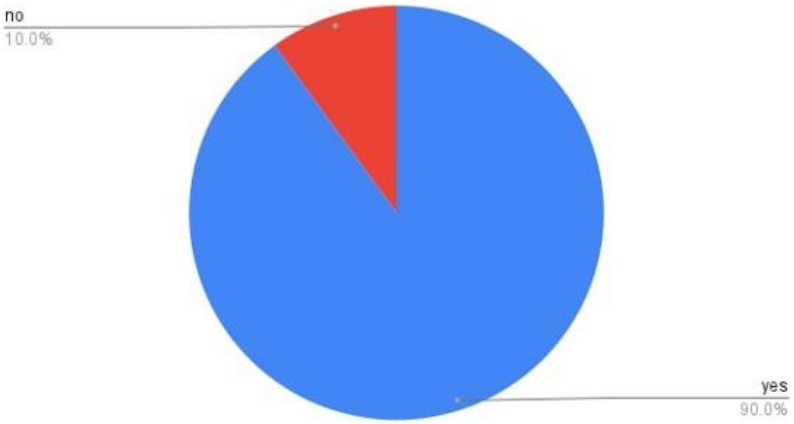
7) Would you prefer under water or over water category of this vehicle?



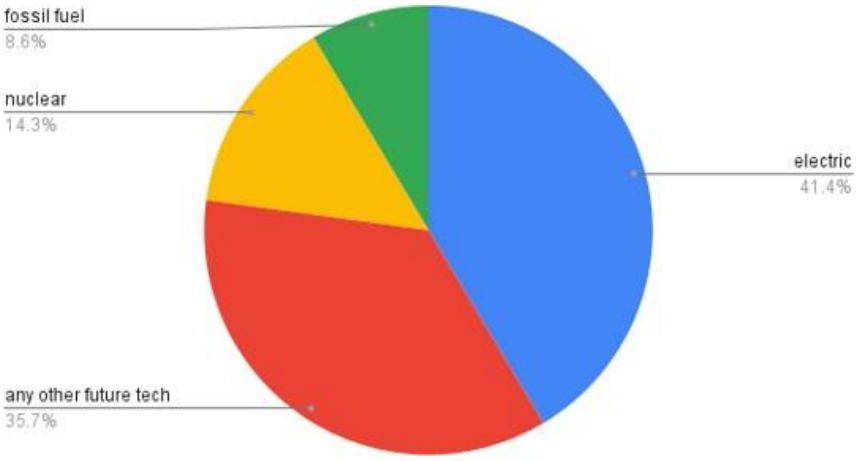
8) What would be preferred characteristics for a future transportation ??



9) Should the vehicle be used for aquatic tourism ??



10) Type of energy this vehicle would be using??



APPENDIX-2

Visual Survey Aesthetic Data Form

Visual Survey Aesthetic Data Form

These are Amphibious Vehicles which means it can go on water as well as run on land. It is electric Amphibious Vehicle.

In order to check its visual aesthetics some 'Visual attributes' are given. You are required to rate these. 1 is poorest, 2 is bad, 3 is fair, 4 is medium, 5 is good, 6 is very good, 7 is excellent.

You have to give visual judgement as how much impressession do these vehicle give aesthetic impression on the following criteria.

		Vehicle 1							Vehicle 2						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
	Attributes														
1	Dynamic														
2	Beautiful														
3	Fluid														
4	Fluidy														
5	Attractive														
6	Delightful														
7	Relaxed														
8	Leisure														
9	Fun														
#	Enjoyable														
11	Interesting														
#	Engaging														
#	Refreshing														
#	Hilarious														
#	Cheerful														
#	Wonderful														
#	Surprising														
#	Explorations														
#	Adventour														
#	Splendid														
#	Estasy														
#	Jeepsy														
#	Graceful														
#	Luxurious														
#	Concurrent														
#	Exciting														
#	Honest														
#	Addictive														
#	Nomadic														
#	Amazing														

Total Variance Explained

APPENDIX 3

Com pone nt	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	T ot al	% of Varianc e	Cumula tive %	Tot al	% of Varianc e
1	23.666	78.888	78.888	23.666	78.888
2	1.155	3.850	82.738	1.155	3.850
3	.911.8	3.035	85.773		
4	43.6	2.809	88.582		
5	47.5	2.155	90.738		
6	87.3	1.958	92.695		
7	51.3	1.170	93.866		
8	09.2	1.029	94.894		
9	24.2	.747	95.642		
10	05.1	.685	96.327		
11	66.1	.553	96.879		
12	40.1	.468	97.348		
13	30.1	.432	97.780		
14	19.1	.396	98.176		
15	00.0	.335	98.510		
16	88.0	.295	98.805		
17	70.0	.232	99.037		
18	56.0	.186	99.223		
19	48	.158	99.381		

20	.041	.135	99.517		
21	.033	.111	99.628		
22	.026	.087	99.715		
23	.023	.078	99.793		
24	.016	.052	99.845		
25	.015	.049	99.893		
26	.013	.045	99.938		
27	.008	.026	99.964		
28	.006	.021	99.985		
29	.004	.012	99.996		
30	.001	.004	100.000		

Total Variance Explained

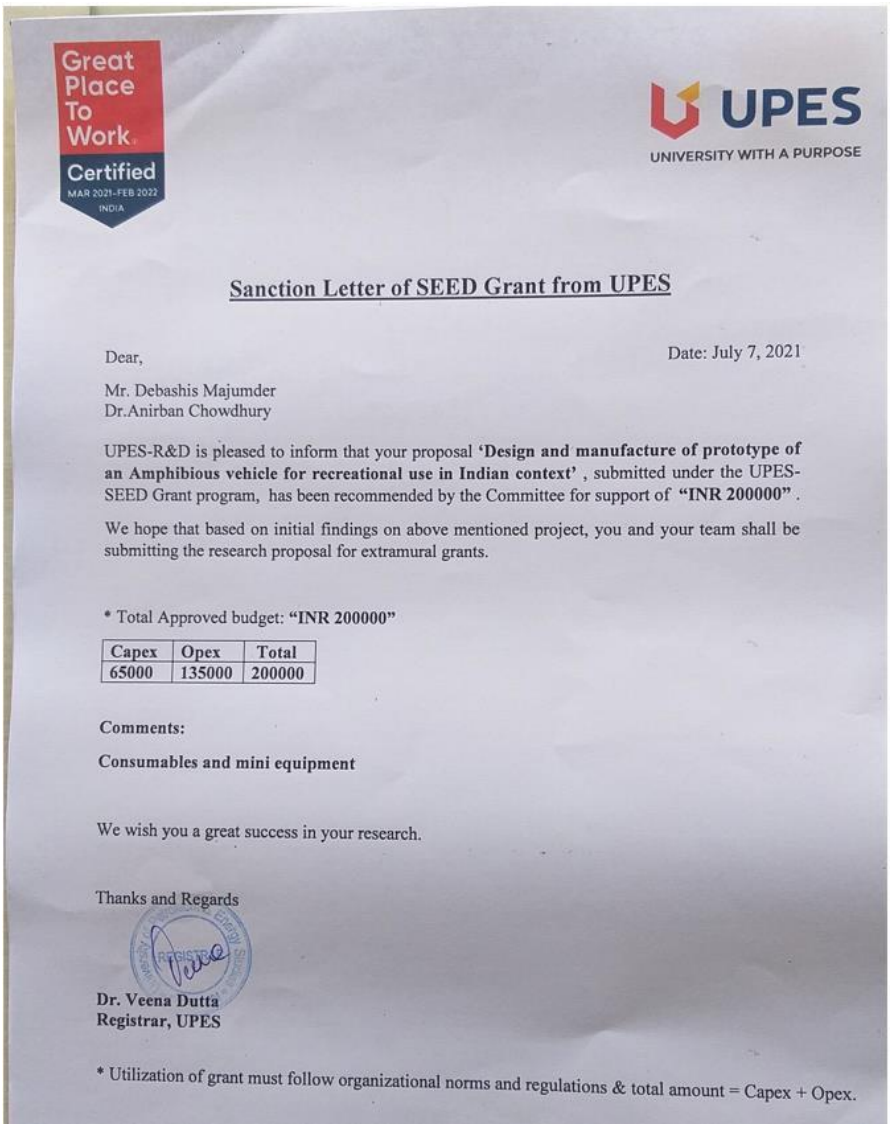
Component	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings		
	Cumulative %	Total	% of Variance	Cumulative %
1	78.888	14.119	47.063	47.063
2	82.738	10.702	35.675	82.738

Inverse of Correlation Matrix

	Pleasant1	Relaxed1	Leaser1	Fun1	Enjoyable1
Dynamic1	-20544.801	1217.879	-25855.766	8526.270	-16228.207
Beautiful1	-78102.848	5044.942	-97863.011	33896.066	-62517.937
Fluid1	37206.904	-2385.339	47700.854	-16094.219	30304.145
Attractive1	39772.171	-2826.537	49328.412	-18062.413	32198.572
Delightful1	-43052.434	2656.289	-54368.419	18220.264	-34317.826
Pleasant1	80538.720	-4885.357	100401.352	-33917.235	63403.905
Relaxed1	-4885.357	428.688	-6069.286	2382.457	-4102.290
Leaser1	100401.352	-6069.286	126711.784	-42227.190	79728.814
Fun1	-33917.235	2382.457	-42227.190	15379.439	-27487.382
Enjoyable1	63403.905	-4102.290	79728.814	-27487.382	50889.265
Interesting1	28070.108	-2027.163	35404.666	-12874.357	23135.870
Engaging1	-139147.461	8744.229	-174581.803	59726.950	-110940.208
Refreshing1	140194.132	-8370.266	176107.731	-58649.335	110727.024
Hilarious1	-10094.792	568.656	-12992.927	4165.721	-8097.395
Cheerful1	-46126.653	2767.697	-58286.014	19400.375	-36660.124
Wonderful1	-83643.185	5270.688	-104153.514	35803.297	-66226.987
Surprising1	134.485	-29.895	212.543	-139.699	179.516
Exploration1	-49083.471	2633.986	-61665.970	19506.896	-38030.187
Adventourous1	27964.910	-1156.566	35933.452	-10006.987	21229.580
Splendid1	22900.617	-1215.746	28379.461	-9044.457	17498.484
Estasy1	64977.444	-4147.982	81530.680	-28144.664	51948.694
Jeepsy1	82910.392	-5187.919	104121.331	-35514.400	66083.979
Graceful1	-30958.362	2002.579	-39355.256	13473.054	-25064.324
Luxurious1	-18502.432	725.990	-23526.255	6554.717	-13856.500
Concurrent1	-30237.865	1981.230	-38311.757	13213.179	-24472.514
Exciting1	-113187.518	6823.558	-142472.229	47600.381	-89745.342
Honest1	-22990.457	1481.905	-29058.830	9976.849	-18543.794
Addictive1	-16989.363	991.436	-21111.018	7037.990	-13204.793
Nomadic1	20784.224	-1232.940	26536.466	-8719.190	16629.421
Amazing1	34890.776	-2292.774	43403.138	-15280.264	27900.912

APPENDIX 4

Seed Fund Project Done on Amphibious Vehicle



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Sanction Letter of SEED Grant from UPES

Dear,

Date: July 7, 2021

Mr. Debashis Majumder
Dr.Anirban Chowdhury

UPES-R&D is pleased to inform that your proposal **'Design and manufacture of prototype of an Amphibious vehicle for recreational use in Indian context'** , submitted under the UPES-SEED Grant program, has been recommended by the Committee for support of **"INR 200000"** .

We hope that based on initial findings on above mentioned project, you and your team shall be submitting the research proposal for extramural grants.

* Total Approved budget: **"INR 200000"**

Capex	Opex	Total
65000	135000	200000

Comments:

Consumables and mini equipment

We wish you a great success in your research.

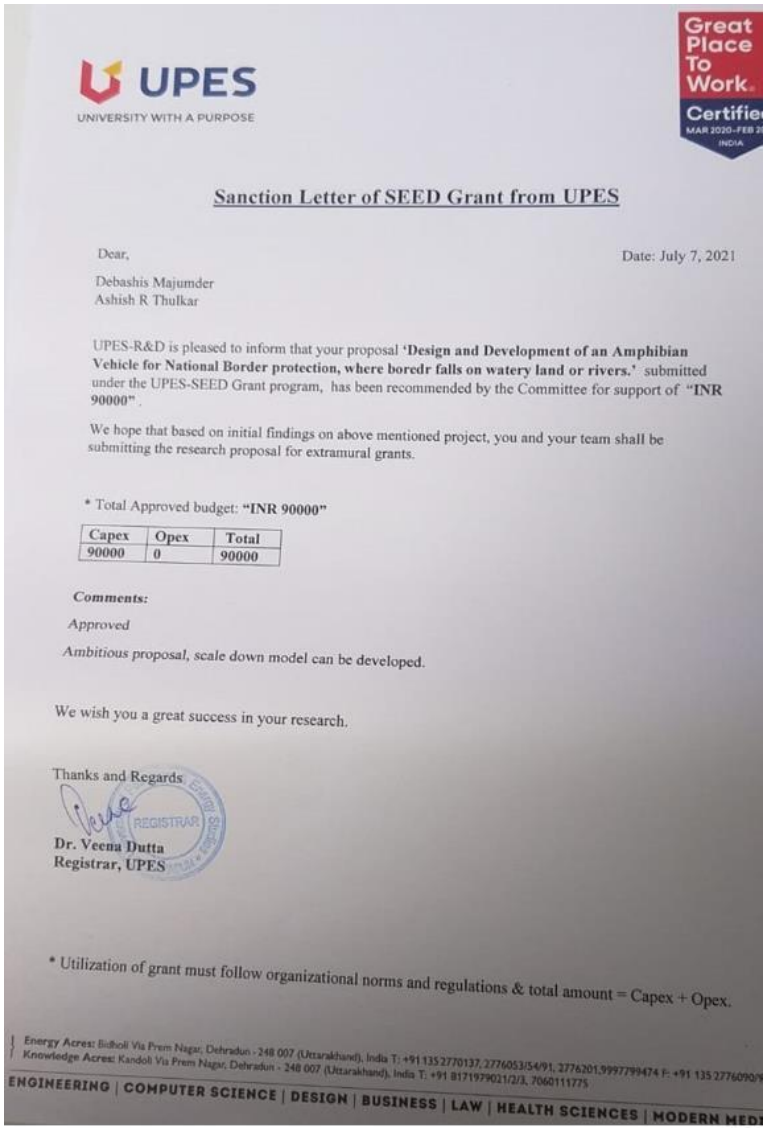
Thanks and Regards

Dr. Veena Dutta
Registrar, UPES

* Utilization of grant must follow organizational norms and regulations & total amount = Capex + Opex.

APPENDIX 5

Seed fund project done on amphibious vehicle for border patrolling applications



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Sanction Letter of SEED Grant from UPES

Dear,

Date: July 7, 2021

Debashis Majumder
Ashish R Thulkar

UPES-R&D is pleased to inform that your proposal **'Design and Development of an Amphibian Vehicle for National Border protection, where boredr falls on watery land or rivers.'** submitted under the UPES-SEED Grant program, has been recommended by the Committee for support of **"INR 90000"**.

We hope that based on initial findings on above mentioned project, you and your team shall be submitting the research proposal for extramural grants.

* Total Approved budget: **"INR 90000"**

Capex	Opex	Total
90000	0	90000

Comments:

Approved

Ambitious proposal, scale down model can be developed.

We wish you a great success in your research.

Thanks and Regards

REGISTRAR

Dr. Veena Dutta
Registrar, UPES

* Utilization of grant must follow organizational norms and regulations & total amount = Capex + Opex.

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Thesis-Debashis-1st March23

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