Design and Development of an Amphibian Ambulance for Riverine Areas

Thesis submitted in partial fulfilment of the requirement for the award of the Degree of

Doctor of Philosophy

By

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March 2018

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Under the supervision of
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CERTIFICATE

This is to certify that the work contained in this thesis entitled **'Design Development of an Amphibian Ambulance for Riverine Areas'** submitted by Mr. Dipanka Boruah to the Indian Institute of Technology Guwahati, Assam (India) for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

Place: Guwahati
Date: 10 March 2018

Prof. Amarendra Kumar Das, PhD
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DECLARATION

I hereby declare that the work contained in this thesis entitled **'Design Development of an Amphibian Ambulance for Riverine Areas'** is my own work done under the supervision of Prof. Amarendra Kumar Das, at the Department of Design, Indian Institute of Technology Guwahati (IITG), Assam. I hereby declare that to the best of my knowledge, it contains no materials previously published or written by another person, or substantial proportion of material which have been accepted for the award of any other degree or diploma at IITG or any other educational institute, except where due acknowledgement is made in this thesis. Any contribution made to the research made by others, with whom I have worked at IITG or elsewhere, is explicitly acknowledged in the thesis. I also hereby declare that the intellectual content of the thesis is the product of my work, and as per general norms of the reporting research findings, due acknowledgements have been made wherever the research findings of other researchers have been cited in the thesis.

Place: Guwahati
Date: 10 March 2018

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DEDICATION

I would like to dedicate this thesis to my family members and people who are living in remote riverine areas in the Brahmaputra valley.

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There are many people who have directly or indirectly contributed to the completion of this research. Before presenting this work in the conscious circle, I would like to take the opportunity to humbly and solemnly acknowledge all of them for their constant support and guidance.

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Last but not the least, I pay my sincere thanks, love, and respect to all who have directly or indirectly helped during my doctoral research work.

Place: Guwahati
Date: 10 March 2018

Dipanka Boruah

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Abstract

Despite rapid urbanisation, majority of the population of Assam inhabit the remote rural areas, and out of this population, 2.5 million people live in the riverine island (popularly known as char- chapari areas in local Assamese language). Many places in riverine areas in Assam are totally inaccessible by road in spite of expanding rural road networks under Pradhan Mantri Gram Sadak Yojana (PMGSY) (Prime Minister's Rural Road Scheme). These riverine islands and many other areas are affected by floods created by the river Brahmaputra and its tributaries in monsoons. As a result, the health services for the people living in these areas are badly affected. To provide health care facilities to the riverine areas, the C-NES (Centre for North East Studies and Policy Research) first developed innovative ideas for implementation to reach the poor and marginalised group by introducing boat based health services called boat clinics. Later, when Government of India introduced NRHM (National Rural Health Mission) to make health services available to the rural population, Government of Assam based on success of boat clinic operated by C-NES, collaborated with it through expansion of boat clinic to make health services available to riverine rural communities in Assam. Although the government expanded boat clinics to cover bigger area, people found it difficult to access these in emergencies, since patients cannot be easily transported by road to these boat clinics in absence of proper road. To bridge this gap requires appropriate ambulances.

An attempt was made to understand the existing scenario of health services in different parts of the country and also globally in under-privileged/ under-developed areas regarding transportation of patients and rural ambulance service. It was found that, in most of the developing countries people need to travel to health care centres by walking or by taking whatever mode of transport is available including buses, rural taxis, private cars, bicycles, animal-drawn carts and local stretchers (Starkey, 2005). To facilitate access to medical services, local communities and transport service providers can work together to plan an appropriate and sustainable transport technology/system. 'eRanger Production' company designed motorbike ambulance for emergency medical services for obstetric care at the district hospital of Masselleh region, Kambia, in the Northern province of Sierra Leone, South Africa which provided an innovative, cost

effective solution to the problem of emergency medical transport in remote areas (www.eranger.com, 25 May, 2011). The present reality is that motorcycles increasingly provide affordable rural transport services. However, this type of transportation is a complicated one for use in riverine areas. Three Canadian students made a stretcher of bamboo called the bambulance stretcher and trailer frame composed of 2-inch diameter bamboo poles, connected with uniform triangular gusset joints. Every day in Africa and the developing world, thousands of people are suffering from HIV/ AIDS, malaria and other serious illness because they have no access to emergency and general health care services (Boruah, 2011). The purpose of this research is to facilitate a solution to provide transport to and from local health centres. Ability to safely and comfortably carry one patient and an outreach medical worker, and emergency supplies for on-site treatment, it can greatly reduce the time taken to get essential and urgent medical assistance to remote communities. To accomplish the stated purpose; a combination of research methods featuring literature survey, questionnaire, direct observation, one to one interview for data collection; statistical analysis of the gathered data, work study technique, prototype development and testing has been used.

After gathering necessary information, it was felt that, for remote riverine areas of Assam, to provide access to rural health care facilities with existing economic situation, road condition and environmental phenomenon, there is a need to design an amphibian ambulance.

The prototype of the proposed amphibian ambulance has been designed and developed as a part of doctoral research in the Department of Design, Indian Institute of Technology Guwahati (IITG). Workshop based prototype of the amphibian ambulance followed by refined field experiments and field trials were carried out at IIT Guwahati campus and Aminagon primary health centre, a location adjacent to IIT Guwahati beside the river Brahmaputra with participatory approach. Through these trials, it was found that the vehicle was an efficient and sustainable solution compared to existing available transportation modes in these places. While the field trials were carried out, it was found that the vehicle was safe for operation from the view of user friendly, comfort, easy access, protection from natural elements and also sustainable for the riverine people, which was a fully amphibian featured and worked both on land and in water.

Thus this research is contextual research endeavour for design development of sustainable amphibian ambulance for riverine people in Assam to be socially responsible in the long run.

This thesis provides various information regarding the aim and objective of the research, human centred design methodology adopted for undertaking the design, results and analysis of the experiments carried out from the point of view of perception of the innovated and developed amphibian ambulance as a sustainable healthcare mode.

Keywords: Riverine areas, healthcare transportation device, product design and development

Table of contents

List of figures

List of flow diagrams

List of tables

Abbreviation used in this thesis

BeRA	Bengali Rural Ambulance
CAD	Computer-Aided Design
CG	Centre of Gravity
CSAD	Cardiff School of Art and Design
CSIR	Council for Science and Industrial Research
DICC	Districts Industries Centre Corporation
DOD	Department of Design
DST	Department of Science and Technology
DT	Design Thinking
FRP	Fibre Reinforced Plastic
GEM	Global Entrepreneurship Monitor
GIAN	Grassroots Innovations Argumentation Network
HCD	Human-Centred Design
HPV	Human Powered Vehicle
IIT	Indian Institute of Technology
IP	Intellectual Property
IPR	Intellectual Property Rights
KTC	Knowledge Transfer Centre
LED	Light-Emitting Diode
MVIF	Micro Venture and Innovation Fund
NCEUS	National Commission for Enterprises in the Unorganized Sector
NGO	Non-Government Organisation
NHM	National Heath Mission
NIF	National Innovation Foundation
NPD	New Product Development
NRHM	National Rural Health Mission
OCED	Organisation for Economic Co-operation and Development
OPD	Out Patient Department

PAC	Patent Assistance Cell
PDR	Product Design and Development Research
PHC	Primary Health Centres
PIC	Prior Informed Consent
PIM	Patient Immobility Monitor
PMGSY	Pradhan Mantri Gram Swarak Yojana
PoP	Plaster of Paris
PPP	Public Private Partnership
PVA	Polyvinyl Alcohol
RPM	Revolutions Per Minute
RRA	Rapid Rural Appraisal
S&T	Science & Technology
SEE	Sharing Experience Europe
SIDBI	Small Industries Development Bank of India
SME	Small and Medium-Sized Enterprises
SRISTI	Society for Research and Initiatives for Sustainable Technologies and Institutions
TBI	Technology Business Incubation
TK	Traditional Knowledge
TSB	Technology Strategy Board
VARD	Value Addition Research and Development
WIN	Wales Innovators Network
WWN	Welsh Wound Network

Chapter 1: Introduction: Health Care Facilities in Riverine Areas of Assam

1.1 Background

India is a developing country and its populations is still growing. Three hundred million people in India still earn less than ₹ 80/- per day (IPFS, 2016). Seventy percent of Indian population is rural and development and deployment of technologies specifically designed for this population group can improve their lifestyles and livelihoods. Most of the efforts for providing basic facility to rural areas have been based on a 'Jugad' approach, using locally available facilities, materials and expertise by the community. There are small adjustments made using low or sometimes appropriate technology. While choosing technological intervention for this type of situation, in contrast to high-tech innovation and development, it is considered that intermediate (Schumacher, 1973) (or appropriate) technologies may be considered effective. Appropriate technology is small scale, energy efficient, low-cost, radical, environmentally sound, labor intensive, and controlled by the local rural community. As Schumacher described it:

> *Such an intermediate technology would be immensely more productive than the indigenous technology…but it would be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry* (Schumacher, 1973, p. 149).

Appropriate technology has been applied as a solution for rural development; it has also gained support as a direction for sustainable technologies. However, it has often been identified as 'cheap' (or 'second hand'), which is carried in modernisation by technological innovation (Vergrapt, 2005). This research deals with health care facilities in riverine areas of Assam, popularly known as *Char*. In this context, in Assam, there are 2251 villages in char (riverine island) areas in which there are only 52 Primary Health Centers (PHCs) and 135 Sub Centers (SCs); the numbers are not sufficient to cover the entire population (www.nrhmassam.in, 10 March 2013). Due to problems created by flood perennially, it is difficult to construct permanent infrastructure in these areas, and people of such areas have to shift their dwellings frequently during flood time.

1.2 Contextual study

A pilot study was carried out to find out shortcomings in the health services rendered to riverine areas so that possible intervention can be initiated. The key findings from this field study carried out in Dhakuakhana sub-division of Assam are split into three linked groups: the places, the people, and the problems. Information recording methods differed between locations. Observations were recorded by the audio-visual medium as well as through interviews of focus groups that facilitated more accurate information. This information was reflected upon and later transcribed, without misinterpretation.

Despite rapid urbanisation, majority of the population of Assam inhabit the remote rural areas, and out of this population, 2.5 million people live in the riverine island (popularly known as char- chapari areas in local language) (Boruah and Das, 2013). Picture below reflects the low-cost housing settlements in the riverine areas [**Figure 1.1**].

Figure 1.1: Traditional house made of bamboos, a local material.
Source of Photograph: Author

Many places in riverine areas in Assam are totally inaccessible by road, and they are shown in **Figure 1.2** in spite of expanding rural road networks under Pradhan Mantri Gram Swarak Yojana (PMGSY) (Prime Minister's Rural Road Scheme). These riverine islands and many other areas are affected by the floods created by the river Brahmaputra and its tributaries during the monsoons [**Figure 1.3**].

Figure 1.2: Bamboo bridge connects between two places.
Source of Photograph: Author

Figure 1.3: Flood affected people move towards high land on a banana raft from their submerged house.
(www.skymetweather.com, 23 September 2014).

Figure 1.4: 30 bedded PHC in semi- urban areas.
Source of Photograph: Author

As a result, the health services of the people living in these areas are badly affected. Although, Government provides one 30 bedded PHC [**Figure 1.4**] and sub- centres [**Figure 1.5**] in semi-urban areas in Dhakuakhana subdivision but patients cannot reach in time due to lack of proper transportation facility from riverine island to semi-urban areas.

Figure 1.5: Sub- Centre in semi- urban areas.
Source of Photograph: Author

To provide health care facilities to the riverine areas, the Centre for North East Studies and Policy Research (C-NES) first developed innovative ideas for implementation to reach the poor and marginalised group by introducing boat based health services called boat clinics. Later, when Government of India introduced National Rural Health Mission (NRHM) to make health services available to the rural population, Government of Assam based on the success of boat clinic operated by C-NES, collaborated with it to expand boat clinic to make health services available to riverine rural communities in Assam. This has resulted into spreading of boat clinic programme to thirteen districts is shown in **Figure 1.7**. The first boat clinic of C-NES was Shahnaz, its first official trial was made from Nagaghuli ghat, Dibrugarh district, Assam on 28th December 2006 is shown in **Figure 1.8.** Although the government expanded boat clinics, people found it difficult to access them in emergencies, since patients cannot be transported by road to these boat clinics [**Figure 1.11**]. The most common practice in riverine areas is that a patient is wrapped up with clothes to be carried by a strong person to the health centres. On several occasions, patients are also found to be transported in a handcart. Even in this case, where there are small water bodies without a bridge, it becomes impossible to cross. Therefore, patients, in many cases, never reach the health centres in time. Designing for the underprivileged section of the society is one of the basic requirements for indigenous design in

Assam, India. This research is an attempt towards developing the current practice for meeting the local transportation needs of the poor population of a remote area for accessing health facilities. The solution to this type of problem can lead to a better health care system for the rural area. Design is increasingly being viewed as a critical and enabling component for sustainability because the design function is a converging point for decisions regarding a large set of human and materials flows.

Research methodology for the application of the process of human- centred design that draws upon Design Thinking for the design and development of healthcare transportation system in riverine areas in Assam is adopted. From the contextual study, questions were formulated in order to define and delineate the research problem clearly.

1.3 Shortcomings of existing health Care facilities in riverine areas

The study was carried out by an interdisciplinary team for studying the existing healthcare facilities in riverine areas of the Brahmaputra valley. The research team consisted of medical professionals, industrial designers, anthropologist and persons with commerce backgrounds.

The study was carried out into four key stages:

i. An initial 12-day field study in riverine areas of Assam [**Figure 1.6**]. Those areas are covered by boat clinics and the team visited: (a) Silapathar in Dhemaji district, (b) a few areas in Lakhimpur district and (c) Majuli district to conduct rapid ethnography.

ii. Three members of the team together spent time in three locations; one medical officer, one physical anthropologist and a social worker from the study site. These three locations have varying degrees of healthcare facilities, social amenities, cultural differences and local transportation.

iii. The findings from Stages (i- ii) were used to facilitate idea generation. The team followed an iterative design process.

iv. After brainstorming, the most appropriate solutions derived from Stage-3 were developed and different concept articulated to facilitate user feedback from local people and compared with entire rural scenario.

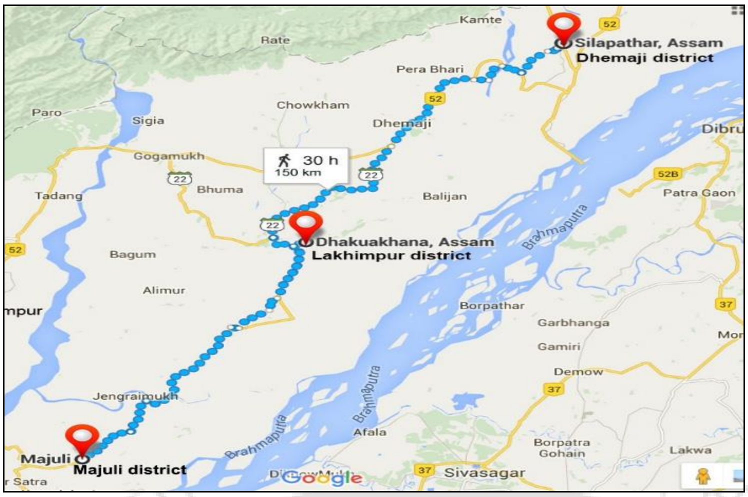


Figure 1.6: Pilot study locations of riverine areas Silapathar, Dhakuakhana and Majuli. (Google map, 2015)

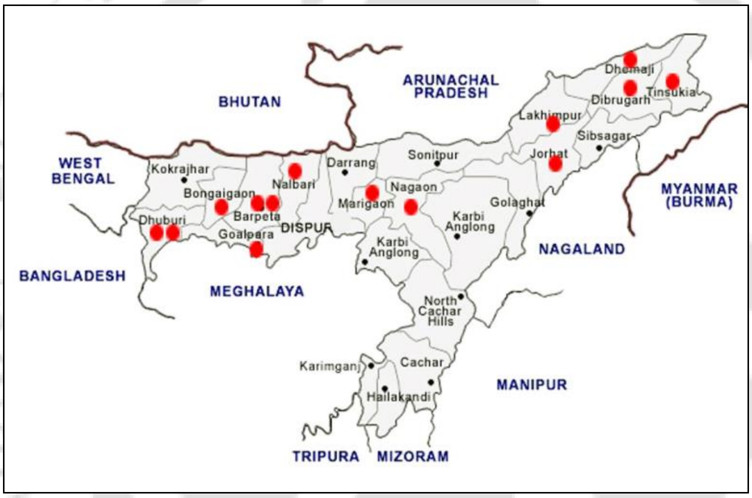


Figure 1.7: Operational locations of C- NES boat clinic. (C-NES, 2013)

Figure 1.8: Shahnaz - the first boat anchored at Simen Chapari, Dhemaji. Source of Photograph: Author

Figure 1.9: Boat crew carrying bundles of medicine. (C-NES, 2015)

Figure 1.10: Locally called Fighter boats used to reach riverine areas for medical camp.
Source of Photograph: Author

Figure 1.11: Way to a riverine village and road condition.
Source of Photograph: Author

In the first stage of the data collection, team members used Ethnography research method. The study was split into three stages: preparation, participation and reflection.

Preparation: Team members shared the experiences among group members to ensure all proposed objectives of the study. It also enabled the sharing of different factors such as cultural anthropology, socio- technical and geographical problems from people living in the rural areas.

Participation: This part of the ethnographic study involved groups of local people, activities from National Rural Heath Mission (NHM), doctors, pharmacists, social workers and farmers.

Reflection: The team members sat together to reflect on the field trip's findings and discussed possible routes of exploration.

1.4 Existing facilities of healthcare treatment at boat clinic

(a): Medical team organises the temporary treatment camp.

(b): Children and women queue at the treatment camp.

(c): Doctor checking a patient's blood pressure.

(d): Delivery of health services are organised by C-NES.

Figure 1.12: Boat clinic providing healthcare in riverine areas in Assam
Source of Photographs: Author

Presently health care services to the people of the char (riverine) areas are provided through health camps [**Figure 1.12**] where sites selected are based on work plan developed by the C- NES. Till now, in the absence of fully functioning permanent health care facilities, this system is found to be appropriate. During winter season, the boat clinic cannot reach the targeted riverine villages on the bank of river Brahmaputra to provide healthcare by the medical team.

1.5 Shortcomings of the existing transportation facilities

During the winter season, the boat clinic cannot reach the targeted riverine villages in the Brahmaputra valley and in that situation the medical team is required to reach the village. It is observed that the medical team uses a variety of methods to reach the target villages that include fighter boats [**Figure 1.10**], bullock carts [**Figure 1.3 (a)**, **Figure 1.3 (c)**], horse drawn carts [**Figure 1.3 (b)**] and they also use power tiller [**Figure 1.3 (d)**] to transport supplies.

(a): Clinic team in a bullock cart to a health care camp.

(b): Horse cart is an alternative arrangement to cover such a long distance.

(c): Bullock cart used for conducting health camps.

(d): Power tiller carrier used for delivering medicine at a boat clinic.

Figure 1.13: Existing transportation facilities in the winter season.
Source of Photographs: Author

1.6 Motivation from the contextual study

There is an endeavour to understand the existing scenario of health services in different parts of the country and also globally in under-privileged/ under-developed areas in terms of transportation of patients by rural ambulance services. This process can give a lot of clues about innovative design and development of appropriate technology of an amphibious ambulance suitable for local use, especially to facilitate patient transportation of rural riverine areas. Rural ambulance services are very rare or almost non-existent in rural areas. People travel to health care centres on foot or taking whatever transport mode is found available including buses, rural taxis, private cars, bicycles, animal-drawn carts and local stretchers (Starkey, 2005). To facilitate access of medical services, local communities and transporters can work together to plan an appropriate and sustainable transport technology/system. 'eRanger Production' company designed motorbike ambulance [**Figure 2.1 (j)**] for emergency medical services for obstetric care at the district hospital of Masselleh region, Kambia (South Africa) which provided an innovative, cost effective solution to the problem of emergency medical transport in remote areas (eRanger, 2008). At present, the reality is that motorcycles increasingly provide affordable rural transport services. This type of transportation is a complicated one for use in riverine areas. Three Canadian students made a stretcher out of bamboo and called it the bambulance. This stretcher and trailer frame are composed of 2-inch diameter bamboo poles, connected with uniform triangular gusset joints [**Figure 2.1(e)**]. Every day in Africa and the developing world, thousands of people have been suffering from HIV/ AIDS, malaria and other serious illness because they have no access to emergency and general health care services (Boruah, 2011). Literature survey of various factors associated with a human powered amphibious vehicle and their effect was carried out. The ambulance needs to be developed to provide transport to and from local health-centres, providing communities with the means to take advantage of distant and widespread health-care resources. Ability to safely and comfortably carry one patient and outreach medical worker, plus emergency supplies for on-site treatment, can greatly reduce the time taken to provide essential and urgent medical assistance to remote communities.

It is evident that a design can be initiated out with the view that it will be viable and socially acceptable using appropriate technology and having a consideration for sustainability. To conclude, specific to the target area, *to facilitate the access to rural health care facilities with existing economic situation, road condition and environmental phenomenon, there is a need to design an amphibian ambulance.* This can change people's perception regarding this kind of products as well as initiate philosophical change in society's attitude.

1.7 Research questions (RQ)

Research questions:

- **RQ1:** What is the product to be designed in order to meet the specific needs of people living in riverine areas better way?
- **RQ2:** How can an innovation be transferred to NGO as a commercialised product with the collaboration of academic institutions like Indian Institute of Technology (IIT)s.

1.8 Hypothesis (H)

- **H1:** If an appropriate transportation is designed for riverine areas in Assam, it can facilitate delivery of healthcare services.
- **H2:** Guidelines drawn from study of support for innovation in India and western countries, may facilitate effectively for the introduction and sustainability of a designed product.

1.9 Aim and objectives

Aim:

The aim of this study is to design and develop an appropriate transport product for providing a better access to healthcare services to the population living in the rural riverine area in Assam.

The overall objectives of the present research are:

- To study existing health care delivery system in the riverine areas of the Brahmaputra valley.

- To design a rural transportation system in order to meet the specific needs of people living in riverine areas based on the above study that can provide transport both on land and water, specifically an amphibian one.
- To study the process of new product development (NPD) being innovated, designed and manufactured in an Indian context considering support for innovation in India and Wales, UK.

1.10 Methods of the study (Methodology)

The research method adopted is Design Research. Design research is an approach which combines scholarly investigations into the phenomena of the various fields of design, including architecture, visual design and industrial design- an underlying objective being the development of new knowledge and original artifacts (Bonollo *et al.,* 2014). Research may be defined as an activity that contributes to the understanding of a phenomenon (Vaishnavi *et al.*, 1996). British educationist, Christopher Frayling (1993) suggested that research in the art and design field could be classified as: 1) Research *'into'* art and design, 2) Research *'through'* art and design, and 3) Research *'for'* art and design. However, research through design practice is in the present time widely accepted. As Linda Candy (2006) defined two types of research practice as 'Practice-based practice' and 'Practice-led research'. If the research is creative artefact undertaken in order to contribute new knowledge it is called as Practice based research. On the other hand, if the research 'leads' primarily to new understanding about the design practice it is called as practice- led design. The question raised in the abstract: Can design be research? The answer to this question of whether or not design is a valid research technique has been a resounding 'yes' for many years.

The research focuses on the need of the flood affected, riverine population in remote areas in the Indian context. Also, it focuses on small enterprises, in many cases tiny enterprises for their manufacturing. In this case, Brown (2009), of IDEO (an international design and consultancy firm in California) argues on how to design for change, what needs a new idea and products capable of tackling the global challenges of health, poverty and education for developing countries like India. His proposal is Design Thinking- an exploratory, iterative and nonlinear process, based upon Human-Centred Design (HCD). HCD as defined by IDEO in 2009, is a process that starts with the people they want to affect with their solution. The process starts with the acceptance of competing constraints, and three stages are shown in **Figure 1.14**: Desirability is *what is desirable from a user perspective?* Feasibility is *what is technology and organisationally feasible?* And Viability is *what can be financially viable from organisational perspective?* (Watkins *et al.*, 2014).

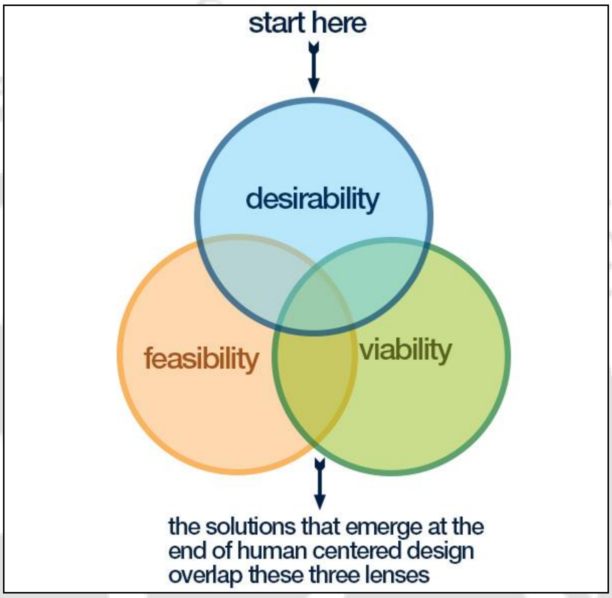


Figure 1.14: Basic stages of Human- Centred Design (Brown, 2009).

In this process of Design Thinking is combined the use of what Brown calls 'smart teams', 'interdisciplinary teams'. In 2009, IDEO developed a toolkit for researchers to help them understand community needs through HCD. This uses interdisciplinary teams combining three elements: hear, create, and deliver. 'Hear' involves qualitative research methods to listen with the aim of identifying users' needs, hopes and aspirations. These are analysed to ensure technical and organisational feasibility and financial viability. 'Create' involves iteratively translating what was heard into frameworks, opportunities, solutions and prototypes. 'Deliver' involves rapid cost modelling and implementation planning ready for product launch.

Ethnography is the main method researchers use to enable the process of HCD and 'listening' demonstrated in Design Thinking and RRA. Ethnography (Oxford

Dictionary, 2011) is the study of 'humankind, patterns of values, behaviour, beliefs, and language of a culture, society and custom'. Mack *et al.* described (2005) ethnography is as 'meaningful and culturally silent to the participant, unanticipated by the researcher, and rich and explanatory in nature.' Ethnography provides researchers/ designers with a deeper understanding of the needs and environmental conditions of people living in developing countries. The objectives of the ethnography are:

- Ethnographic research is the observation of 'groups of people or a culture and their natural setting.
- Observations are the main form of data collection, but interviews are used to clarify the researcher's observations.
- The researcher pays attention to the context, artifacts, and environments of the subjects in addition to their interactions with each other.
- Ethnographies are long-term studies. This allows the researcher to experience the regular patterns and routines of the community of study, as well as seeing how it responds to new or different situations.

The ethnographic research methods adopted for this study include: observation, interviews, focus groups, discussions and user involvement. These methods were supported by a small toolkit to capture the required information: a camera, video recorder, note pad, and audio recorder. The study was split into three stages: preparation, participation and reflection.

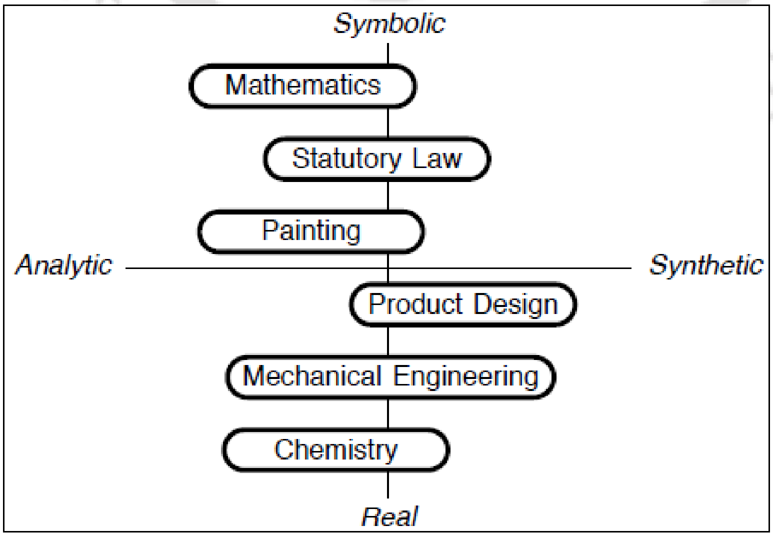


Figure 1.15: A map of design disciplines (Owen, 1997).

As a context for thinking about specialised knowledge acquisition and use, a map of disciplines reveals interesting differences among traditional fields of study and practice and two axes define in **Figure 1.15**. Dividing the map equally into two parts i.e. one is analytical and the other is Synthetics axis, discipline positioned to the left of centre are more concerned with 'finding' or discovering; disciplines to the right are more oriented towards 'making' and inventing. A symbolic/ real axis divides the map again into halves- vertically this time, according to the nature of the subjects of interest. Discipline in the upper half of the map is more concerned with the abstract world and the artefacts and systems that enables us to operate in the physical, environment, that is not always friendly.

The design discipline of the multi- paradigmatic discipline lies predominantly on the synthetic side of the map. Design discipline from the ancient times has a history of building their knowledge base through making- the construction of artefacts and evaluation of the performance after its construction i.e. that can be cited in architecture. It is a strongly construction- oriented discipline with a history extending over thousands of years. Its knowledge base consists of a pool of structural designs that effectively encourage the wide variety of human activities. This has been accumulated largely through the post- hoc observation of successful constructions (Alexander, 1964). Aeronautical engineering is another discipline that provides a more recent example. Its knowledge base built almost exclusively by analysing from the Montgolfier balloon onwards was made during the period of First World War.

As depicted in **Figure 1.16**, a general model for generating and accumulating knowledge presented by Owen is helpful in understanding design discipline and the design research process.

> *Knowledge is generated and accumulated through action. Doing something and judging the results is the general model- the process is shown as a cycle in which knowledge is used to create works, and works are evaluated to build knowledge* (Owen, 1997, p. 37).

The general model of generating and accumulating knowledge **(Figure 1.16)** is defined as a model that fits the dual nature of actions suggested by the analytic/synthetic dimension of the map of design disciplines (**Figure 1.15**). Knowledge building through construction is sometimes considered to lack rigor. However, the process is not unstructured. In the diagram of the general model, the channels are the system of conventions and rules under which the discipline operates. Channels embody the measure and values that have been empirically developed as ways of knowing as the discipline has matured. They may borrow or emulate aspects of channels from other disciplines. However, they are special to the discipline and are products of its evaluation.

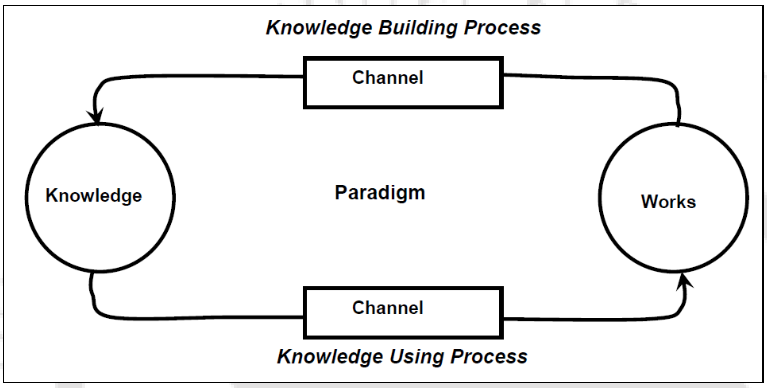


Figure 1.16: A general model for generating and accumulating knowledge (Owen, 1997).

A generic model of the Research Process (Figure 1.17)

- First phase which is 'problem formulation', is about formulating research problem, research questions including research proposal, problem statement, aims and objectives, research gaps, hypothesis, overall plan, literature review, state of art with summery and findings.
- Second phase is 'theoretical development', which is concerned with conceptualising, theory building and modelling, based on the findings of the literature reviews. This phase also includes formulating a plan to conduct the experimental programme or fieldwork using appropriate methods that are required for developing the experimental programme.
- Third phase is 'experimental programme' where the experimental work is conducted based on phase- 2.
- Fourth phase is 'research result' that constructs final theory, modelling and validation based on data collection in phase-3.

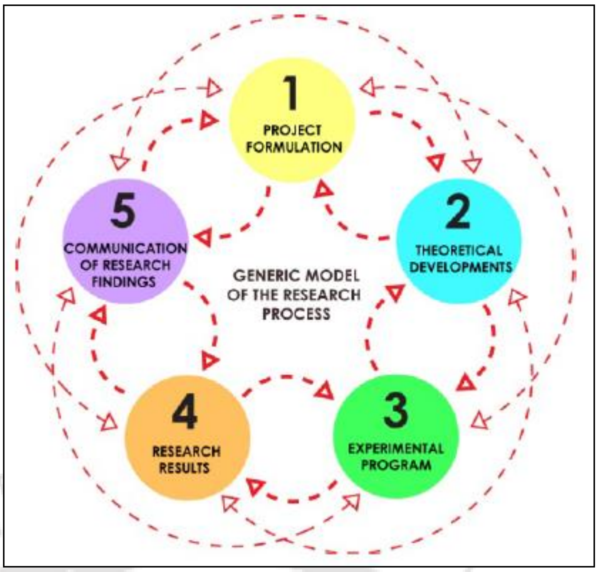


Figure 1.17: Generic models of the research process (Bonollo and Hoyos, 2014).

Finally, the phase 'communication of research finding' is connected with disseminating the findings and conclusions of the research, which includes documenting the contribution to new knowledge.

A generic model of the Design Process

Lewis and Bonollo emphasise five phases of design process shown in **Figure 1.18** and stated its design process in **Table 1.1**.

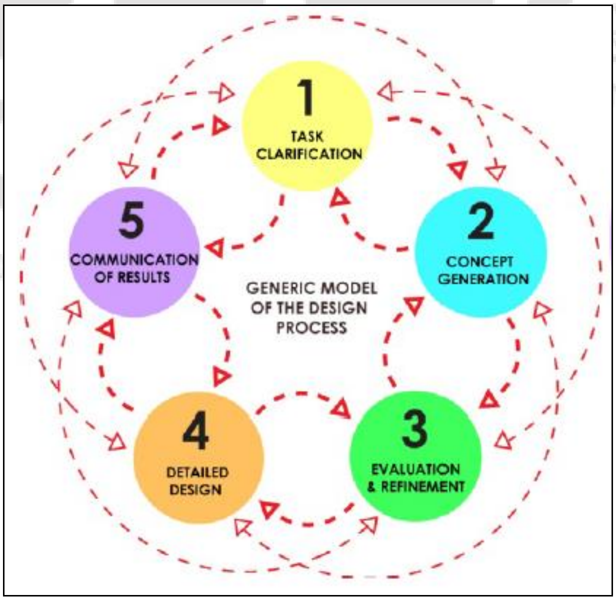


Figure 1.18: Typical 5-phase generic model of the design process (Bonollo and Hoyos, 2014).

The global market is becoming increasingly competitive. It has become necessary to integrate design into the concept-to-market process and encourage designers to participate in decision-making for product planning and positioning. While one considers the underdeveloped or developing countries, above considerations need to be modified in the local context and cultural perspective.

Table 1.1: Generic model of the design process.

Sl.	Subordinate process	Nature of process	Output from process
1.	Task clarification	A set of tasks including negotiating a design brief with the client, setting objectives, planning and scheduling subsequent tasks, preparing time and cost estimates	Design brief, including design specification, project plan with time line and cost estimates
2.	Concept generation	A set of creative tasks aimed at generating a wide range of concepts as potential solutions to the design problem specified in the brief	A folio of concept sketches, supported by simple models or mock ups, providing a visual representation of design ideas
3.	Evaluation and refinement	A set of analytical tasks in which the concepts in (2) are evaluated and reduced to a small number of refined solutions usually only one or two candidates solutions	A folio of refined concept sketches, supported by models and technical, information as required and illustrating the preferred concepts
4.	Detailed design of proffered concept	A set of tasks aimed at developing and validating the preferred concept, including layout drawings, dimensional specifications, selection of materials finishes, indicative tolerances	A folio of layout and detailed component drawings, supported by a technical report giving preliminary manufacturing information.
5.	Communication of results	A set of tasks whereby the concept detailed in (4) is communicated to the client via appropriate two- and three-dimensional media and written report	A folio of presentation drawings including technical drawings from (4) and supported by a refined three dimensional model or prototype

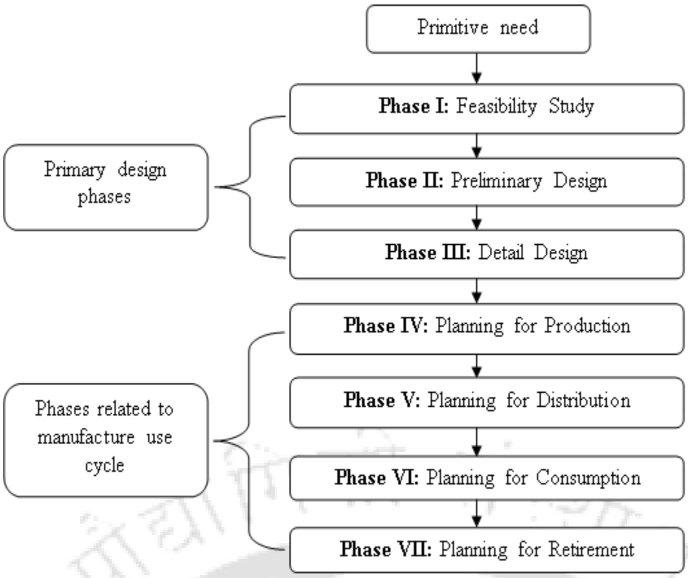
A new product begins as an idea or a concept and product developers are interested in lean product development to get products faster and at a lower cost to the market (Boruah and Das, 2012). The constant change in markets and technology require companies to meet new challenges. Developing new products and improving existing products forms an important step in meeting this challenge. However, this set of knowledge base may not be able to satisfy contextual situation and design students from underdeveloped and developing countries have to understand the stark context of the use of their product.

Human-Centred Design is a creative approach to solve the problems that starts with people and ends with innovative solutions. The process begins with three key points by examining the needs, dreams and behaviors of the people. Desirability is what people desires, sense or activities for people. Feasibility is what is functionally feasible and viability is what can be financially viable.

Design, etymologically and linguistically, comprises a wide varieties of meanings that are tough to specialise in a generic definition. However, there are numerous definitions addressing ‘design’ from very different views. A design includes drawing, instructions or model that contain all the data for the manufacture of a product or the introduction of a process or system. Design means "to invent and bring to being" (Webster's Dictionary and Thesaurus, 1992). Design deals with making one thing new that will not exist in nature. The design artefacts are unit associated activity needed for hundreds of years by humanity. This activity also distinguishes the professions from the science. Designer Richard Seymour (2002) mentioned it in style in Design Council's Design in Business Week, UK, Design is 'making things better for people'.

For design process of the tentative amphibian ambulance, Design morphology by Morris Asimow was followed. As mentioned in the **Flow diagram 1.1**, in morphology of design process there must be a primitive need to start design process. In the first phase, Feasibility study, actual feasibility of design development of an amphibian ambulance was carried out.

The research work carried out is described in the same sequence as the morphology of design with all the iterative steps followed as and when necessary. This is primarily to facilitate the presentation works smoothly and appropriately. **Figure 1.19** shows production- consumption cycle of a product. While designing a product consideration of Production- consumption cycle is important.



Flow diagram 1.1: Morphology of design process (Asimow, 1962).

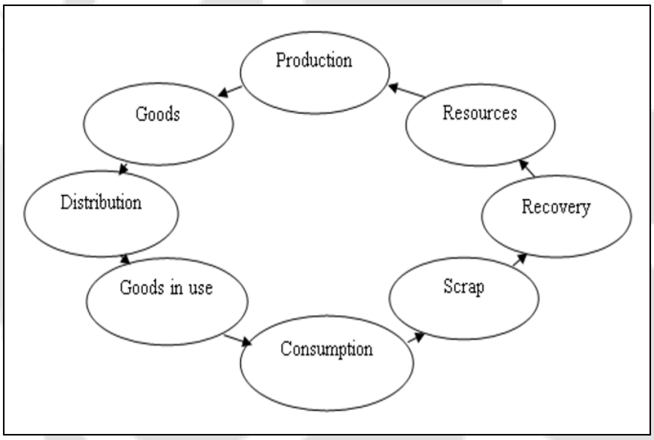


Figure 1.19: Production – consumption cycle (Chitale and Gupta, 2013).

1.11 Structure of the thesis

The thesis contains 7 chapters and is structured into the following chapters:

Chapter 1 titled *Introduction: Health Care Facilities in Riverine Areas of Assam.* The introduction deals with rural health care facilities available in the context of the study, i.e. riverine areas in the Brahmaputra valley. It also deals with the Aim and Objectives of the research.

Chapter 2 titled *Design Development of an appropriate Ambulance: Issues and Contextual Relevance*, contains discussion regarding traditional transportation system in rural India as well as the existing intermediate ambulance in global situation. It briefly describes the history of different types of human powered vehicle such as bicycle, tricycle, tandem cycle with structural layout. The chapter covers status and associated factors relevant to the Indian cultural context.

Chapter 3 titled *Conceptual Design of an Amphibian Ambulance* covers design and development brief for amphibian ambulance, feasibility study, identification and formulation of the design problem, different concepts and evaluation. Also it deals with preliminary design with testing of mathematical model and validation of the design concept.

Chapter 4 titled *Detailed Design, Prototyping and Testing of the Amphibian Ambulance*, describes the detailed design process for selected concept of the newly designed and developed amphibian ambulance. Also it covers various prototyping phases and field trials on land and in water and redesigning of the parts based on user feedbacks.

Chapter 5 titled *Product Test Programme, Data Collection and Analysis*, covers experimental set up and preparation of questionnaires. Describes operational testing of the prototype through actual field trial on land and in water and also describes validation of the design and research hypothesis through the results of field trials. Statistical analysis of data collected in the experiments and discussion on the field experiments and the methodology adopted are described in details.

Chapter 6 titled *Institutionalisation of innovation*, covers contextual guidelines for support to innovators between two countries viz. India and Wales and compares and contrasts grassroots innovations are supported in a developing country such as India with how the support is offered in Wales, UK.

Chapter 7 titled *Discussion, Conclusion and Recommendation*, describes the finding of the research, contribution and limitations of the current research. Describes the future scopes of work for the development of the concept and its greater application. Also mentions recommendation for the application of the finding of the research in the remote riverine areas in the Brahmaputra valley.

1.12 Contribution of the present research

The research can contribute to the knowledge in the area of contextual design and possible design and technology transfer of the amphibian ambulance to the market planned in Indian context, specifically considering the rural riverine areas in Assam.

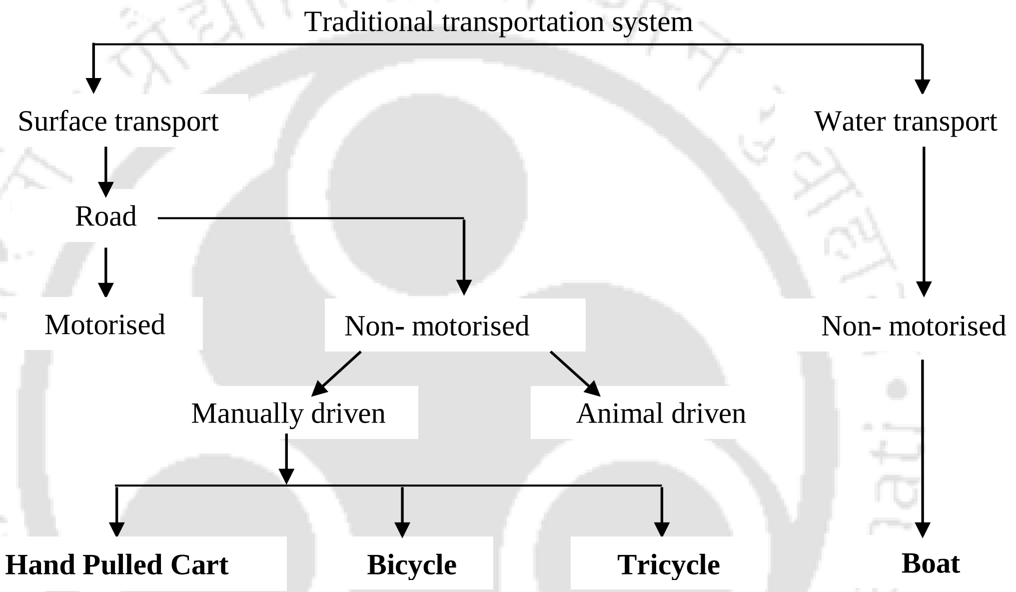
The outcome of the research provides a solution to improve the current transportation system in remote riverine areas in Assam for accessing health care services. As mentioned earlier, context specific design and development of an innovative product is the best possible way to solve the problem of accessibility to health care services in rural riverine areas where proper road network does not exist. The newly designed and developed amphibian ambulance branded as *Dola* was prototyped and its manufacturing system management was evolved in the Department of Design, IIT Guwahati with participation from M/s Dipon Design Pvt. Ltd., a start-up under Technology Incubation Centre under IIT Guwahati located at North Guwahati, Assam. The *Dola,* amphibian ambulance can be manufactured easily since the whole design development has been done through participatory approach. C-NES and one more NGO have shown interest to introduce the amphibian ambulance which is ready for the production and use in the riverine areas of Assam.

Considering emergency care can make an important contribution to reducing avoidable death and disability in low-income groups in developing countries, the designed and developed amphibian ambulance can play a very significant role. With better planning and co-ordination with boat clinics etc., within the present cost incurred for emergency care at present can achieve higher outcomes. The type of research can lead to filling up the gaps in accessing health care facilities in target areas including emergency care.

Chapter 2: Design Development of Ambulance: Issues and Contextual Relevance

2.1 Traditional transportation system in rural India

Transportation plays an important role in the sustainable economic growth of a country. In the earlier days, palanquins or palkee or dola were popular means of transport for women of all social stratum. Traditional transportation system can be classified as:



Flow diagram 2.1: Traditional transportation system in rural India.

In the above flow diagram, branching of surface transport is only shown up to hand-pulled cart, bicycle, tricycle and boat that are relevant to the area of research. The traditional transportation scenario of rural India inaccessible by motorised modes of transportation comprised of followings:

- Walking
- Bullock carts and horse carriage
- Bicycle
- Tricycle rickshaw
- Human powered country boat

2.2 Shortcomings of intermediate ambulance in global situation

Study of intermediate technology (or appropriate technology) seeks in developing new and context-specific healthcare solution in rural societies stated in section 1.1, p 1. Particular attention is given to the need of the ambulance transit in developing countries where access to the healthcare facilities is not easy. The existing ambulance as shown below in [**Figure 2.1 (a)- Figure 2.1 (f)**] is powered by the driver pedalling as that of a bicycle. In India and Bangladesh, usually these ambulances are a delta configured tricycle, the puller pedalling at the front [**Figure 2.1 (a)**, **Figure 2.1 (b)**]; Bicycle ambulances were used widely in the remote areas in Africa and some parts of South Asia i.e. Nepal. These ambulances are bicycles with a trailer [**Figure 2.1 (c)**, **Figure 2.1 (d)**, **Figure2.1 (e)** and **Figure 2.1 (f)**]. There are tricycle ambulances as shown in **Figure 2.1 (g)**, powered by solar photovoltaic energy.

(a): Low cost ambulance in Bihar, India (Manish, 2012).

(b): Bengali rural ambulance (BeRA), Kolkata, India (Innoaid, 2010).

(c): Bicycle ambulance in Malawi, East Africa (Jensen, 2009).

(d): Bicycle trailer attachment for medical carrier in Nepal (Notley, 2010).

(e): Bamboo made emergency medical transportation in Africa (Gordon, 2009).

(f): Canadian designer Niki Dun designed sustainable ambulance for remote Africa (PtatDFD, 2008).

(g): Solar powered ambulance in Bangladesh (Madan, 2017).

(h): Motorbike trailer ambulance in Pune (Dorairaj, 2016).

(i): Motorbike ambulance, created by ambulance dada in India (Rajdeep, 2017).

(j): Motorbike ambulance in Zambia, Africa (Koros, 2014).

Figure 2.1: Exiting intermediate ambulance in developing countries.

As an improvement over human powered ambulances, the motorbike ambulance has a sidecar with an adapted stretcher attached on a motorcycle [**Figure 2.1 (h)**, **Figure 2.1 (i)** and **Figure 2.1 (j)**]. Historically speaking, **t**he motorbike ambulances were first used during the World War- I by British, French and Americans (Lungo, 2011).

The importance of providing Ambulance services is recognised in India too. Mr. Karimul Haq has been awarded Padmashree award in the year 2017 by the Govt. of India in recognition of his services rendered by him using his motorbike ambulance.

2.2.1 History and evolution of bicycle

It has been seen that all the intermediate ambulances in most of the developing countries without good road are based on a bicycle with a trailer or tricycle. So the understanding of evaluation of bicycle and tricycle can help in this research. The chronology of the evolution of bicycle with period and invention is stated in **Table 2.1**.

Running Machine:

The bicycle is a socio-cultural indicator. The bicycle first appeared in 1817, a sort of walking machine is shown in **Figure 2.2 (a)** (Hoefer, 2007) that had been invented by Baron von Drais. The walking machine was later known as Dandy or a Hobby- horse. He made it to get around his home estate. The design -a structure that was made of wood and a pair of in-line wheels with identical dimensions, but no pedals was propelled by the rider sitting on it and pushing off with the feet. It had a steerable front wheel.

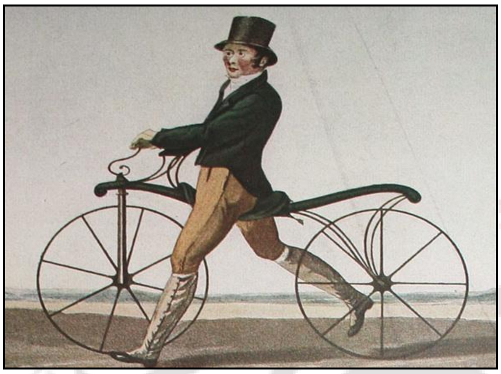
In 1865, finally, pedals were attached to the front wheel of the walking machine and it is shown in **Figure 2.2 (b)** (Hoefer, 2007) and was called velocipede which means fast-foot. The velocipedes were made entirely of wood and required to be balanced by directing the front wheel a bit.

MacMillan's bicycle:

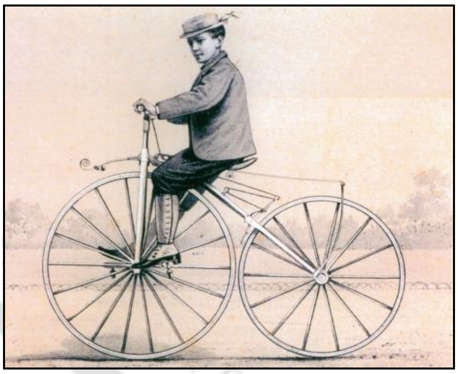
This first pedal bicycle was propelled by a horizontal mutual movement of the rider's feet on the pedals. Scottish blacksmith, Kirkpatrick Macmillan invented the new machine in around 1839 (Hoefer, 2007). One day he saw a hobbyhorse being ridden along a close-by road and he decided to build one for himself. Upon completion, he realised what a radical improvement it would be if he may propel it while not swing his feet on the bottom. The overall system of the McMillan's bicycle is shown in **Figure 2.2 (c)** and was transmitted to cranks on the rear wheel by connecting rods.

High wheel bicycle:

The high-wheel bicycle is shown in **Figure 2.2 (d)** (Hoefer, 2007) which was developed in 1870 with metal machine and the first machine to be referred to as a bicycle.



(a): The Running Machine/ Draisienne or Hobby horse.



(b): The velocipede or Boneshaker, 1868.

(c): MacMillan's bicycle.

(d): The High wheel bicycle or Penny Farthing (80 inches heights from ground).

Figure 2.2: Evolution of bicycle (Hoefer, 2007).

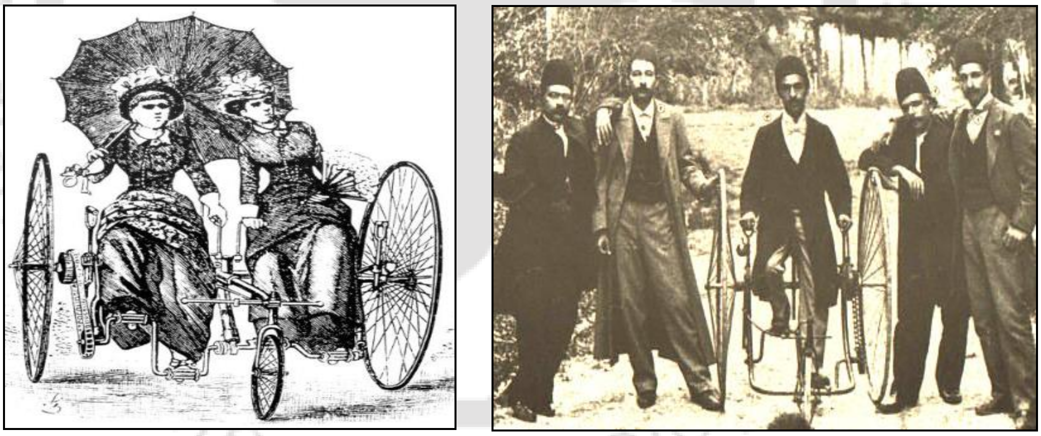
The pedals were hooked up to the front wheel and rubber tires were employed in addition to long spokes on the larger front wheel. Later researchers discovered that the larger front wheel helped travel with less pedalling. The pedals were still attached directly to the front wheel with no freewheeling mechanism.

Table 2.1: Chronology of evolution of bicycle with period and inventors.

Year	Details of configuration/ improvement	Country	Innovation
1440	Concept of bicycle- sketched a modern bicycle.	Italy	Leonardo Da vinci
1790	Two wheels connected by a wooden beam without steering, rider sitting on the beam propels the machine by thrusting feet on the ground.	France	Comte Mede de Sivrac
1816	Dandy or Hobby horse- two wheels connected by a wooden beam with steering, rider sitting on the beam propels the machine by thrusting feet on the ground.	France	J. N. Niepee
1817	Draisienne- Added rest for arms, steerable front wheel mounted on a fork.	Germany	Baron von
1830	Traditionally credited with a machine in which power was supplied to the back wheel via rods connected to treadle-type pedals.	Scotland	Kirkpatrick Macmillan
1848	Pneumatic tyre	Scotland	Robert W. Thompson
1865	Rotary crank-	France	Pierre Lallement
1865	Boneshaker bicycle derived from Velocipede (fast foot), two wheel riding machine with crank with rotary cranks fitted to a slightly larger front wheel and pedalled like the children's tricycle. It had wooden wheel with iron rim, a lever shoe brake on the rear wheel and the front wheel carried on a fork and pivoted at the front of the frame for purpose of steering.	France	
1869	Ball bearing bicycle	Iran	Jules Suriray
1871	Penny Farthing or Ordinary bicycle- the first with a very large front wheel and a small rear wheel	England	James Starley
1876	Safety bicycle- original configuration of two same size wheel.	England	Henry John Lawson
1877	Rover cycle- a company formed to build bicycles	England	John Starley and William Sutton
1988	The air- filled pneumatic tyre	Ireland	Veterinarian J. B. Dunlop
1896	Internal hub gearing	England	William Riley
1898	Free wheel	Germany	Ernest Sachs
1914	Recumbent bicycle	France	Charles Mochet
1915	Dual suspension mountain bike- Bianchi company produced a folding bicycle for the Italian army with telescoping seat stays.	Italy	Edoardo Bianchi

2.2.2 History and evolution of tricycle

There are several commonalities between present day bicycle and tricycle even though they evolved separately. These are in terms of operation, parts they share and the process of manufacturing. The word 'tricycle' stems from the Greek tri (treia), meaning three, and kyklos, meaning a circle or wheel and has been in use since the early nineteenth century. The first recorded usage of this word is in 1829, denoting a 'three- wheeled horse- drawn carriage'. However, tricycles have evolved to include numerous varieties of propulsion together with pedals for manually powered ones and steam and internal combustion engines for mechanised power- driven ones, electric motors for electrical power- driven ones. The abbreviation trike is popularly used denoting tricycle has been in use since 1883. In this discussion, only Human Powered Vehicle (HPV)s are covered. The most commonly found sort of tricycle now a day is that the child's toy pedal tricycle that existed from the development of this type HPV. Adult pedal tricycles can be traced back to 1868. Single seater tricycle for adults is uncommon in India than bicycles.



(a): Two women riding a double tricycle in 1886.

(b): 19th century tricycle used in Iran.

Figure 2.3: Evolution of tricycle (Caitlin, 2015).

On the other hand, the tandem bicycle may be a form of bicycle or tricycle that was designed for more than one rider. The term tandem refers to the seating arrangement (fore and aft, not side by side). A bike with two riders by the side is called a sociable.

2.2.3 History and evolution of tandem bicycle

Danish inventor Mikael Pedersen developed a two rider tandem bicycle in 1898 that weighed 10.9 kg (24 pounds) and it is familiar as Pedersen bicycle, and a four-rider, or 'quad' that weighed 29 kg (64 pounds). These were also used in the Second Anglo-Boer War. Tandem's popularity began to decline after World war-II until a revival started in the late sixties. Later in the USA, Bill McReady founded Santana tandem cycle in 1976. The terminology of a conventional tandem bicycle has minimum two riders:

- The front rider steer is named pilot.
- The rear rider is understood and referred to as the stoker.

The tandem has two sets of cranks and it is automatically connected by a temporal order chain and flip at a similar rate. Recumbent tandem tricycles are conjointly gaining quality throughout the world.

Tandem tricycles:

It can be disassembled into smaller pieces to facilitate packing and travel.

(a): Delta type tandem trike (Mtbr, 2013).

(b): Hand and foot tadpole type tandem trike for coupler (Choi, 2008).

Figure 2.4: Different types of tandem tricycle.

Santana manufactures a 'triplet' (or quad) that can be transformed into a tandem by simply removing the centre section of the frame.

2.3 Classification of tricycle based on user and use

The tricycle can be classified based on several criteria. Most commonly used are based on user and use. A tricycle based on the physical layout of the 3 wheels in the tricycle can be classified as delta [**Figure 2.4 (a)**] or tadpole [**Figure 2.4 (b)**].

The importance of layout of wheels is for the stability of the tricycle. The sophistication of the tricycle depends on the user and the use it is put to.

- Children tricycle: Adjustable children tricycle [**Figure 2.5 (a)**]
- Cargo tricycle: For goods carrying [**Figure 2.5 (b)**]
- Disabled persons tricycle: Specially for lower limb disabled persons [**Figure 2.5 (c)**]
- Sports tricycle: For adults, off road tricycle [**Figure 2.5 (d)**]
- Public transportation: For public, passengers [**Figure 2.5 (e)- (f)**]

(a): Children's tricycle (Cycle, 1998).

(b): Pashley Freightmate cargo tricycle (www.cargocycling.org, 2008).

(c): Lower limb disable tricycle (www.wheelchair.com, 2015).

(d): Sports (off-road) tricycle (Rungu, 2017).

(e): Dipbahan- tricycle rickshaw (Punekar, 2012).

(f): Rainshadow velomobile tricycle (Bentrider, 2008).

Figure 2.5: Different types of modern tricycle and their different use.

Most of the upright tricycles are used for carrying the passengers after they hire. The tricycles are found in both layout i.e. delta and tadpole. These are widely used in South and Southeast Asia as a common mode of transport. Means of different uses of tricycle where design and technology used varies from simple, comfort, lifestyle and sophisticated. Aerodynamic forms and aesthetic, colour, and lifestyle have evolved in terms of public transportation and sports.

2.4 Human powered tricycle in global situation

At present people of rural areas use human powered tricycle rickshaw as a mode of public transportation. Human powered land vehicles can be propelled by a person riding in the vehicle. The tricycle also known as trishaw is shown in **Figure 2.6 (d)**. In India and Bangladesh, the tricycle is known as tricycle rickshaw [**Figure 2.6 (b)**]. In China, the tricycle is known as cycle rickshaw [**Figure 2.6 (a)**]. The tricycle rickshaw popularly known as the pedicab (pedal operated taxi) is shown in **Figure 2.6 (c)**, **Figure 2.6 (e)**, **Figure 2.6 (g)**, Ecotaxi is shown in **Figure 2.6 (h)** and Velotaxis are used in Berlin and many European countries [**Figure 2.6 (f)**].

There is context specific variation of bicycles used for special purpose. Cyclomer [**Figure 2.7 (a)**] an amphibian bike was first innovated and demonstrated by French innovator in Paris, 1932. The bike had hollow wheels, bulbous floats that, with the aid of four smaller globes on outriggers, sustain it in the water. All of it floats and revolve freely like wheels, resulting in a minimum of drag. When the rider pedals it in the water, fins at the rear wheel serves as paddles to drive the machine forward. For a ride on dry land, the out triggers supporting the outer floats folded up clears the ground. Cyclomer had sufficient buoyancy to support the rider when the inventor navigated his device without difficulty across the shallow water pond. National Innovation Foundation (NIF) provides national biennial competition to the grassroots innovator who innovates in local Indian context. Mohammad Saidullah received [**Figure 2.7 (b)**] award for his noble innovation Amphibious bicycle in 2005 (Tewary, 2008). His bicycle comprises a conventional bicycle modified with two extra attachments which enable it to travel on both water and land. These rectangular attachments are in two pairs and each pair is attached to the front and rear wheel of the bicycle. These floats can be folded when the bicycle runs on land. NIF had sanctioned a micro venture innovation fund ₹ 33,750.00 for the development of the prototype, but it never came to the Indian market. In 2007, Mirzapur (Uttar Pradesh) innovator Dwarka P. Chaurasiya developed an alternative arrangement for crossing water bodies without a boat [**Figure 2.7 (c)**].

(a): Cycle rickshaw in China (Authur *et al*., 2013).

(b): Tricycle rickshaw in Bangladesh (Wysiati, 2017).

(c): Philippines pedicab, or 'trisikad' (Marie *et al*., 2004).

(d): Trishaw in Myanmar (Arcane Candy, 2012).

(e): Recumbent pedicab in London (Ecochariots, 2011).

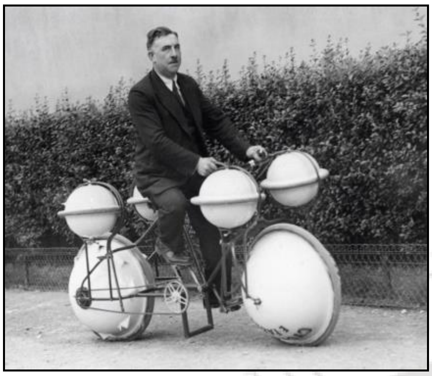
(f): Velotaxi in Berlin (Reichel, 2005).

(g): Hybrid pedicab and driver in downtown Mexico City (Mitchell, 2009).

(h): Ecotaxi pedicab in London, Scotland and Ireland (Walters, 2009).

Figure 2.6: Various types of tricycle in the world.

In this context, a Chinese DIYer, Mr. Li Weiguo tried to build an amphibious bicycle shown in **Figure 2.7 (d)** that has eight empty water jugs which act as pontoons and adjustable vane wheels that provide the thrust in water.



(a): Cyclomer- first amphibious bike in Paris, 1932 (Adrian, 2016).

(b): Mohammad Saidullah's innovation to travel on water (Tewary, 2008).

(c): Dwarka P. Chaurasiya in the amphibious cycle (NIF, 2015).

(d): Homemade amphibious bicycle in China (Chapa, 2010).

Figure 2.7: Various amphibian bicycle in prototype stage.

2.4.1 Relevance and development of tricycle in Asia

The rickshaw was first developed around 1870 in Japan (Rahman *et al.*, 2008). In the early 20th century, rickshaw became a popular mode of transportation in different parts of Asia. In India around 1880, rickshaw was first introduced in Simla by Reverend J. Fordyce (Chandran *et al.*, 2015). Later in the beginning of 20th century (1914) in Calcutta (present Kolkata), hand pulled rickshaw was popular as a mode of transportation (Jim, 2011; Singh *et al.*, 2011). The rickshaw derives its name from Japanese word 'jinrikisha', and it means human powered vehicle. Based on the design of operation, the hand pulled rickshaw is mostly found in India. Cycle rickshaw appeared in Calcutta itself, in 1935s, and by 1950s (Chandran *et al.*, 2015). Currently, people of Bangladesh use approximately 2 million rickshaws while India has 10 million rickshaw pullers (Rahman *et al.*, 2008). At present time, China has banned hand pulled rickshaw under Mao regime, but now- a- days we have seen the rising of the motorised rickshaw. The role of the rickshaw is always evolving in the rural and semi-urban community depending on the culture, economic ability, and geographical locations. In India, most of the rickshaw pullers are migrant from the rural area looking for employment in urban areas. Considering the public transportation across rural and riverine areas in North East India, a large population that uses this mode of transportation is considered for introduction of:

- Amphibian vehicle as ambulance
- Amphibian vehicle for public transportation

This modes of transportation may serve in the rural area for common people in both situations in land and water as ambulance as well as they may serve as public transportation.

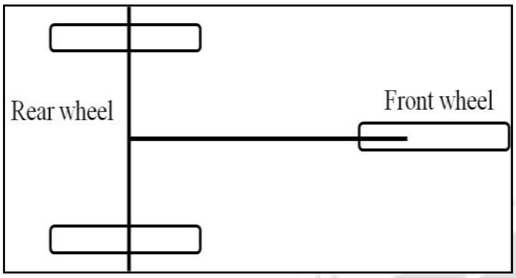
2.4.2 Classification of tricycle based on the wheel layout

Normal tricycle generally consists of either of the two layouts:

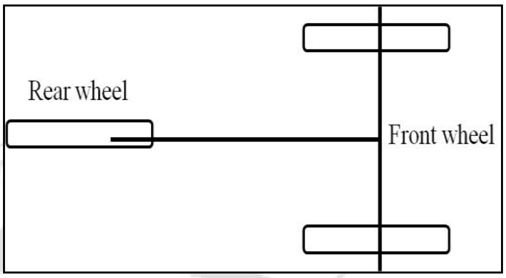
Delta [**Figure 2.8 (a)**, **Figure 2.8 (c)**, **Figure 2.8 (g)**] (www.jetrike.com, 2015), with two wheels at the back and one steered wheel at the front. Out of two rear wheels at the back, usually one is driven.

Tadpole [**Figure 2.8 (b)**, **Figure 2.8 (d)**, **Figure 2.8 (h)**] (www.jetrike.com, 2015), a tadpole tricycle has two front wheels and one rear wheel. Usually driven by wheels at the front that are also steered.

All trikes do not fall into one of those two categories. For example, some early pedal tricycle used two wheels in tandem on one side and large driving wheel on the opposite. The only thing common for a tricycle is front and rear wheels of various sizes. The upright tricycles are delta formed with two-wheels in the back, and they are being preferred sometimes for comfort and toughness. In addition, from the usability point of view, these trikes are much easier to enter and exit. As a result, the seat is higher on the delta tricycle, and it makes the rider more visible to drivers of vehicles coming from opposite direction. These are sometimes a lot heavier than tadpole tricycle. In India, there is no manufacturer for single seater trike for an adult. George Longstaff, Higgins and Pashley Cycle in the UK are the manufacturer of upright trikes which was started in 1960. Italian company 'Di Blasi' manufactured folding upright trike. The largest manufacturer company 'Sun Bicycle' was established in Taiwan for manufacturing both delta and tadpole trikes. The centre of gravity (CG) for the delta riders is usually high [**Figure 2.8 (e)**] but it is located behind the forward tipping axis.



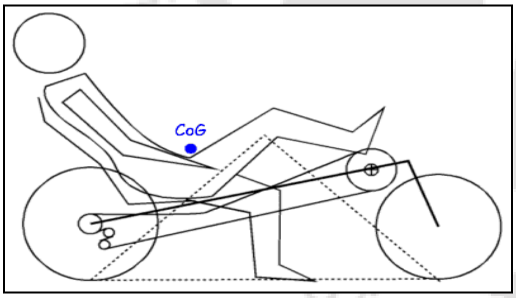
(a): 'Delta' form recumbent wheeler.



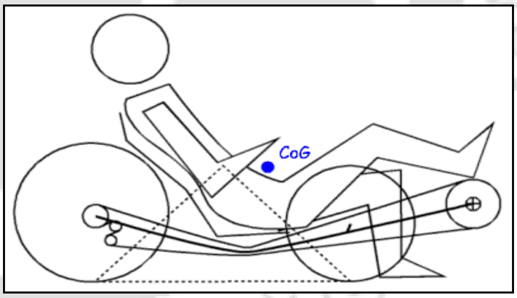
(b): 'Tadpole' form recumbent wheeler.

(c): 'Delta' recumbent tricycle

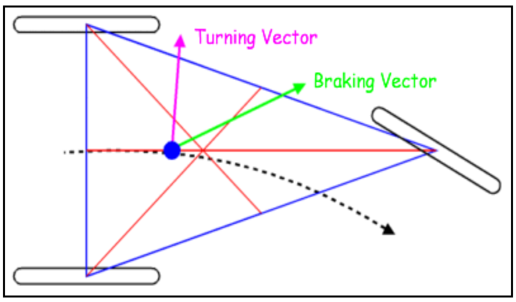
(d): 'Tadpole' recumbent tricycle



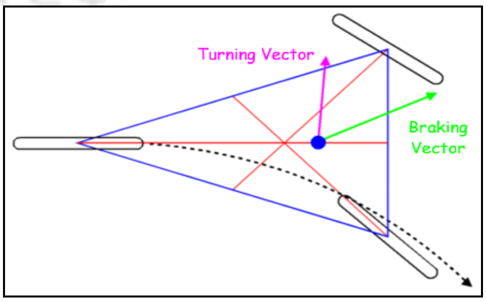
(e): Centre of gravity at 'Delta' recumbent tricycle.



(f): Centre of gravity at 'Tadpole' recumbent tricycle.



(g): Delta turning vectors



(h): Tadpole turning vectors

Figure 2.8: Wheel layout and centre of gravity of Delta and Tadpole tricycle.

On the other hand, the tadpole riders CG is lower [**Figure 2.8 (f)**] but located ahead of the forward tipping axis. Even with the higher seat, a delta trike can be quite stable provided most of the weight shifts back towards the rear wheels.

2.5 Need for transportation system as a present practice

Need of current practice on the localised transportation in the rural region depends on people, native culture, economic capability, local road infrastructure and natural phenomenon. In the Indian context, this need is served by bicycle, rickshaw, shared taxi as well as 4 wheelers. Most of the areas of North East India are often difficult to access during flood situation. However, in the healthcare context existing ambulances cannot reach the remote riverine areas so that medical staffs need to visit those places by country boat (or non-motorised boat).

It is observed that the mode of healthcare transportation is not popular or rather popularised. But some examples are already found **(Figure 2.1)**. To change the situation, there is a need for design and development of a human powered ambulance to change the people's perception as well as initiate philosophical change in society's attitude.

Observation during the field visit and discussion with the experts of riverine people can justify the rest.

- There is no intermediate transportation device in riverine areas in North East India particularly in Assam.
- Road condition is very bad so human powered tricycle is the best solution.
- The tricycle is not comfortable for the passengers due to a variety of reasons, some reasons are narrow seats, excessively titled seat, double row seat make it uncomfortable.
- The design of the tricycle was found to be odd in comparison to the present scenario with varieties of automobiles on road. This situation arises because they were designed primarily for the basic functional use for moving on road almost one and half century ago. Thus, it did not take into account many important aspect of safety on road as perceived and required at present, comfort, human factors, aesthetics in relation to present context.
- Getting on and off the tricycle is difficult due to the height of the footboard. It is much difficult for older persons and children.

- The stability of tricycle is a matter of concern due to high CG.
- The tricycles available in India are having sufficient space for carrying luggage by the passenger or after a marketing trip for which they are extensively used.

2.5.1 Indian cultural context

Design in the Indian context focuses on people, their ethnography, and various socio-cultural issues. Nadkarni (1995) also emphasised that knowledge of the origins of Indian value system is essential to understand the common and comprehensive way of living of the target population and this can provide a clue to Indian- ness and Indian context. For a design to be fruitful, it must meet and fulfil the physical needs of the consumer, and can incorporate the conventional, social, cultural and ecological aspects of the region. The products should be produced locally as far as possible in terms of appearance, efficiency, performance and quality of the product. Targeting the rural riverine people becomes crucial for a technological innovation as well as economic development of the target group. Thus, in a design context, when we consider a human centred design for the present group of Indian people, the design must be in right context which is that of Indian context and must meet the need of this group of Indians in their context only and should take into account their culture, tradition and way of living.

2.5.2 Perception about health care transportation

Human powered health care transportations are not given importance because of people's perception about this mode of transportation as slow moving, low grade, low tech (Boruah and Das, 2013). Even then some of these products shown in the **Figure 2.1** are used in the emergency health care concerns in rural areas globally. To find out probable reasons behind this perception, direct observation method, personal interviews while meeting team and individuals and secondary data and participatory and non- participatory methods were used. However, in comparison to motorised transportation development, not much research has been carried out to improve the mode of healthcare transportation. Due to slow moving nature, it is a very good mode of local transportation within riverine localities of the

Brahmaputra valley since people in case can use these for short distance travel to reach the healthcare centre.

Rural people's perception (Boruah and Das, 2013) regarding the existing varieties of a human powered vehicle as of poor quality is seen from aesthetics, ergonomics as well as point of safety of the passengers and the rider. Experience shared by people has inspired this researcher to prepare a design for this kind of transportation system for riverine areas. The project aims at improving the access of poor people in rural areas with regard to health, education, employment and trade opportunities in a sustainable way.

2.5.3 Process of manufacture

The findings from the study through a visit to the local manufacturer engaged in making products similar to the ones shown in **Figure 2.1** revealed that the followings are the inherent deficiency of the existing intermediate ambulances in local context due to process of manufacturing employed locally.

- Each intermediate ambulance is made individually
- Various components are also made individually and there is no serious attempt at standardisation of the components in their exact size, shape and materials since different persons make them individually.
- Other components are procured off the shelf from components manufacturer.

2.5.4 Quality and the craftsmanship

The quality of basic frame with driving chain etc. is acceptable but region wise the fabrication of the upper body has variations which are not negligible. Various materials e.g. foam, plywood, iron, aluminium, rexine cloth, and metal net etc. are used for its construction. Due to craft based fabrication technique, standardisation is lacking even within the traditional rickshaw factory. This creates a perception of low quality of these ambulances.

2.5.5 Contemporary look of the amphibian ambulance

The proposed amphibian ambulance needs to be designed with a contemporary aesthetics suitable in Indian context. Based on the observation of the existing intermediate ambulances [**Figure 2.1 (b)**], [**Figure 2.1 (g)**], [**Figure 2.1 (h)**] and

[**Figure 2.1 (i)**], these cycle ambulances are a delta type and all three ambulances have roof to protect the user from elements of nature.

(a): Amphibian passenger vehicle at St Michael, UK while on land.

(b): Amphibian passenger vehicle at St Michael, UK while in water.

Figure 2.9: Amphibian passenger vehicle (www.itv.com, 2013).

The function of the ambulance for riverine people should be depicted as the function of a duck bird which is explained in **Figure 3.1**. In **Figure 2.9** an amphibian ambulance is shown and it shows how it looks while using on land and using in water.

2.5.6 Users' ergonomic aspect

The amphibian ambulance needs to be designed with better ergonomic feature. A traditional passenger tricycle rickshaw, except Dipbahan does not provide a reasonable comfort to the passenger. In traditional tricycle based rural ambulance, the passengers are provided protection from the sun and rain but the riders remain exposed to the elements of nature.

2.5.7 Safety features

Safety associated with existing tricycle under present road condition where the rider, attendant, patient and medical equipment are fully exposed to others on road and elements of nature, should also be protected from other vehicles. On the other hand, the buoyancy can be achieved by a fully structured hull. A catamaran type hull could be utilised to give buoyancy and stability and could be produced moderately economically out of an assortment of materials. The hull should be strong or inflatable and produced to the desired shape.

It could limit resistance in water but would be expanded to accommodate the persons and essential driving system and subsystems. It would guarantee that the rider and additional sub-systems are protected from reaching of surrounding water, minimising issues related to corrosion. Nevertheless, the hull would need to be punctured to allow wheels to be controlled when driving on land and in water and the means of propulsion when floating.

The above need can be achieved through a new product innovation. The process needs to be indigenous and sustainable.

2.5.8 Hull terminology

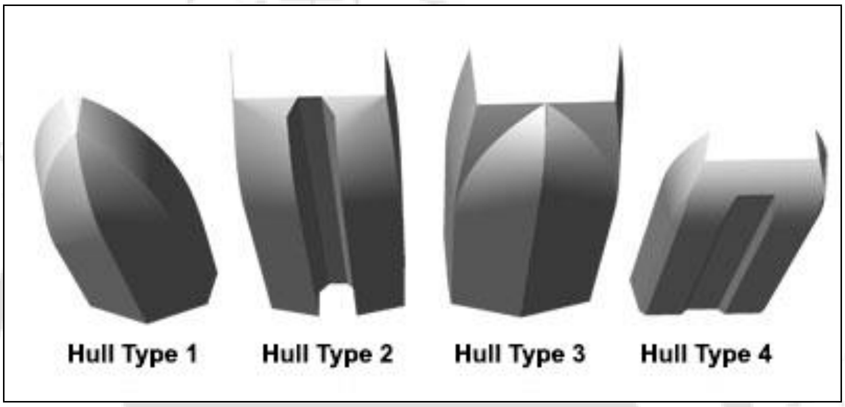


Figure 2.10: Different types of hull.

The different types of the hull are mentioned in **Figure 2.10**. The hull type- 1 is called Deep- V- Hull, which provides a boat maneuverability when driving in rough water. The design is popular for offshore sports boats but less suitable for shallow water use.

The hull type- 2 is known as Catamaran type, it has excellent manoeuverability and also it very stable, which makes working on deck easy and enables safe freighting of heavy loads. This type of boat easier to handle in port and maintaining the boat’s function in water.

Type- 3 is the modified version of type- 1. This is the most common hull for small boats because it combines some of the best characteristics of the other shapes such as type- 1 and type- 2. This type of modified- V is not the best in any situation but it provides a good solution to most family boating needs. The type- 4 is a cathedral type hull which is not easy to manoeuvre as a catamaran type hull. The cathedral type hull provides a slow boat with a good stability.

2.6 Need of sustainable indigenous innovation: meaning of associated terms

2.6.1 Inventors and inventions

An inventor is an individual who is able to generate an idea for a brand new or improved device, product or process. The idea should then be remodelled into concrete design within the variety of an outline, sketch or model.

An invention is an idea, concept or design for a new or improved device, product or process that is available for concrete information in the form of a description, sketch or model. Invention is defined as "Creating one thing new that has never existed before" (The New Oxford Dictionary of English, 1998).

2.6.2 Entrepreneur

A persuasive individual or group provide resources to an organisation necessary to flip associate invention into an associate innovation. The act of entrepreneurship is only a technique of transferring associate innovation to the marketplace. Technology entrepreneurs often select to build a start-up company around a technological innovation.

2.6.3 Improver

At different stages of the method of invention, design and innovation there is a role that somebody plays by improver. The improver is an individual or cluster whose concern is to try to do things better by creating enhancements to existing products and method. In 1877, Edison developed a carbon transmitter that helped improve Bell's recently improved telephone (Rutgers, 2016)

2.6.4 Innovation

Innovation means "making changes to something established by introducing something new" (The New Oxford Dictionary of English, 1998). Although Gerard H. Gaynor (2002), in his book 'Innovation by Design', mentions that innovation occurs from the bottom-up or be sponsored from the top-down; every approach has its own specific exigencies and approaches. The ‘innovation = invention + implementation/ commercialisation’ (Mehta *et al.,* 2008). Innovation is the introduction of latest ideas, goods, services and practices which are supposed to be helpful (Bulsara *et al.*, 2013). The main objective of an innovation is often the courage and energy to better the world.

2.6.5 Robust design and lean product development

Robust design in elastic product is additional seemingly, and it gets commercially successful. As a result, it is appropriate for various uses. The robust design was pioneered by Dr. Genichi Taguchi, which will facilitate with producing variations and guarantee client satisfaction (Taguchi, 1986; Phadke, 1989). Robust Design focuses on rising perform of a product or process throughout producing and operations.

The definition of lean product development may be a practical approach to fast time-to-market through aggressive waste elimination in designing, resource management, design management, and interdisciplinary communication (McMahon, 2013). A lean product development process contains three basic components i.e. (1) driving waste out of the product development process, (2) visualising the product development process.

2.6.6 Conceptual definition of product innovation

- Schumpeter (1934) outlined product innovations as the creation of a new sensible product that adequately satisfies existing and antecedently glad desires.
- Utterback and Abernathy (1975) defined a product innovation as a new technology or combination of technologies introduced commercially to meet a user or market would like.
- Freeman (1982) outlined 'innovation' as well as technical design, manufacturing management and industrial activities concerned in the promotion of a brand new (or improved) product or the primary commercial use of a brand new (or improved) method or equipment.
- As per OECD (1992), technological innovations comprise new product and processes and vital technological changes of products and processes. An innovation has been enforced if it has been introduced on the market (product innovation).

- Leonard and Swap (1999) outlined innovation as the embodiment, combination, and/or synthesis of knowledge in novel, relevant, valued new product, processes or services.
- Sethi *et al.* (2001) mentioned the degree of innovation in a replacement product is the extent to which a new product provides meaningfully distinctive edges.

2.6.7 Intellectual property rights (IPR)

Intellectual property (IP) is observed as creations of the intellect innovation that a monopoly is assigned to designated owners by law. IPR include (1) Patents (2) Trademarks (3) Registered designs (4) Trade secrets and know- how in design. At this innovation process, from invention to diffusion, a bright idea with market potential will be targeted for unscrupulous copying.

- **Patents**: Invention in all branches of technology, whether products or processes, shall be patentable if they meet the involving an ingenious step and being capable of industrial application (www.ipindia.nic.in. patents.htm, 2015).
- **Trademarks:** The Trade Marks Registry was established in India in 1940 and presently it administers the Trade Marks Act, 1999. A trademark is a distinguished product or services of a selected trader. The objective of this act is to register trademarks applied in India and to supply for higher protection of trademark for product and services and additionally to stop deceitful use of the mark (www.ipindia.nic.in/trade-marks.htm, 2015).
- **Registered designs:** An industrial design refers to creative activity that consists of the creation of a form, configuration or composition of pattern or colour, or combination of pattern and colour in three-dimensional form containing aesthetic value (www.ipindia.nic.in/designs.htm, 2015).
- **Trade secrets and know-how in design:** A trade secrets and know- how is a formula, practice, design, instrument, pattern and compilation of technical information, knowledge and skill. It is a procedure, a process, a

place able knowledgeable means of doing one thing. That information should be secret.

2.7 Entrepreneurial quality of an innovator

Entrepreneurship is the solution to solve a problem of unemployment in any economy. Generally, a technology innovation can be thought of coming from engineers of top Technology Institutions. However, innovations may also come from grassroots people. Many times innovation dies due to lack of support to commercialise their ideas. Technology entrepreneur is one who organises, manages and assumes the risk of a technology based business enterprise (Bulsara *et al.*, 2003). William James, an American philosopher, mentions in his book "The Meaning of Truth (1907)" that *truth is something that happens to an idea*. Entrepreneurship is the process by which creative ideas become useful innovations (Chamorro-P, 2013). Entrepreneurial activity requires both a supportive and a productive business climate, and a physical environment where creativity and innovation can flourish. Successful entrepreneurial behaviour is also supported by a strong and diverse knowledge base, well-developed capital resources and appropriate social networks (Henrik and Sten, 2005), and an ability to identify opportunities (Lee *et al.*, 2004).

According to Rice and Matthews (1995), *an incubator's network in general offers access to resources and know- how that entrepreneurs often do not have, but definitely need. Although without assistance of incubator, an entrepreneur might face hard time situation in finding the proper channel and right individuals. Besides the public sector traditional business model, many different forms of private sector emerge to support the soft and hard elements of entrepreneurship. However, the incubator personnel can assist and support for creating and developing of value-adding network relations (Rice, 2002) because an incubator and its external networks link client tenants with service providers and with other local businesses (Lyons, 2002a, b)* (Henrik and Sten, 2005).

Chapter 3: Conceptual Design of an Amphibian Ambulance

It has been mentioned in Chapter 1, that one of the objectives of this research work is to design an amphibian ambulance to provide better access to the health care facilities to the riverine people of the Brahmaputra valley. The design work carried out is described in the same sequence as the morphology of design with all the iterative steps followed as and when necessary. This is primarily to facilitate the presentation works smoothly and appropriately.

3.1 The context of the design and innovation: user survey

This research work describes the application of a human-centred approach to medical product design in the context of Assam, Northeast India with insights into the impact of cultural differences and varying environments that can have on the application of design methodologies.

With enormous erosion and frequent floods by rivers in Assam, people living on the chars (river islands) have an insecure life and it is very difficult for them to access primary health centres. C-NES is providing basic health care services to the flood vulnerable population living in riverine islands in the Brahmaputra valley through specially developed boat clinic (Akha). First introduced in 2004, this boat clinic is popularly known as the "Ships of Hope in the valley of floods" (Hazarika, 2014); the boat clinics are equipped with Out Patient Department (OPD), laboratories on board as well as pharmacies. Later, this boat clinic was extended to thirteen districts with riverine islands in Assam through a Public Private Partnership (PPP) model by the NRHM, Government of Assam, India. However, the access to these boat clinics by people living in the riverine areas are still difficult in absence of all-weather road network in these areas and any mode of motorised transportation leading to taking up this research work to fulfil this gap. Based on literature/product survey of existing appropriate technology based rural ambulance in a global scenario including in India and considering the context of riverine areas of Assam, it was found that a *tricycle based amphibian ambulance* *will be best suitable for the purpose* as it can travel on land as well as in water. This can be considered as primitive need.

3.2 Brief for design development of an amphibian ambulance

To incorporate the various features in the design, the following product brief and work was initiated to provide an appropriate and aesthetically appealing bio-mimicry form with amphibian characteristics that does not make the patient feel insecure to use it with his/ her illness and yet use it with dignity. Also, rider and patient's attendant should find it easy to use and feel safe in both modes of operations - on land and in water.

The design should also meet the following aspects:

It provides easy maneuverability, keeping up to the present day transportation needs. It also provides easy access so that the patient, attendant, and rider can get in and out of the ambulance with ease.

- Protects the user from elements of nature by providing an enclosed structure.
- Fulfils the relevant ergonomics aspect.
- Consider process of introduction of the designed ambulance taking into account prevailing system of introduction of socially relevant innovative products in the market
- Should facilitate manufacturing by using the modern appropriate materials and manufacturing technologies and through small enterprises incorporating various customised features.
- To make it cost effective during design and development as well as for manufacturing, it should use maximum amounts of existing components from the related industry like bicycle, tricycle, motorcycle and boat industry.

The above design brief led to the initial concept that was tested initially for its functional feasibility with the aspect of buoyancy principle and aerodynamic principle. A small boat with catamaran type hull to provide stability in water fitted appropriately with three wheels similar to a delta configured tricycle for moving on land was conceived and designed. This will enable it to travel over land and through water with ease and comfort. The driving mechanism is foot pedalling, similar to a common form of tandem tricycle for an able bodied user and a stretcher was placed between rider and attendant. Transitions from land to water and vice versa are expected to be accomplished smoothly and seamlessly.

On the road it should be stable and safe; in water it should be stable and tractable. This human powered vehicle should appeal to bicycle enthusiasts as well as country boat fans and should be able to be fabricated using simple techniques, common tools, and readily available materials.

Concept generated for the design of ambulance for riverine rural people utilised the basic 3D form to provide the necessary strength to the structure. The other major constraints considered for the conceptualisation of the design of the ambulance was as under:

- Component and subsystem readily available from commercial bicycle/tricycle industry forms the components of the design and can be outsourced to facilitate easy maintenance by the local cycle repairing shops and availability of spare parts.
- For the boat's hull, although wood/timbers are readily available and used in making of country boats in rural areas and, if it is used, can minimise capital investment required for setting up of a commercial manufacturing facility for the ambulance, keeping in view, tedious process of manufacturing, durability, ease of maintenance and operational optimisation. While on land, it was not considered favourable compared to FRP hull.

The initial 3 phases in the morphology of design namely feasibility study, preliminary design and detailed design falling in the area of industrial design of the amphibian ambulance are covered in the following subsections.

3.3 Feasibility study

The feasibility study was conducted in selected riverine areas in Assam and in IIT Guwahati. The feasibility study was carried out presuming that the original need does indeed have present existence or strong evidence of latent existence. The first step in the feasibility study demonstrated this need to be valid. In the second step, design problem generated by the established need was explored to identify its various elements such as parameters, constraints, and major design criteria. In the third step, a number of feasible sets in three steps on the basis of physical realisability, economic worthwhileness, and financial feasibility were considered. Feasibility study process after it has completed, finally indicated that a current and potential need exists. It also helped to formulate the design problem and possibility that useful solutions can be found.

3.3.1 Establishing economic existence of the identified need

The first step in feasibility design is establishing the economic existence of the identified need. The starting point of the design research project was a hypothetical need that had been observed during the research on the socio-economic scenarios. The need existed during the initiation of the project, and there was evidence that it is latent and that it may arise when socio-economic means for its satisfaction through design intervention become available.

3.3.2 Identification and formulation of the design problem

The second step in the feasibility study is the identification and formulation of the design of amphibian ambulance. The following factors were identified and design problem was formulated in the preliminary design of the ambulance.

- The initially conceived design is a small boat with Catamaran type hull to provide stability in water and facilitate its movement through water with ease; for movement on land with comfort, it is fitted appropriately with 3 wheels similar to a delta configured tricycle.
- The driving mechanism is foot pedalling similar to a common form of tandem tricycle for an able-bodied user with the stretcher for the patient placed between rider and attendant.
- Design should accommodate three persons with the ergonomic arrangement; one for the rider controlling the vehicle, another for the attendant to look after the patient and assist the rider in propelling the ambulance and third one, in the form of a stretcher for the patient to be carried to health care centre.
- Provision to safely and comfortably transport a patient and attendant and protect the users from elements of nature.

- Provision of proper space for the user to carry first-aid equipment.
- Appropriate ground clearance for ease of movement in riverine landscape (280 mm to 300 mm from the ground level to the chassis level).
- Provision of grab rail for getting in and out of the ambulance with ease of access by the users and to provide support for getting the ambulance in and out of the water with ease.
- The patient should be made to feel comfortable. The angle of the seat and stretcher is maintained at around 10 degrees, which is an ergonomically optimum angle for sleeping/lying down purpose. The size of the Indian standard stretcher is 1850 mm × 610 mm (Narang Medical Ltd., 2015).
- Proper space for carrying medicine, fast-aid, water bottles and other luggage is to be provided. Reinforced platform for enabling it to support the structure and carrying of luggage is to be used.
- It should have an aesthetically appealing form which is visually perceived light with contemporary visual identity giving it a feeling of sophistication.
- **Cost:** The cost of components required in building an amphibian rural ambulance must be lower than comparable products in the market in order to be attractive to potential customers. To achieve this, components were selected, as far as possible, from the existing components available in the market.
- **Durability**: The components and materials chosen for the amphibian ambulance should be durable for sufficient period of time to be economically viable. It will be better if it lasts, say, seven years (considering an annual depreciation of roughly fifteen percent per year).
- **Safety:** The rural ambulance should protect the patients from injuries, accidents and any emergency medical situation while on road or in water. This may be possible by providing enclosure where damage done after collision with another vehicle on road will protect the users of the ambulance. While in water, users must always wear a buoyancy aid.
- **Maintenance:** The amphibian ambulance should be easy to maintain and should be repaired in local bicycle and tricycle repairing shops.
- **Performance:** The human powered amphibian ambulance will be required to carry a patient, an attendant and a rider which is to be its maximum

payload. The vehicle should be tested on both rural and urban roads and in water by different users to evaluate its performance in terms of the ease of use, maximum speed possible and braking time required while in use on road and in water.

- **Form inspiration:** Going by the bio-mimicry methods, inspiration was derived from ducks (**Figure 3.1**). Ducks have webbed feet; a duck waddles instead of walking because of its webbed feet. Ducks' feathers are waterproof. There is a special gland that produces oil near the tail that spreads and covers the outer coat of feathers. They have evolved to survive in nature by adaptation. Ducks web feet work like a paddle and the space of three toes are closed which allow them to swim fast.

(a): Transformation of duck forms.

(b): Duck webbed feet on land.

(c): Duck webbed feet help them to push water.

Figure 3.1: Brainstorming the basic concept (www.fohn.net, 2006).

- **Branding:** The amphibian ambulance has been branded as 'Dola', conceptually Dola is known as palki or palanquin, derived its name from Sanskrit word 'Palanki' for a bed or couch, suspended by the four corners from a bamboo pole; it used to be carried by two bearers. Palki has two door openings on both sides. Given image in **Figure 3.2** symbolised the theme of the amphibian ambulance.

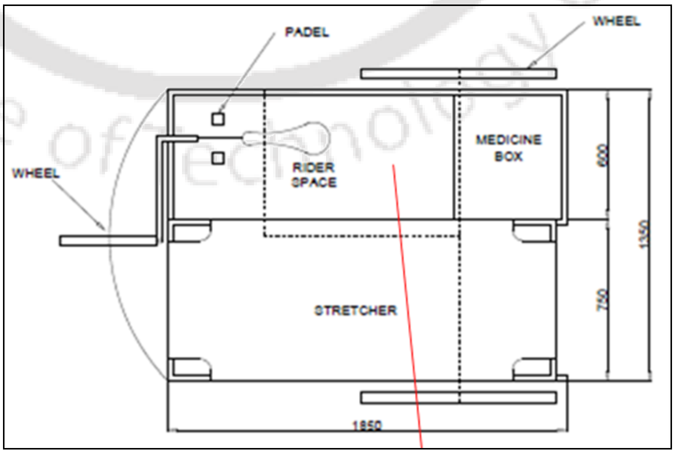
Figure 3.2: A man being carried on a palanquin by Indian bearers (etc.usf.edu/clipart/49800/49807/49807_palanquin.htm, 21 March 2016).

Based on the above criteria, three concepts were conceptualised; these are:

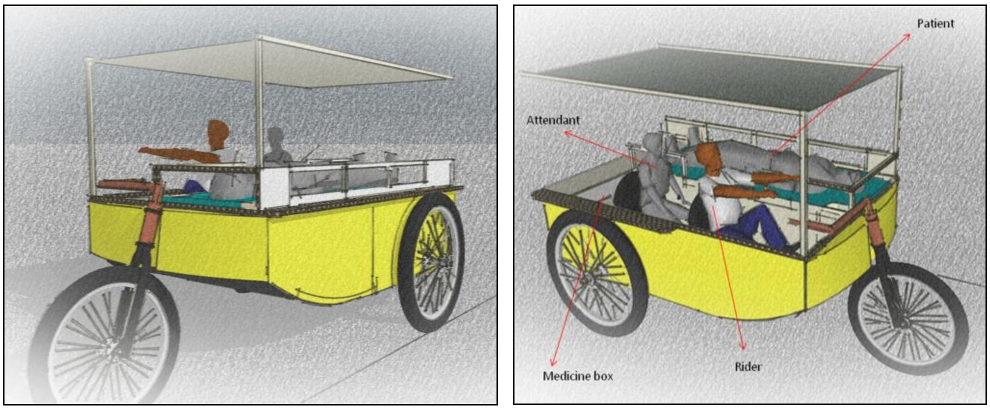
Concept 1: Operation on land

In concept 1, a tricycle's form and function was visualised to have similarity with a duck (bird) which is truly amphibian, **Figure 3.3 (a)**. The internal space of the concept vehicle is divided into two equal parts; one part is for the stretcher and other parts for rider and attendant [**Figure 3.3 (b)**]. The medical equipment (first aid box) is placed in the bottom part of the attendant's seat and oxygen cylinder is placed in the bottom part of the stretcher seat then it will be equally balanced. The vehicle has roof fulcrum permanently over it [**Figure 3.3 (c)- 3.3 (d)**].

(a): Duck as an inspiration for the concept- 1.



(b): Concept- 1, vehicle top view



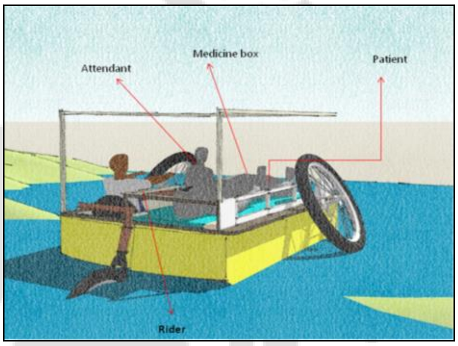
(c): Concept- 1, 3D view **(d):** Concept- 1, different position

Figure 3.3: CAD simulation of Concept- 1 for operation on land.

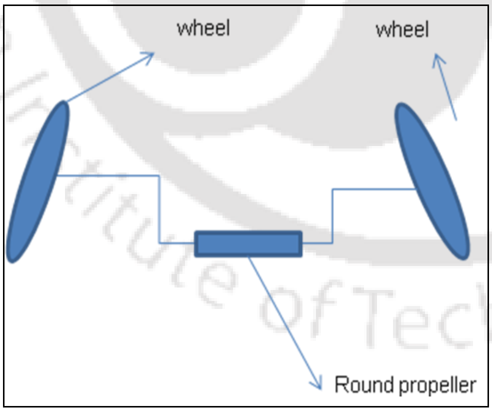
Concept 1: Operation in water

Concept- 1: The vehicle is simulated for operation in water (**Figure 3.4**).

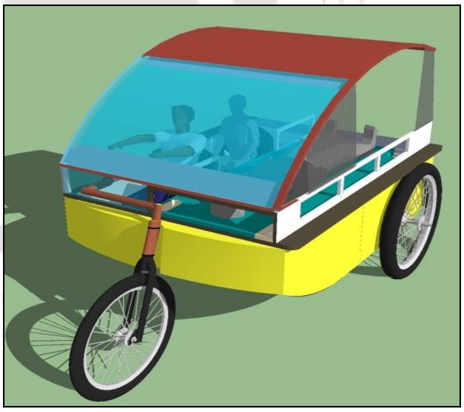
(a): Inspiration of the concept- 1



(b): Concept- 1, sketch up view



(c): Mechanism of water operation.



(d): Concept- 1, modified view

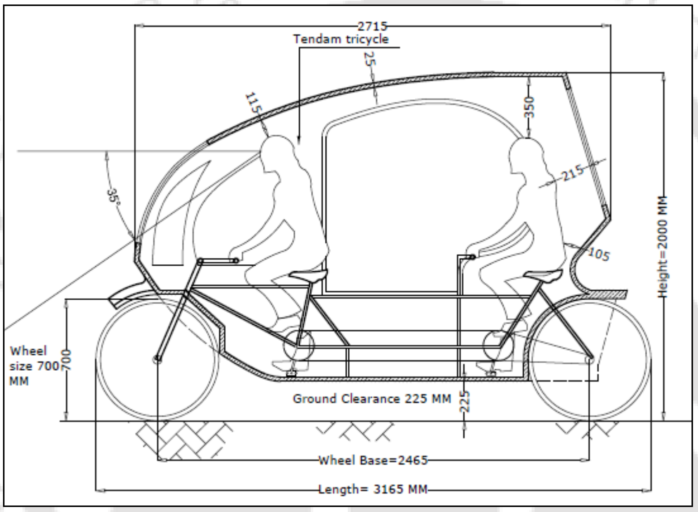
Figure 3.4: CAD simulation of Concept- 1 for operation in water.

As mentioned above, the concept originated from the duck's webbed feet and its ability to navigate its body in water. The duck pushes its feet backward through water, the toes spread apart, causing the webs to spread out to move ahead. The vehicle with an integral canopy to protect patient, attendant and rider with a spacious structure made of the tubular material in Mild Steel. The lower part of the vehicle is made of sheet metal.

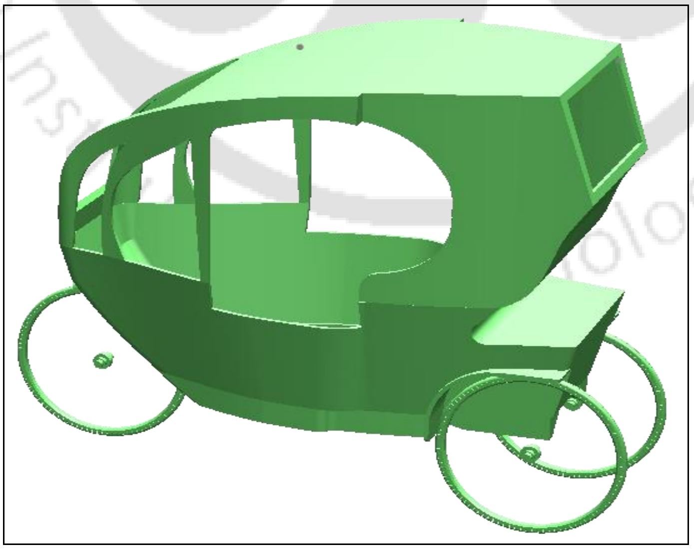
In the above concept at the time of operation in water, the rear wheel will retract upward and round propeller which is fixed in the middle part of the vehicle, it will work.

Concept 2

In the second concept of the vehicle, the stretcher is positioned properly between the rider and attendant.



(a): Concept- 2 using AutoCAD.
(Note: All dimensions are in mm.)



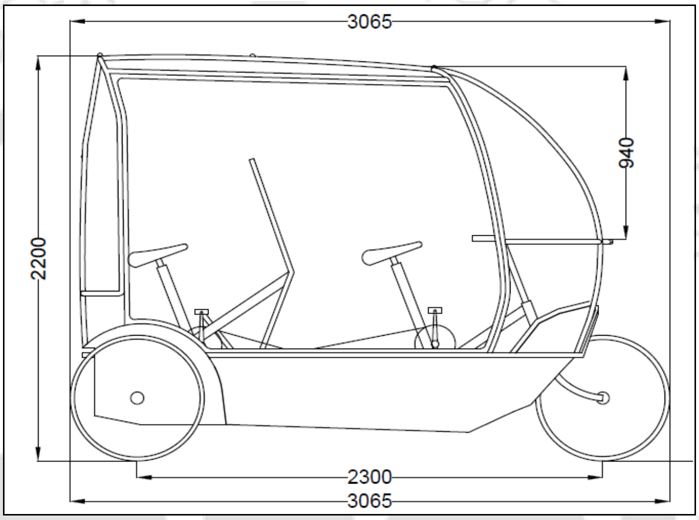
(b): 3D view of concept- 2.

Figure 3.5: Development of concept- 2, form and function.

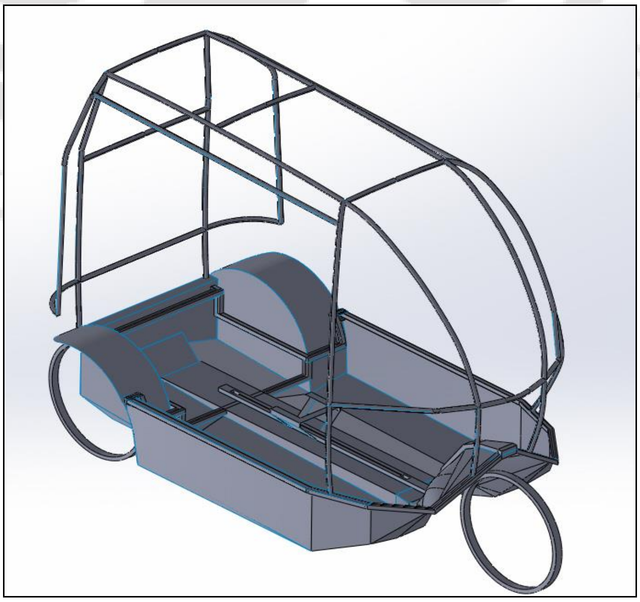
The form of the vehicle is more organic and created for hydraulic and aerodynamic performance from the point of hull and canopy. The operation of paddling by the rider and the attendant is more like normal bicycling (upright style of pedalling). Thus, it is a tandem tricycle mechanism with existing footprints of a common tricycle rickshaw, covered by permanent roof.

Concept 3

The third concept of the amphibian ambulance differs from the earlier concepts from the point of hull design for stability in water, and it consists of a catamaran type hull.



(a): Concept- 3 using AutoCAD.
(Note: All dimensions are in mm.)



(b): 3D view of the concept- 3.

Figure 3.6: Development of concept- 3, form and position.

The operation of peddling by the rider and the attendant is more like normal bicycling (upright style of pedalling). Thus it is a tricycle with tandem bicycle mechanism with existing footprints of a common tricycle rickshaw but fitted in a catamaran hull made of Fibre reinforced plastic (FRP). For propulsion in water, rear wheels are fitted with radial propellers. The stretcher is placed on the right side lower part.

3.3.3 Evaluation of the concepts

The third step in the feasibility study is to evaluate the possible solutions. In the evaluation of concept design, the various concepts were evaluated for their advantages and shortcomings with respect to each other for various factors considered essential for the function for which the designs were conceptualised. Integration of various features to create an integrated product is also essential. This requires innovative and creative effort, creativity being an essential ingredient for innovative design. The following possible features for the previously identified problems were arrived at through the preliminary design and generated concepts:

- An aerodynamic orientation of the proposed design can provide contemporary aesthetics and dynamic form.
- Upward door opening for enabling easy access of stretcher with the patient and entry and exit of the rider and the attendant.

Any product design with specific context for the Brahmaputra riverine areas has to have enough economic worth to be accepted by target users and should be financially feasible to be undertaken by individuals, NGO, and other Government organisations.

Calculation of the stability of the amphibian ambulance

Catamaran type hull to achieve stability in water. The height of the sub merged of the catamaran type hull is shown in **Figure 3.7**.

Stability:

Floating or submerged body of the catamaran type hull sometime acted upon by certain external force such as wind and wave action, pressure due to water current, pressure due to maneuvering a floating hull in a curved path etc. These external forces cause a small displacement of the body, which may overturn it. If any floating body is unstable, otherwise after imposing the displacement the body restores its original position, that body is known as stable equilibrium.

Stability of a submerged body:

Consider a catamaran type hull fully submerged in water in the case given in **Figure 3.7 (a)**, the centre of gravity (CG) of the catamaran type is below the centre of buoyancy. When a small angular displacement is applied a moment will generate and restore the body to its original position; the body is stable [**Figure 3.7 (b)**]. However, if the CG is above the centre of buoyancy an overturning rotates the catamaran hull of the amphibian ambulance from its original position and the vehicle is unstable. When the catamaran hull is fully submerged, the shape of the displacement water remains the same when the hull is tilted. Therefore the centre of buoyancy in a submerged hull remains unchanged.

Determination of Metacentric Height

Where consider, M- metacentre, G- centre of gravity, B- buoyancy, and GM- metacentric height

$$\overline{BM} = BB'/\theta$$
$$= \frac{I_o \tan\theta}{\theta . V_{AECCO}}$$
$$= \frac{I_o}{V_{AECCO}}$$

Since,

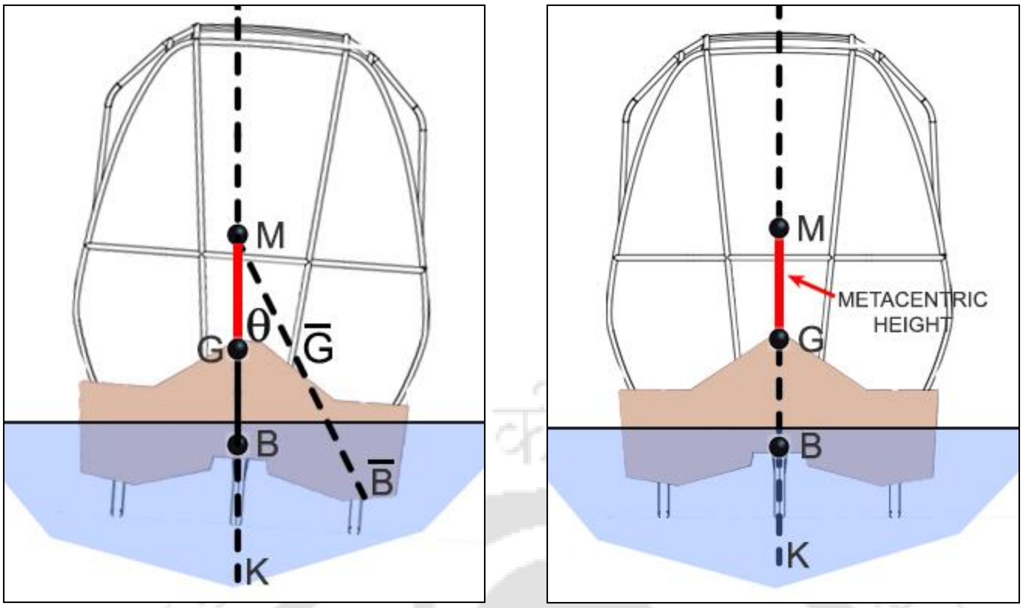
$$\overline{BM} = \overline{GM} + \overline{BG}$$
$$\overline{GM} = \frac{I_o}{V_{submerged}} - \overline{BG}$$

When an overturning moment which results an angular displacement θ to floating catamaran hull is suddenly removed, the floating body sets in state of oscillation. This oscillation behave as in the same manner of a simple pendulum suspended at metacentre *M*.

$$\overline{BM} = \overline{GM} + \overline{BG}$$
$$\overline{GM} = \frac{I_o}{V_{submerged}} - \overline{BG}$$

GM = I_0/ 0.6 X Total volume- [1.15- (1/3x 0.225)]

= 0.774 m



(a) **(b)**

Figure 3.7: Stability of the amphibian ambulance

Since, some typical metacentric height of the various floating vessels are, e.g. river going vessels is 0.3 m to 1.2 m, for war ship is 1 m to 1.5 m and ocean craft is less than 3.6 m. Therefore the amphibian ambulance is stable because the metacentric height of the amphibian ambulance is 0.774 m and it is less than 1.2 m.

3.3.4 Physical realisability for the concept

This is the fourth step of the feasibility study. The design concepts need to have the possibility to achieve practical physical encapsulation, as conceptualised. The concept designs of an amphibian ambulance were visualised. It was found from expert opinion of the people in this area that the design concepts can be physically realised with varied difficulties for different concepts. Skill workers required for fabrication was found to be readily available. Setting up a facility for fabrication and assembly of the amphibian ambulance is possible within ₹ 1.5 Million.

3.3.5 Economic worthwhileness of the concept

The fifth step in the feasibility study is economic worthwhileness of the concept. From Indian perspective, there is an increasing demand for a human powered ambulance in the market. Most products in the market are not able to navigate on both land and water. The proposed design will be a new attraction in the market by adding amphibian features and it can fit into the riverine context for the people.

Based on the concepts, it was found from local industry that various concepts proposed will be possible to be manufactured at a price range of ₹ 45,000-60,000/- This price is economically worthwhile for the function that the ambulance can perform over an anticipated duration of at least seven years.

3.3.6 Financial feasibility

The sixth step in the feasibility study is the financial feasibility. In the real sense, the development expenditure was sponsored by the Department of Design, Indian Institute of Technology Guwahati (IIT G). If the design can be implemented with an investment of ₹ 1.5 Million, and put into actual use through NGOs and Governmental assistance, it can be sold in sufficient numbers in the state of Assam and can easily be implemented in West Bengal, parts of Bihar and Uttar Pradesh and Bangladesh that will provide financial feasibility for the product. In this way, the concept was found economically worthwhile and financially feasible. These last three step viz. physical realisability, economic worthwhileness and financial feasibility of the concepts, worked like strainers. Physical realisability of the concepts is the first strainer; evaluation of the concepts to possess economic worthwhileness for production/ manufacturing, distributor, and consumer is the second strainer and financial feasibility of the concepts is the third strainer. All solutions at the concept development process passing successfully through every three strainers were the important set of solution. During the research work at the conceptualisation stage itself, it was ensured that the concepts created were physically realisable. For assessment of the concepts, the experimental setup using surveys was conducted. For information gathering, groups with diverse background participated and consist of 14 students and 10 technical staffs from technical institution and 10 villagers from rural background. These villagers are experienced people in operating popular Dipbahan rickshaws for local and semi-urban transportation or using locally available country boats. Some of the group members also used pedal boats for recreation. These group members were selected randomly from IIT Guwahati and its nearby areas and different places of riverine areas in Dhakuakhana, Assam. In view of their skill, they were asked to assess the concepts. A Concept Matrix was created with their physical realisability, economic worthwhileness and financial feasibility (Chandra, 2004). Although, there are three concepts, surveys were prepared with 5-points Likert scale, a relative score of 'better than' (+), 'same as', or 'worse than' (-) is placed in each cell of matrix to represent how each concept rates in comparison to reference concept relative to the particular criterion. In the case of physical realisability, the lowest scores meant the concept that may not be realisable. With the above criteria, a preferential matrix was stated in **Table 3.1**.

Table 3.1: Concept Matrix based on physical realisability, economic worthwhileness, and financial feasibility (14 students, 10 technical staffs and 10 villagers).

Concept ⟹	**Concept- 1**	**Concept- 2**	**Concept- 3**
Physical realisability	2	4	5
Economic worthwhilness	3	3	4
Finacial feasibility	2	3	4
Total	7	10	13

3.3.7 Discussion regarding amphibian ambulance concept

All concepts were considered in the context of the riverine area of Assam. Among the three concepts of the amphibian ambulance, the **Concept- 1** cannot be realised physically with the human powered vehicle. This is due to the recumbent position for the rider and attendant as well as inadequate provision for propulsion in water. Although the concept was with retracting rear wheel while in operation in water to prevent these wheels touching the ground at the bottom of the shallow water body to impede its movement, without retracting facility for the front wheel, the same problem will occur.

Concept- 2, Although it appears simple it has many difficulties in its physical realisability. The concept was of a single hull. Making organic form in materials by joining is cumbersome and concept proposed of a single hull with very low length to width proportion makes it very unstable in water. The stretcher is positioned between the rider and attendant and this resultant ambulance will be much bigger. At the time of operation in water, the entire body may become unbalanced. In addition, entry and exit of the rider and attendant are very cumbersome since stretcher occupies the exit and entry openings.

Concept- 3 can be comparatively easy to realise physically with the existing level of capability of the Dipbahan tricycle rickshaw fabricator and small enterprises engaged in fabrication of the fibre-reinforced plastics, mild steel items. The canopy encloses the entire ambulance but it still has very easy entry and exit for all due to the gull wing type side openings. Catamaran type hull can be fabricated in FRP with all hydraulic details and is very stable in water in spite of low length to width proportion. This concept meets greater part of the terms of design consideration for the amphibian ambulance. This makes the concept an economically worthwhile project for investment competing with the existing decentralised manufacture.

3.4 Preliminary design

The preliminary design was initiated to establish an overall concept for the ambulance and serves as a guideline for the detailed design. The decision can be made for commitment to the next phase.

3.4.1 Selection of the design concept

For human comfort for the riders and passengers currently using Dipbahan tricycle rickshaw were involved. They are briefed about the features of the various concepts and where possible were made for actual physical assessment simulating the concept e.g. height of foot pedal, handle, passenger access etc. **Table 3.2** is the summarised response based on factors and preferential rating for concept 1- 3.

Table 3.2: Preferential Matrix based on Design parameters.

Concept ⇨	**Concept- 1**	**Concept- 2**	**Concept- 3**
Overall design	3	5	5
Aesthetics	3	4	4
Human comfort Factor- overall	3	2	4
Puller			
Access	3	2	5
Ease of operation	3	2	4
Protection from the elements of weather	5	5	5
Patient			
Access	5	3	5
Protection from the elements of weather	5	5	5
Seating posture	4	4	5
Space for first- aid	4	3	5

Concept ⇨	Concept- 1	Concept- 2	Concept- 3
Safety	2	2	4
Manufacturing	3	4	5
Material used	4	5	5
Manufacturing process	2	3	4
Manufacturability by SMEs	3	4	4
Eco-friendly	4	4	4
Maintenance	2	4	5
Cost	3	3	3
Reliability	3	4	5
Space for advertisement	1	4	4
Total points	62	68	101
Rank	3rd	2nd	1st

The last row in the table provides the rating of all three concepts. Thus out of various design concepts, concept 3 with space structure, also referred as monologue structure appeared to be most promising. The same type of structure used in Dipbahan rickshaw, traditional rickshaws and E- rickshaws. The structure apart from meeting the objectives of the project also provides utilities as envisaged. Such as structure gives optimum safety to the passenger and riders. The structure seems to be highly reliable and cost-effective.

The first step in preliminary design is selection of a design concept. The concept that performed better in terms of physical realisability, economic worthwhileness, and financial feasibility, is selected for further consideration. However, the selected concepts were tested for its functionality too. One factor tested initially is with respect to the principle of buoyancy. Also, a preferential matrix was created for various other parameters as shown in **Table 3.2**, p. 61. 5 point Likert scale was used for this matrix.

3.4.2 Formulation of mathematical model

The second step in preliminary design is the formulation of the mathematical model. Design proceeds from the abstract to the concept. This is achieved by describing the idea in words, in graphic illustrations, and in mathematical equations. Mathematical models enable useful software to be developed so that the design can be optimised on a computer. In the case of the amphibian ambulance design process, formulation of mathematical model was required regarding the stability of the tricycle and its relationship with respect to the change in the centre of gravity. While in water stability against toppling was essential and CG is required to be at a point lower than the water level outside the hull.

Sensitive analysis

The third step in preliminary design is sensitive analysis. Hypothetically, a framework is visualised as being described in the form of equations or a mathematical model involving the design parameters and the input and output variables. It is essential to know how sensitive performance of the framework is about the adjustment of a few design parameters specifically those which basically influence the execution.

3.4.3 Compatibility analysis

The fourth step in preliminary design is compatibility analysis. Hypothetically, a system or a complicated product or a device is considered as an object which is combination of the various objects on the next lower order of complexity. In a complex system, such constituent objects are referred as the sub-system. Straightforward consideration such as geometrical tolerance or chemical tolerance may be involved in compatibility in a normal situation. The critical problem of compatibility arises when in interacting co-members require matching operating characteristics. This may be due to one member is in series with another and the outputs of one area the input of the other. One example of this aspect of compatibility is propulsion system used in the amphibian ambulance which involves pedals, cranks, chains, sprockets, free wheel shaft, bearing, bearing block, brackets, idler gear, gear hub, rudder, rudder steering to the frame of the ambulance and finally the wheels and propeller as one subsystem and the catamaran type hull and chassis as another subsystem. To obtain optimum output from the system using human power, each subsystem has to be compatible with each other. Considering the amphibian ambulance as a system, various subsystems were established.

The subsystems are:

- Chassis where all transmission systems, steering systems are fitted and mounted on the middle of the catamaran hull using it as a platform.

- Catamaran type multihull for floating in water.
- Handle for steering with front wheel operation on land and rudder system integrated with handle for steering in water. Control such as brake, signal lights are also integrated with handle.
- Transmission system with pedals, cranks, chains, sprockets, idler gear, gear hub etc. integrated with a propeller for propulsion in water.
- Arrangement for the patient (stretcher), rider (front) and attendant (rear).
- Space for medical equipment (first aid box). Space for battery.
- Canopy for protecting the occupants from elements of nature with doors for easy access for the users.
- The system of a siren, and revolving light for an ambulance.
- Special attention was given to each subsystem and its part and components individually.

3.4.4 Formal optimisation

The sixth step in preliminary design is formal optimisation. Till then, this focused effort was not directed to fix all the design parameters as defined in singular values. For the design to advance, it is essential that the parameters are allotted specific design values. Among all the feasible combinations of parameter value, there is one superior to all others

3.4.5 Projection into the future

The seventh step in preliminary design is a projection into the future. Two main questions that require being considered at these stages are:

- The socio-economic environment that will exist when the product comes into actual use.
- The race against technical obsolescence.

The aim was to reduce the development period for the amphibian ambulance so that by the time it comes in the market, the possible competitor would not be able to launch a superior vehicle in the context of design that the project was undertaken. Actually, there was no existing and eager technology provider for the implementation of an ambulance suitable in the riverine areas in Assam. A consumer may have queries related to the need of the ambulance in riverine areas.

In such a case, one should appropriate question about the basic needs of an ambulance - *'Why an ambulance?' 'Why an amphibian vehicle?' 'How an amphibian ambulance can serve in the riverine areas of the Brahmaputra region'?* The prevailing socio-economic environment itself answers these questions. The simplicity of the amphibian ambulance model increases its chances of greater use in future. Another projection is conversion of this ambulance to motorised propulsion using petrol/diesel powered engine or electric powered ones using photovoltaic solar panels for charging the storage battery and propelling the vehicle through electric motor. During the design phase, these possibilities were considered and they formed one of the constraints in the second layer of priority.

3.4.6 Prediction of the system behaviour

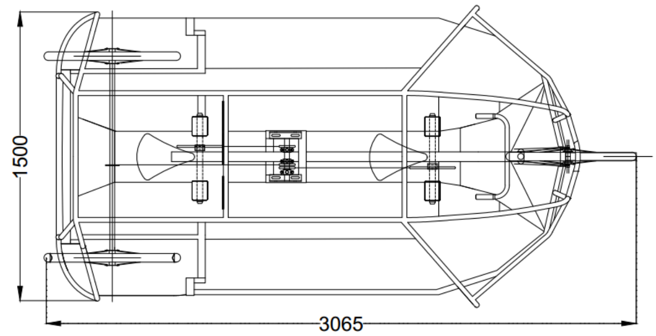
The eight steps in preliminary design is prediction of system behaviour (Chitale and Gupta, 1999). The amphibian ambulance as a system to be successful in the marketplace must function in an acceptable manner throughout a reasonable service life in every riverine area. The minimum durable service life for a newly innovated amphibian ambulance is expected to be around 6-7 years for the riverine people.

3.4.7 Testing and validation of the design concept

The ninth step in preliminary design is testing the design concept.

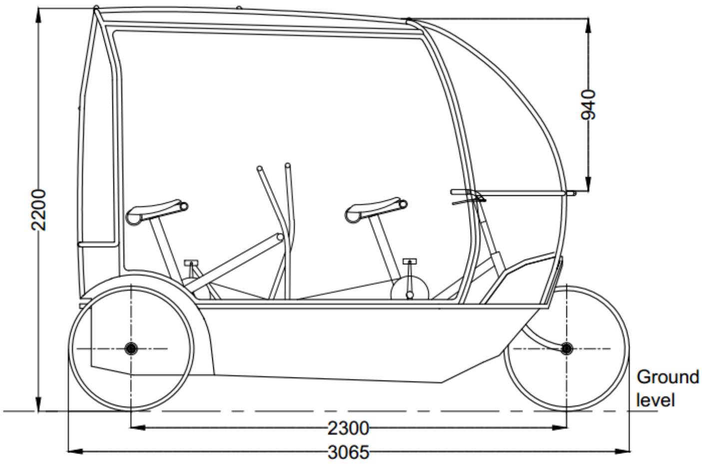
The appropriateness of the design project and the resultant amphibian ambulance can be tested through its use. Amphibian ambulance design is not purely evolutionary design that waits for evidence for its utility to be revealed; the vehicle concept was tested with a scale model and through virtual simulation, using AutoCAD [**Figure 3.8**] and various Solid works views of the selected concepts are shown in **Figure 3.9**.

CAD modelling was followed by construction of the prototype in actual materials/ other than the ones in which the actual production version will be manufactured have been described in detail in Chapter 4. The purpose of this step was to study various ergonomic issues such as ease of entry and exit.



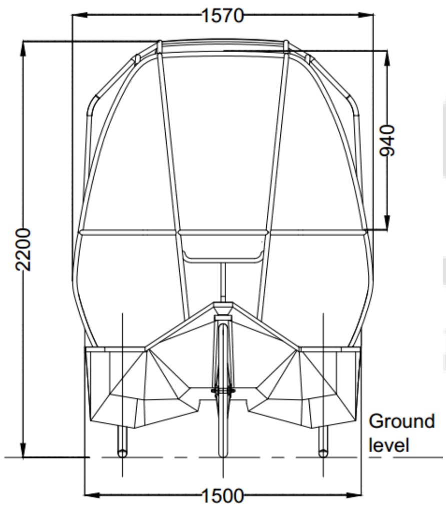
(a): Top view of selected concept in AutoCAD.

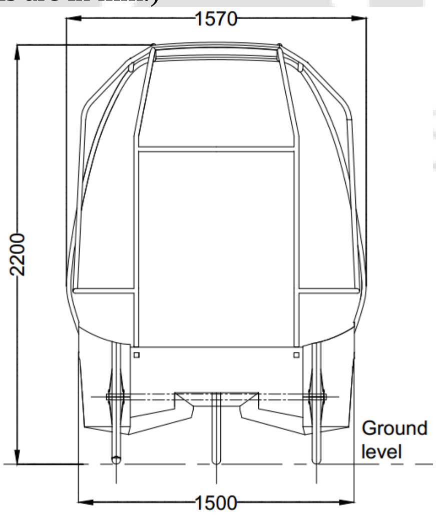
(Note: All dimensions are in mm.)



(b): Side view of selected concept in AutoCAD.

(Note: All dimensions are in mm.)

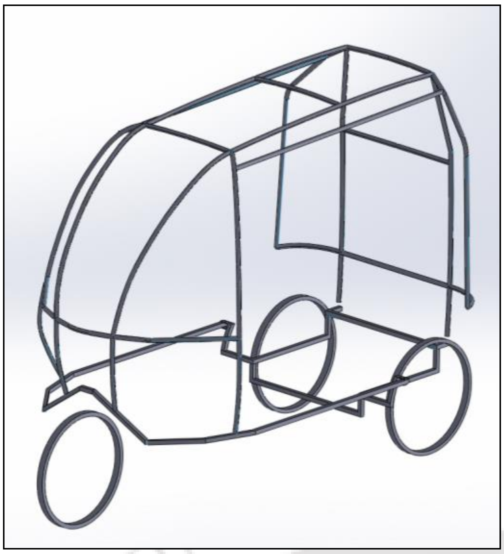


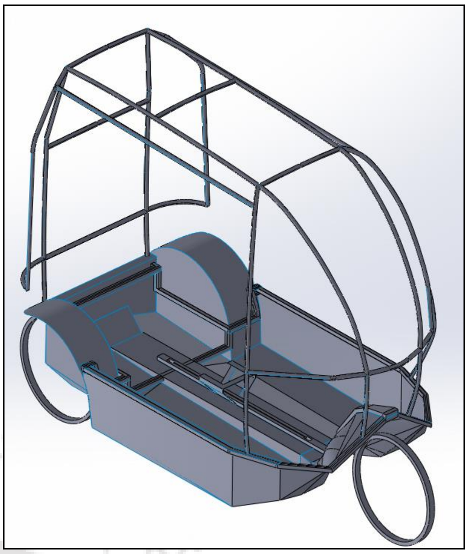


(c): Front view of selected concept. **(d):** Rear view of selected concept.

(Note: All dimensions are in mm.)

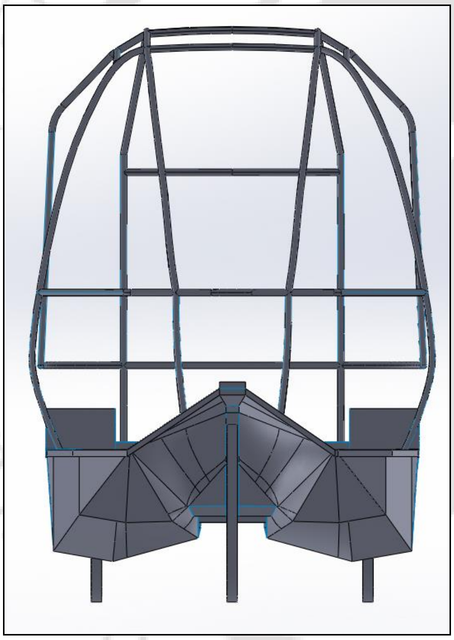
Figure 3.8: AutoCAD modelling of selected concept.

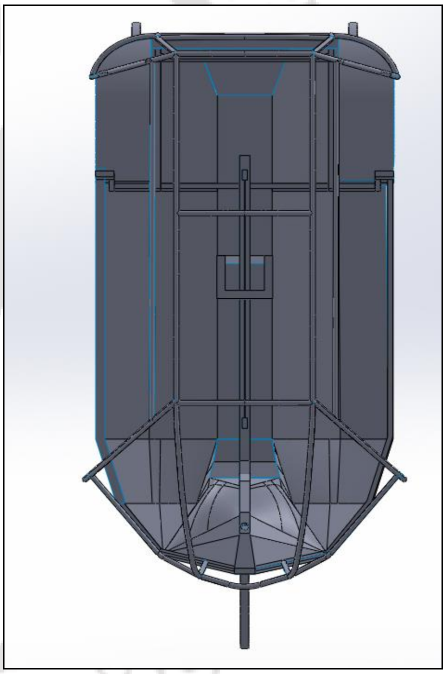




(a): Basic body shell in three quarter front view in Solid works CAD.

(b): Three quarter front view





(c): Front view

(d): Top view

Figure 3.9: 3D CAD modelling using Solid works.

3.4.8 Simplification of the Design

The tenth step in preliminary design is Simplification of the Design. The whole design process of the amphibian ambulance moved through many steps; the actual concept is more complicated than the earlier thought of and required simplification. The steps of the Simplification of the Design are given below:

Expertise available with innovator and designers on the specialised area who is working for the similar product can be utilised for:

- A search of the existing shortcomings of the amphibian ambulance or similar innovations.
- Redesigning the function of the innovation/products/parts.
- Use of the value engineering.
- Methodology for design and manufacturing.
- Change with alternative materials for manufacturing.

The detailed design of the amphibian ambulance discussed onwards carries the design concept, developed in its preliminary phase, to the final product form. To do so, the overall concept was prototyped to a stage that is clearly physically realisable. This stage is achieved by finally constructing a prototype from a full set of design instruction, testing and making necessary revisions in both prototype and design instruction until the design of the amphibian ambulance is satisfactory for production, distribution, and consumption.

Chapter 4: Detailed Design, Prototyping and Testing of the Amphibian Ambulance

4.1 Detailed design

Detail design is the last design activity before implementation process. The concept evolved in the preliminary design is considered for detailed design phase (Chitale and Gupta, 1999). In this detail design phase, the design is featured by greater flexibility. This provides variety of views where each view is a different modelling technique.

4.1.1 Preparation of design

The first step in detailed design comprise of fixing the design specifically.

- Setting up need criteria to be accomplished.

  For any design, an idea to continue to evolve for physical realisation needs financial support and a dedicated design team. Also close monitoring of time and economic resources are basic requirements of the design team. Hypothetically and for practical reason in a business set up, it is just the top management vested with the responsibility and authority regarding the final financial commitment of the venture (Chitale and Gupta, 1999), can settle on the choice to endorse the financial budgets or to suspend a venture. In this case of amphibian ambulance design and development, none other than procedures of estimation were observed to be vital since emphasis was on social cost. With a view to emphasising social cost as an advantage in this socially relevant venture, the aim was to fulfil local transportation need of riverine people to health centre/camp or boat clinic. The financial requirements as practiced in any corporate sector was not considered. The objective was to create contextual innovative design and transfer the same to local entrepreneurs.

- Planning a manufacturing facility that can be utilised for prototyping of the concept, design and technology transfer to NGO/SMEs for manufacturing of amphibian ambulance.

The physical infrastructure required for prototyping the design concept of the amphibian ambulance was readily available in the workshop of Department of Design, Indian Institute of Technology Guwahati. A roller type pipe-bending machine [**Figure 4.1 (a)**] for forming round tubular pipe, arc welding machine [**Figure 4.1 (b)**], electric cut- off machine [**Figure 4.1 (c)**] and a Fibreglass Reinforced Plastic (FRP) fabrication facilities were part of the existing machineries and facilities in the department. In addition to the above, a good carpentry section was also part of the departmental workshop used for prototyping and preparation of pattern of the catamaran hull in wood. The above constituted the preparation for prototyping and initial infrastructure required for the amphibian ambulance. Required Mild Steel (M.S.) tubular components were measured and cut based on dimension available from CAD drawings.

(a): Pedestal roller type pipe bending machine

(b): Arc welding machine

(c): Electric Cut-off machine

Figure 4.1: Machineries primarily used for prototyping.
Source of Photographs: Author

4.2 The detailed design of the parts

This phase provides a detailed specification with interfaces and functions for each component. The entire design, development and prototyping of the amphibian ambulance have been proposed in the following sequence:

- Design of hull of amphibian ambulance
- Plywood pattern making for the catamaran type hull
- Design validation of the catamaran type hull of ambulance
- Stability test of FRP hull in water
- Propulsion system for land
- Simulation of Cross Trainer mechanism using bamboo
- Frame design prototype simulation of Cross Trainer mechanism incorporated in the amphibian ambulance
- Modification of the frame design of Cross Trainer mechanism for the final prototype
- Simulation of gear hub
- Simulation of idler gear
- Alignment of chain and sprocket
- Oil seal for main axle for rear wheels for making it watertight.
- Propeller
- System of mounting and removal of the paddle wheel
- System of removal of the rear wheel of the amphibian ambulance
- Rudder and rudder steering system
- Design for reliability
- Distribution of weight uniformly for balance of the ambulance in water
- Arrangement of winch
- Design for convenience in use (consideration of human factor)
- Design of door opening latches
- Design of stretcher
- Design for aesthetic features
- Design for safety
- Design for buoyancy

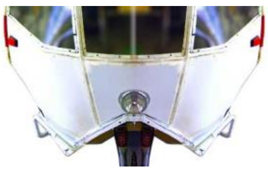
To integrate all sub-systems with each other, System compatibility chart for sub-system, components with complete system was prepared as given below:

Table 4.1: System compatibility chart for sub- systems, components with complete system after improvement.

<table>
<tr><th colspan="5">Level</th><th rowspan="2">Link element between two sub-systems</th></tr>
<tr><th>1</th><th colspan="2">2</th><th colspan="2">3</th></tr>
<tr><td rowspan="5">Complete System (Amphibious Ambulance)</td><td rowspan="5">Subsystem of System</td><td>Catamaran type hull (Figure 4.6)</td><td rowspan="5">Components of System</td><td>Mainframe and chassis.</td><td>Main frame and chassis joined through FRP layer</td></tr>
<tr><td>Integrated Chassis [Figure 4.26 (a)]</td><td>Mainframe, chassis with pedalling, Cross Trainer and gear system, housing for rear axle.</td><td>Mainframe and chassis joined by welding and bolting of various elements/links.</td></tr>
<tr><td>Propulsion system on land</td><td>Tyre, tube, wheel rim, spoke, wheel hub, axle, bearing, bearing block, free wheel sprocket, chain, sprocket on crank, Pedal, BB socket assembly.</td><td>Bearing block to integrated chassis with nuts- bolts, lock washer and spacer (wooden or rubber), BB socket and gear hub to main chassis by welding, Cross Trainer mechanism with pedal, nuts and bolts.</td></tr>
<tr><td>Steering system
</td><td>Handle bar, head cup assembly, front fork assembly, front axle and hub assembly, spokes, wheel, rim, tube and tyre
Modified:
E- Rickshaw handle, bearing, front axle, handle T, tube, front rim, front hub with drum brake.</td><td>Head cup assembly with head pipe in mainframe.</td></tr>
<tr><td>Braking system front wheel
</td><td>Initial: Hand operated brake lever assembly on handle bar, brake link, fork, fork bracket on front fork, brake shoe and pads, right hand operated brake lever, link rod, brake shaft with brake shoe and rubber brake pad</td><td>Brake lever assembly and handle bar.

Brake lever with brackets welded to the mainframe and bracket shaft with the chassis.</td></tr>
</table>

Level					Link element between two sub-systems
1	2		3		
Complete System (Amphibious Ambulance)	Subsystem of System		Components of System	**Modified:** E- Rickshaw brake cable, brake lever. 	
		Seating arrangement for rider 		Saddle post, seat assembly with shock absorbing spring structure.	Saddle post with the main frame. Seat structure with nuts, bolts.
		Seating arrangement for medical attendant 		Saddle post, seat assembly with shock absorbing spring structure, Additional backrest.	Saddle post with the main frame. Seat structure with nuts, bolts.
		Stretcher for patient [**Figure 4.31 (a)-(d)**]		Sliding door wheel pulley 	M.S. framed track channel
		Roof for protection from elements of nature and as a protecting rolling cage		Tubular structure side frames and binding cross bars, Rexine cloth hood.	Tubular structure side frames and pasting with male-female Velcro at the rexine cloth. Rexine made hood fitted to the tubular structure with Fevikwik adhesive, screw and lock washer.

Level			Link element between two sub-systems
1	**2**	**3**	
Complete System (Amphibious Ambulance)	**Subsystem of System** Protection from the wind	Acrylic sheet as front wind protecting shield.	Fixed with screw and nuts with tubular structures.
	Entry and exit door **(Section 4.4.5)**	Intermediate pivot hinge between door and the top encloser	Oil less spring shock absorber and pivot hinge
	Battery position 	Placed at right side of the attendant's saddle.	
	Medical equipment- medical fast-aid box 	Rear side of the medical attendant seat position, floor board in FRP on the ambulance.	Placed the medical Fast- Aid box on the junction of the rear exposed rudder Placed oxygen cylinder near the attendant (easily accessible for the patient).
	Front light- Night visibility by the puller and by the others on road and water -Royal Enfield Thunderbird 350 	Battery powered electric head lamp mounted on the chassis frame.	12 volt Battery powered LED electric head lamp mounted on the chassis frame.
	Alto car signal indicator red (right and left side). 	Side mounted direction indicator lamp with a rubber base. One 12 Volt bulb inside. Two indicator are placed in both side (right and left). 	12 volt Battery powered LED electric signal indicator mounted on the front façade of the vehicle.

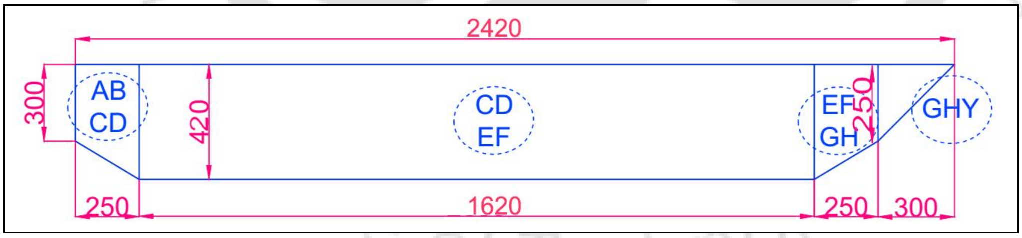
Level				Link element between two sub-systems
1	2		3	
Complete System (Amphibious Ambulance)	Subsystem of System	4 LED trailer back light for signal 	Side mounted direction indicator lamp with a rubber base. One 12 Volt bulb inside.	12 volt Battery powered 2 numbers of LED electric signal indicator mounted on the rear facade of the vehicle.
		Rear view mirror 	Rear view mirror plain/convex with mounting bracket.	Bracket on the front tubular structure , near the wind protecting acrylic frame or on the tubular structure side frames at the front
		Ambulance Siren horn 	Siren horn with ambulance revolving blue light (Lumax). 	Siren horn and ambulance revolving blue light fixed at the roof of the ambulance, just above the puller seat. Both are screwed on bracket plate welded on top of the tubular frame structure.

4.2.1 Design of hull for the amphibian ambulance

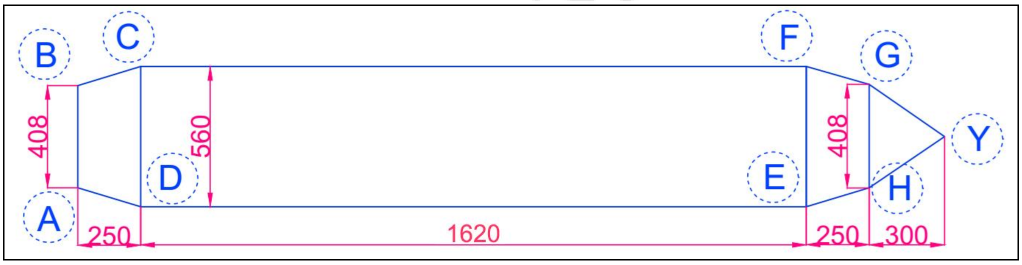
The flotation factor of the amphibian vehicle is crucial for the safety of the riders and patient when the vehicle is in water. It will need to provide adequate buoyancy and stability for ease of operation and safety. In addition to appropriate buoyancy, the stability of the amphibian ambulance in water is the very important step to be ensured before designing next stage of the prototype. Initially, theoretical calculations were used to arrive at the volume of flotation required to provide a factor of safety more than two and this should keep the load line at lower than two-thirds the height of FRP hull. However, from the design point of view, the design concept of the amphibian ambulance was having a low proportion of length to the breadth and if the hull is made in a single hull, it can get easily destabilised when the persons in the ambulance move around. So, to keep the stability high, the design of the hull was done in a catamaran form with two hulls joined together with the clear separation of the two above water. However, since the ambulance will be amphibian, the hull would have to be built in such a way that it provides scopes for fitting wheels, one wheel in the front and two rear wheels to be operated when on land and to provide means of propulsion when floating. Accordingly, front and rear of the hull were designed. To accommodate rear wheels, there was the loss of buoyancy and it was taken care of at the design stage itself.

4.2.2 Plywood pattern making for catamaran type hull

The pattern is the exact replica of the final FRP hull made of materials that can be easily curved and the first step in making an FRP component to be made using a mould for the final component. Thus pattern making was the first step towards realising a catamaran type hull in FRP. Based on expertise and resources available for other requirement like functional testing, a pattern can also be made in Plaster of Paris (PoP) which is extremely suitable for carving instead of wood. In the present case, pattern was made using plywood, since the hull was to be tested for buoyancy and stability in water prior to moulding which would not be possible in PoP pattern.



(a): Dimensions of catamaran type hull – side view.



(b): Dimensions of catamaran type hull - top view.
(Note: All dimensions are in mm.)

Figure 4.2: Measurements of catamaran type hull.

Based on dimensions available from CAD [**Figure 4.2 (a)**, **Figure 4.2 (b)**], 10 mm thick plywood was cut as per the design of the hull. As seen in the drawings, surfaces of the hull are mostly linear and flat. This is for avoiding any undercut in the mould so that final hull can be easily taken out of the mould. The pieces obtained were joined using nails and Fevicol glue and gaps between parts were filled with sawdust and chips (small pieces of wood) mixed with Fevicol [**Figure 4.3 (a)**- **Figure 4.3 (d)**]. Resin based putty was applied to cover up holes and gaps that occurred in the joints to make it waterproof.

After 24 hours, when putty dried out and the fabricated wooden hull was ready for further finishing, the following process was carried out:

- The joints and edges were rounded off using a chisel, wood files, as well as sand paper and further waterproofing, was done on the edges of the catamaran type hull by applying FRP putty [**Figure 4.3 (e)**] and then smoothening it with sand paper once it dried off.
- A layer of FRP was applied over the wooden pattern to strengthen it for testing it in water for buoyancy and stability [**Figure 4.3 (f)**].

The process is as under:

Glass fibre sheets were measured, cut and prepared according to the required dimensions. A thick coat of resin was prepared and then applied evenly over the entire outer surface of the wooden pattern of the hull.

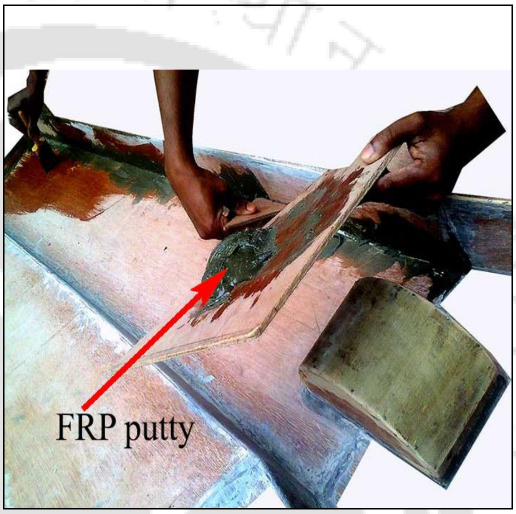
Glass fibre sheets were now applied on the top of the resin coating accordingly. Another coating of resin was applied after each glass fibre sheet was placed on the hull surface, thus forming a sandwich of resin coat and glass fibre sheets. The glass fibre sheets being flexible take on the shape of the plywood pattern of the hull. The resin wets the glass fibre sheets for making it easier to work with and also giving it the flexibility to take whatever shapes and corners it has to form and binds the fibres to finally form the composite when it is cured and dried. Once dried, the FRP layer binds properly to the wooden pattern giving it required strength for testing [**Figure 4.3 (g)**] as well as for making mould out of it from which the final catamaran type hull of the amphibian ambulance in FRP can be manufactured.

(a): Fabrication of the catamaran hull (front view).

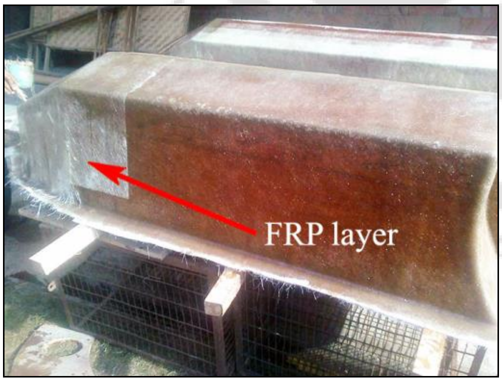
(b): Fabrication (rear view)

(c): Side view of individual hulls in plywood before joining.

(d): Preparation of pattern for catamaran type hull; applying FRP putty.



(e): Preparation of pattern for **c**atamaran type hull; after application FRP putty.



(f): Application of one layer of FRP on the wooden pattern to strengthen.

(g): Catamaran type hull pattern is ready for field test.

Figure 4.3: Various steps for fabrication of pattern of catamaran type hull.
Source of Photographs: Author

4.2.3 Buoyancy calculation

The buoyancy calculation was prepared based on the **Figure 4.2**.

Volume of Part1: [ABCD] of Figure 4.2 (a)** and **Figure 4.2 (b)

Changing Average height = (450 + 300) ÷ 2 = 375 mm
Base1 =420 mm, Base2 = 560 mm
Distance B/w Bases =250 mm
Volume = ½ × (560 + 420) × 375 × 250

= 45937500 mm3 = 45.94 L

Volume of Part2: [CDEF] of Figure 4.2 (a)** and **Figure 4.2 (b)

Length = 1620 mm, Width =560 mm, Height = 450 mm
Volume = 1620 × 560 × 450

= 408240000 mm3= 408.24 L

Volume of Part3: [EFGH] of Figure 4.2 (a)** and **Figure 4.2 (b)

Changing Average height = (450 + 250) ÷ 2 = 350 mm
Base1 =408 mm, Base2 = 560 mm
Distance B/w Bases =250 mm
Volume = ½ × (560 + 408) × 350 × 250

= 42350000 mm^3 = 42.35 L

Volume of Part4: [GHY] of Figure 4.2 (a)** and **Figure 4.2 (b)

Changing Average height = (0 + 250) ÷ 2 = 125 mm
Base = 408 mm, Height = 300 mm
Volume = ½ × 300 × 408 × 125

=7650000 mm^3= 7.65 L

Total volume of single hull:

=Part1 + Part2 + Part3 + Part4
= (45.94 + 408.24 + 42.35 + 7.65) L
= 504.18 L
= **0.504 m^3**

Total volume of double hulls= 0.504 m^3 × 2= 1.008 m^3

Buoyant force (F.B) = V × v × SP of water

Where, V = volume of the hull

v= % of the object submerged in water.

Specific weight of water (SP) = 9.810 kN/ m^3

Buoyant force of two hulls (100%)=

(Volume of two hulls) × (% of the object submerged in water) × (SP weight of water) =1.008 m^3 × 1 × 9.81 kN/ m^3= 9.89 kN= 1008.50 Kg- force

Buoyant force for 50% of hull = (1008.5 Kg- force) × 0.50 = 504.25 Kg- force

Total weight of the vehicle is 450 Kg and it is less than the buoyancy force. So the vehicle will float in water and the float line is located at 50% of the catamaran hull.

4.2.4 Design validation of the catamaran type hull for the amphibian ambulance

Stability test of wooden pattern in water

After wooden pattern was ready, testing of the catamaran type hull for the amphibious ambulance in water was initiated. This testing validated the calculations for the buoyancy.

(a): Stability test in water using wooden pattern with three persons.

(b): Stability test in water using wooden pattern with the maximum flotation.

Figure 4.4: Stability test in water using wooden pattern.

Source of Photographs: Author

The second step for making FRP components is the fabrication of the moulds for the hull of the amphibian ambulance. After the procedure of preparation of pattern in plywood was completed, mould making in FRP was initiated. Since the catamaran type hull was big to be conveniently made into a single piece using a single mould, the mould was made in two parts called as split moulds. For this, the pattern in plywood was measured equally in two parts longitudinally for making the mould and separator fixed. This separator [**Figure 4.5 (a)**] is made of galvanised sheet metal cut as per the profile of the hull where separation is intended. This separator is fixed to the wooden pattern with nails to hold securely. The pattern was to be covered with releasing agent [**Figure 4.5 (b)**]. Polyvinyl Alcohol (PVA) is used as a releasing agent. PVA is regularly available in white crystalline granules. It is boiled in water in the ratio of 1:10 solid to liquid proportion and after cooling the solution, it is applied with a brush or sponge on the pattern and dried in shade to get a fine layer of film. Generally, two coats of PVA are applied. After the pattern is covered with releasing agent, it is ready for application of FRP layers. Normally, after releasing agent, a layer of gel coat is applied. Gel coat is either polyester or epoxy resins with different viscosity than resin used to bind the glass fibres and is used for imparting colours to the FRP components.

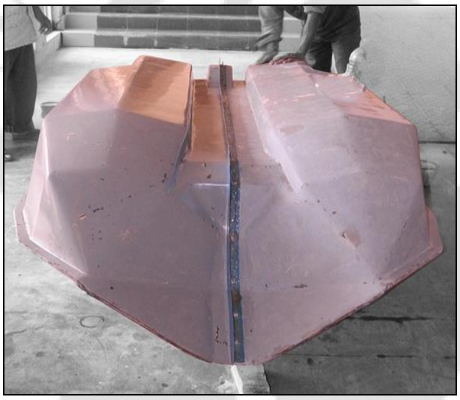


Figure 4.5 (a): Fixing the separator on wooden pattern.

Figure 4.5 (b): Smoothening the surface of the pattern for applying releasing agent.

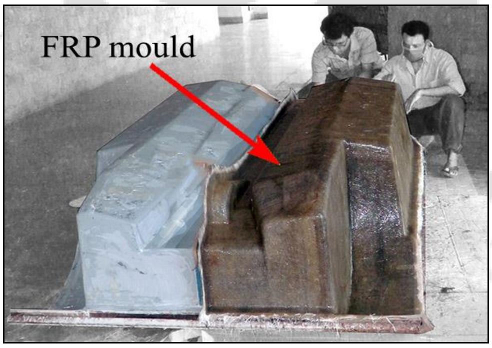


Figure 4.5 (c): Preparation of FRP mould using the pattern.

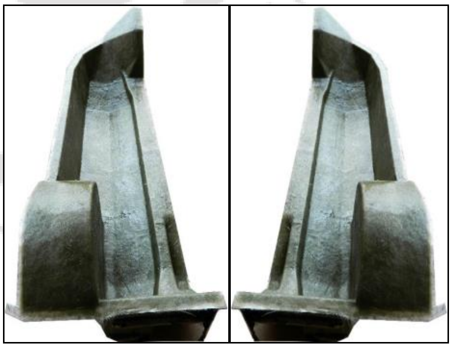


Figure 4.5 (d): FRP split mould after release from the pattern.

Figure 4.5: Mould making in FRP.
Source of Photographs: Author

The final step is making the components using the mould. This is precisely the same as making of the mould. Mould is coated with PVA used as releasing agent and once it gets dried, gel coat mixed with the required shade of colour is applied on the mould. After applying the gel coat, it too has to be dried. Care must be taken to see that entire surface is consistently coated to keep away any unevenness in the shade of colour of the component. Once the gel coat is dried, glass fibre is applied and impregnated with resin. For the final component, a surface mat with a smooth surface and low GSM is first laid and based on the size and type of component, it is possible to use 400 GSM FRP mat in single or multiple layers in conjunction with either 300 or 200 GSM mat after alternative layer of 400 GSM mat [**Figure 4.5 (c)**]. These mats are randomly oriented mat, but for directional strength, woven mats can also be used. For the acutely turned surfaces where surfaces turn around the component, the fine surface mat of low GSM can be utilised. Once the resin is set, it can take 3-4 hours depending on thickness and percentages of catalyst and accelerator agent mixed with the resin, the component can be taken out [**Figure 4.5 (d)**], and this process is repeated for more components.

4.2.5 Buoyancy and stability test of FRP hull in water

The stability of the hull decreases [**Figure 4.6 (a)**] if the occupants stand at one side of the hull. However, when the occupants are in a seated position [**Figure 4.6 (b)**] the hull is sufficiently stable for comfortable operation. In terms of buoyancy, the catamaran type hull properly floats on water with an appropriately located CG.

(a): Trial in water with FRP catamaran type hull.

(b): Stability test in water with catamaran type hull.

Figure 4.6: Stability test of FRP hull in water.
Source of Photographs: Author

To facilitate easy manufacturability and maintenance many components for drive and propulsion systems were procured from readily available bicycle, tricycle and electric rickshaws.

The different types of outsourced components were used are given below:

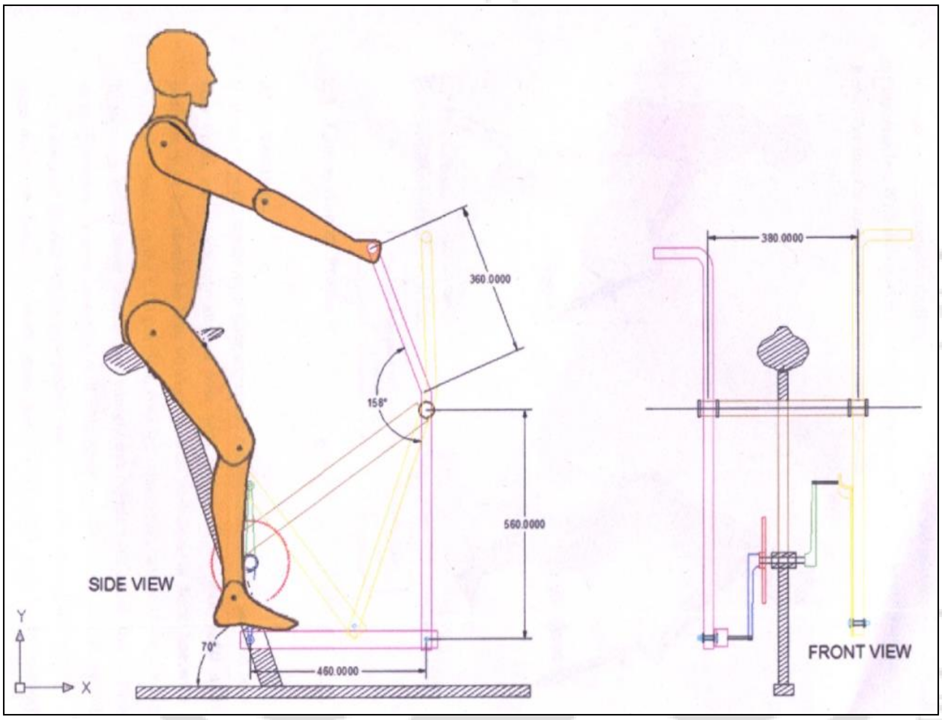
1. 10 gauge rim of 28" x 1 ½" size (3 nos.)
2. 10 gauge spokes 40 nos. x 3 (120 nos.)
3. 10 gauge front hub (1 no.)
4. 10 gauge back hub (1 pair)
5. Heavy-duty tyre 28" x 1 ½" size (3 nos.)
6. 06 bearing block (2 nos.)
7. 06 bearing (1 pair)
8. Rubber tube (3 nos.)
9. Fork guard (1 pair)
10. Front fork (1 no.)
11. Screw racer (1 set)
12. Ball racer (1 set)
13. ¼ ball steel (1 packet)
14. Front handle (1 no.)
15. Rickshaw brake set (1 set)
16. 06 socket for rear shaft (1 pair)
17. BB socket black (1 no.)
18. BB axel black (1 no.)
19. BB cup black (1 set)
20. KW gear crank- 48T (2 set)
21. KW pedal (2 pedals)
22. Cotter pin (2 nos.)
23. 5/4 ball centre (1 packet)
24. 22 teeth freewheel (1 set)
25. Freewheel plate 29 teeth (1 no.)
26. Freewheel socket (1 no.)
27. Heavy duty chain (3 nos.)
28. 10" seat pillar (2 nos.)
29. Seat pillar socket (2 nos.)
30. Saddle (2 nos.)
31. Heavy duty heavy frame cup (1 set)
32. Frame sockets (4 nos.)
33. Head pipe (1 no.)
34. Rear side shaft axle (1 no.)
35. E- Rickshaw front wheel assembly (1 no.)
36. Rudder steering wheel (1 no.)
37. Alto car oil less spring door shock absorber (4 nos.)
38. Aluminium green nets (8 mitre)
39. Oil seals (2 nos.)- 25x35x5 mm
40. Ambulance siren (1 no.)
41. Blue revolving light (1 no.)
42. Turning indicator light (2 nos.)
43. Head light (1 no.)
44. Winch (1 no.)
45. 12-Volt battery (1no.)
46. 12- Volt flasher buzzer (1 no.)

4.3 Propulsion system for land

There are two sets of handlebars. The first one is for the rider who steers the vehicle and other is for the attendant. The rear set of the handle bar is connected with a set of pedals that can be pushed to and fro synchronous with the pedals and assists in enhancing the movement of the amphibian ambulance. Basically, this is a Cross Trainer exercise bike system (also called elliptical Cross Trainer bike) [**Figure 4.7 (b)**, **Figure 4.7 (a)**] implemented to provide additional force for propelling the amphibian ambulance using best possible configuration for the attendant to assist the main rider, since the ambulance is heavy enough for a single rider to propel easily [**Figure 4.7 (c)**]. Thus, the riding position is similar to Tandem Bike but with an additional system of Cross Trainer exercise bike system integrated with the design.

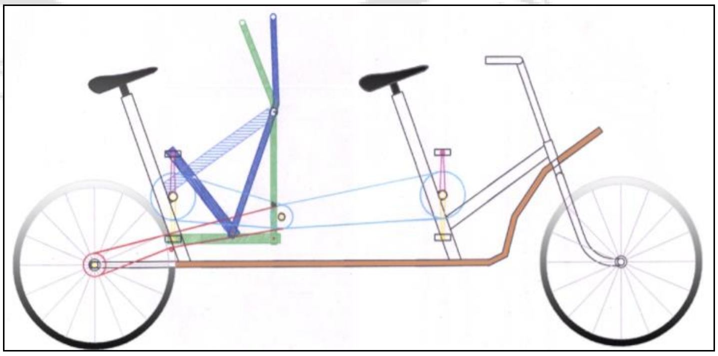
Initially, to verify the working of the Cross Trainer bike mechanism on the drive system, prototyping was made using bamboo [**Figure 4.7 (d) -Figure 4.7 (e)**]. The links were made with nails which are fastened with one bamboo shaft but can freely turn about the axis of the other. The T-shaped arrangement is held onto the mainframe by tying with ropes systematically. The connecting arm [**Figure 4.9**] is used to connect the crank wheel through foot pedals [**Figure 4.11**] to the lower end of the handlebars to transmit the force applied by the hands onto the crank wheel. A descriptive picture is shown in **Figure 4.10 (a)**.

4.3.1 Simulation of the Cross Trainer mechanism using bamboo



(a): CAD drawing of cross trainer mechanism, upper limb cycle.
(Note: All dimensions are in mm.)

(b): Cross Trainer exerciser



(c): CAD drawing of the Cross Trainer mechanism placed with rear side of the amphibian ambulance.

(d): Experimental prototype making of the Cross Trainer mechanism by bamboo.

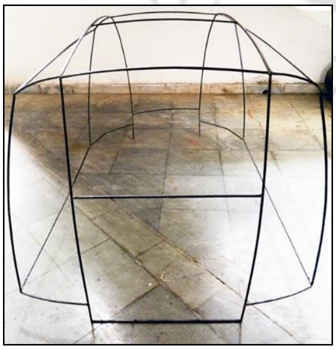
(e): Usability test with Cross Trainer mechanism.

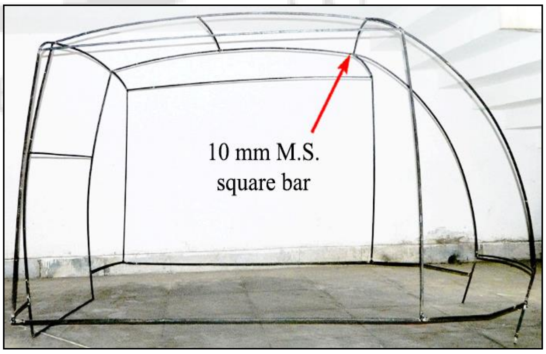
Figure 4.7: Preparation of experimental prototype using Cross Trainer mechanism
Source of Photographs: Author

First version of experimental prototype was built [**Figure 4.8 (a)**, **Figure 4.8 (b)**] to get overview of various parameters affecting things such as aesthetic, ergonomic for front rider, attendant, patient and their accessibility etc. Overall body was constructed using 10 mm square bars to get the desired form and shape [**Figure 4.8 (c)**, **Figure 4.8 (d)**].

(a): Experimental prototype without person.

(b): Experimental prototype with person.





(c): Rear view of rolling cage.

(d): Side view of rolling cage fabricated in 10 mm M.S. square bar to study aesthetics and form.

Figure 4.8: Experimental prototype development in initial stage.
Source of Photographs: Author

4.3.2 Frame design prototype simulation of the Cross Trainer mechanism used in amphibian ambulance

A M.S. metal flat bar of width and thickness of 30 mm, and 5 mm is cut into the required length. It was found that a straight connecting arm [**Figure 4.10**] will interfere with the rotatory motion of the rear foot pedals. Hence, the shape of the connecting arm was slightly modified.

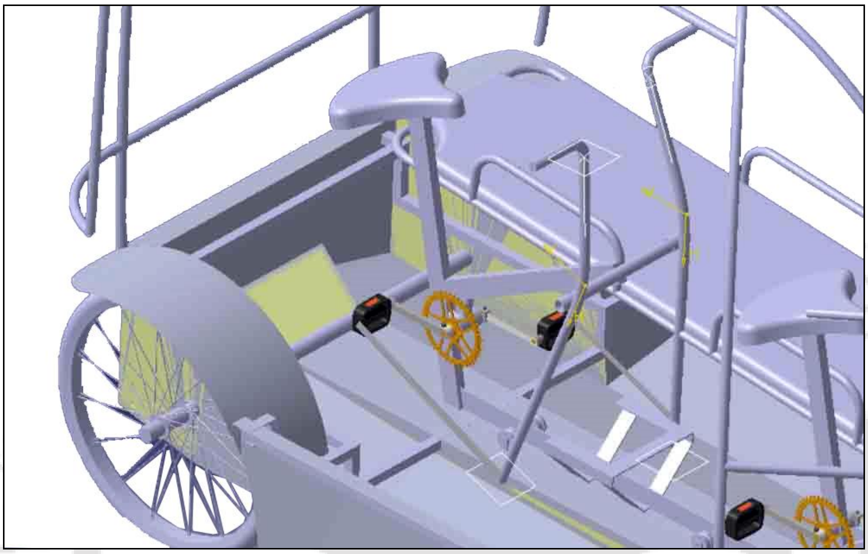
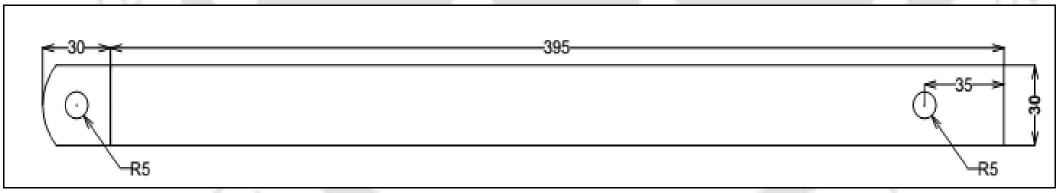
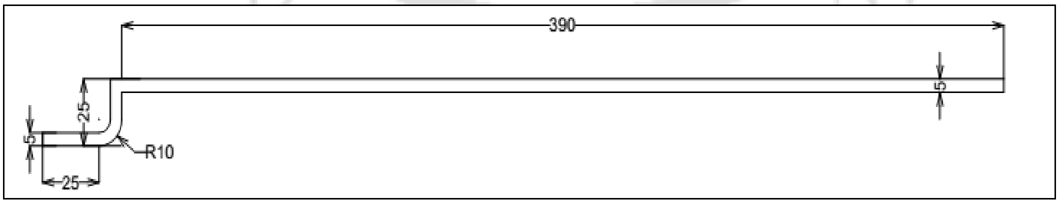


Figure 4.9: CAD drawing of Cross Trainer mechanism for prototype.

Connecting arms



(a): Top view of 425 x 30 x 5 connecting arm.



(b): Side view of 425 x 30 x 5 connecting arm.

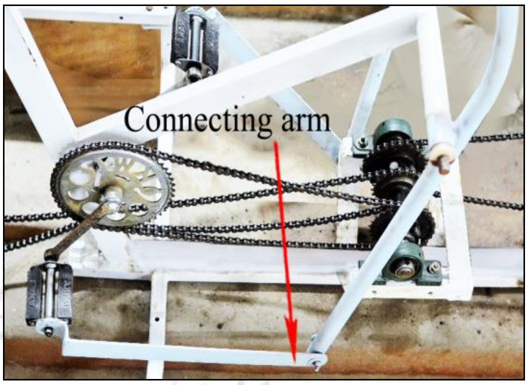
(Note: All dimensions are in mm.)

Figure 4.10: Cross Trainer foot pedal connecting arm.

A M.S. metal piece of the same width and thickness (5 mm) was bent in L- shape using a Hydraulic Press and is welded to the main connecting arm to increase the clearance of the connecting arm from the mainframe which accounts for the rotatory motion of the pedal. The edges of the connecting arm are rounded off using a grinding machine. The connecting arm of the Cross Trainer system has to be linked to the pedal spindle by means of the nut and bolt. However, the existing design of the pedals does not support the linking of the connecting arm and the pedal spindle. Also, the length of the pedal cannot be changed taking into account the ergonomics factors. Therefore, the design of pedal was changed to suit the requirements [**Figure 4.12 (b)**].

The ends of the connecting arms were drilled according to the diameter of the pedal spindle to connect it to the spindle at one end and the handlebar at the other end. It is connected to the spindle of the pedal by means of nuts that can rotate freely about the pedal.

After testing of the prototype of Cross Trainer mechanism fabricated in bamboo, actual prototyping of the systems started with the main frame for rear rider [**Figure 4.11 (a)**]. The frame of the Cross Trainer mechanism is used to hold the handlebars through an assembly; it is welded into the main frame of the vehicle in the T-shaped arrangement. For holding the assembly onto the main frame a semi- circular groove is made in the bar of the mainframe using a semi- circular file. The other end of the bar is welded to the mainframe in a position below the rear seat. The assembly which holds the two handle bars is a complex assembly, and it accounts for the to and fro motion of the handlebars [**Figure 4.11 (b)**]. The assembly consists of a hollow metal tube which houses a solid metal rod. The shaft is held onto the hollow tube by means of sleeves [**Figure 4.11 (c)**]. The handles of the Cross Trainer exercise bike system were designed and standard anthropometric dimension was maintained between two handlebars. The hollow metal tube of the inner diameter 22 was used for making the handlebars. The metal tube and the handlebar setup is then holding within the setup of two nylon sleeves [**Figure 4.11 (d)**] such that the handlebar moves to and fro when the pedal is being rotated. It was given the desired shape by bending it in a hydraulic pipe bending machine. The lower end of the handlebar was drilled to connect it to the solid shaft via a link which consists of a hollow metal tube that passes through the solid shaft and the handle bars. The setting is held together by means of nut and bolt which passes through the hollow metal tube. The solid shaft and handlebar can have individually rotary motion. The handlebar is filled in a semi- circular shape at the section where it is being welded to the smaller hollow tube [**Figure 4.11 (e)**] of the T- section. It is filled because the hollow tube to be welded are in circular shape and wouldn't have formed a strong welded joint.

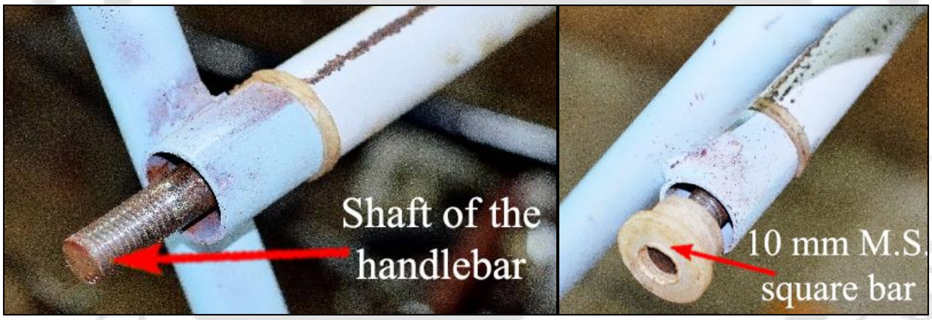


(a): Upper limb and lower limb pedal with handlebar.

(b): Cross Trainer mechanism used in the frame design.

(c): Shaft of the handlebar with sleeve.

(d): Nylon sleeve



(e): Shaft of the handlebar for rear rider (attendant).
Figure 4.11: Cross Trainer mechanism after machining.
Source of Photographs: Author

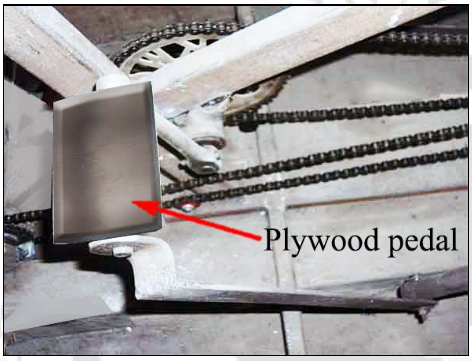
The two sleeves hold the solid shaft and two sleeves mounted on external sides of the solid rod allows two hollow rods of the smaller length to rotate freely over the two set of the sleeves on either sides of the solid rod.

The sleeves are made of nylon and it has a smoother surface which reduces the friction during the rotation of the smaller hollow rods over the sleeves. Sleeves are turned, faced and drilled using a lathe machine and is a stepped design and it houses the solid rod (axle) onto the external hollow rod and provides rotatory motion to the smaller rods.

The ends of the shaft were threaded using tapping tools so that the rotating arrangement at the extreme end of the solid rod can be held on to the hollow rod by means of nuts.

4.3.3 Design of foot pedal for the attendant

Before modification of the existing foot pedal for the attendant of the amphibian ambulance, a piece of plywood was cut and attached to the pedal's pivot arm [**Figure 4.12 (a)**] and take a trial of proper foot position over the pedal. The pedal's pivot arm is the axis, which runs through the foot pedal body.



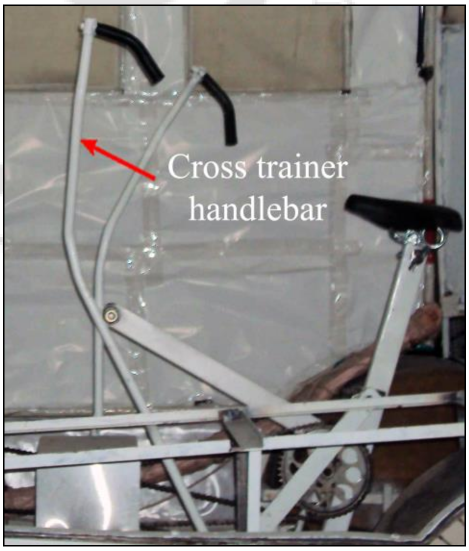
(a): Foot pedal design using plywood.

(b): Designing of modified pedal.

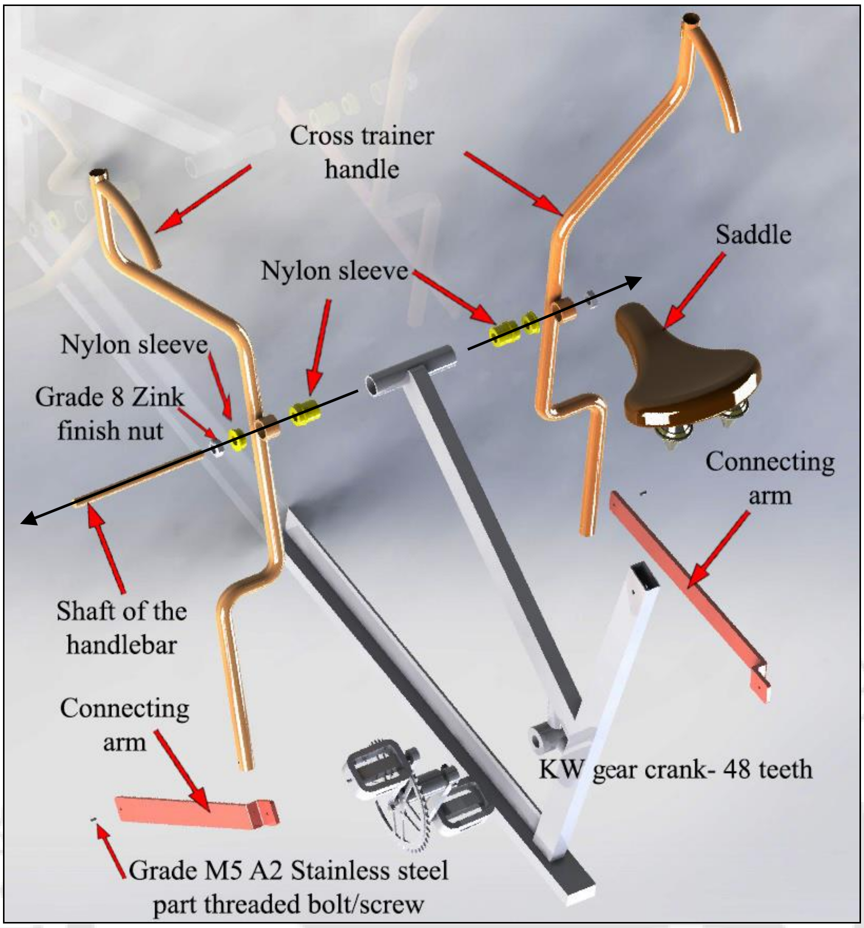
Figure 4.12: Design of the pedal for rear rider (attendant).
Source of Photographs: Author

4.3.4 Modification of the frame design of Cross Trainer mechanism for final prototype

(a): CAD drawing of Cross Trainer mechanism for final prototype development.



(b): Prototype of Cross Trainer mechanism for the attendant.



(c): Exploded view of Cross Trainer mechanism.

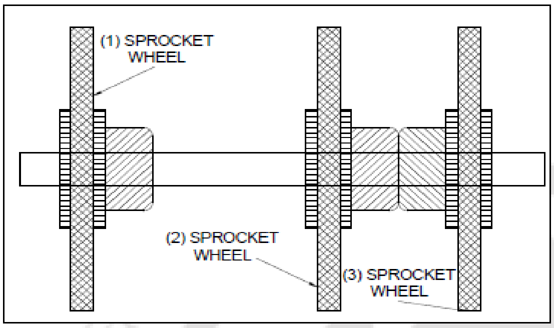
Figure 4.13: Prototype of Cross Trainer mechanism for rear rider (attendant).
Source of Photographs: Author

When maximum effort is required, the rear person can use both his hands and legs to propel the vehicle, facilitate by incorporating an exerciser as shown in **Figure 4.7 (a)** and **Figure 4.13 (b)** with synchronous lower limb and upper limb movement [**Figure 4.11 (a)**]. At this stage, the final cross trainer mechanism using CAD modelling for the final prototype is shown in **Figure 4.13 (a)** and exploded view of CAD modelling is shown in **Figure 4.13 (c)**.

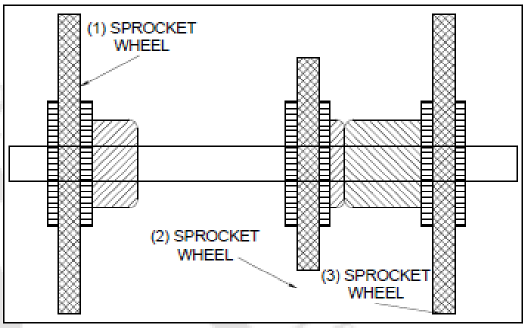
Based on actual testing of the products for various attributes, the design was finally modified for mass manufacturing using FRP moulding etc. The idea was for local assembly and manufacture through SMEs production facilities, a FRP component manufacture in various stages. Thus, decision making was easy task. The production planning phase for amphibian ambulance involves multiple steps. These are, however, similar to mass production industry such as production industry and in particular to amphibian vehicle industry.

4.3.5 Simulation of gear hub

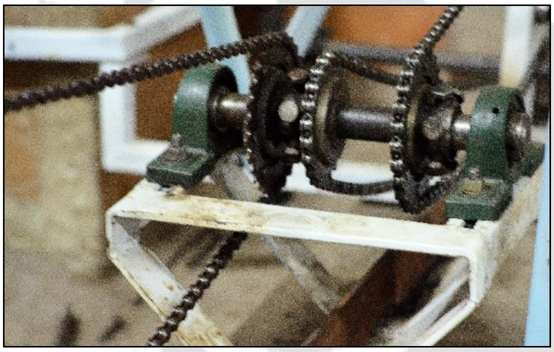
The gear hub [**Figure 4.14 (c)**] was made using Mild Steel flat bar of dimension (50 mm x 5 mm). A V-shaped [**Figure 4.14 (d)**] form of design was proposed to optimise product cost. The metal bars were cut according to the dimensions and are welded to the mainframe. The gear hub has to be strong enough to hold the sprocket gear along with the jackshaft and the bearing housing.



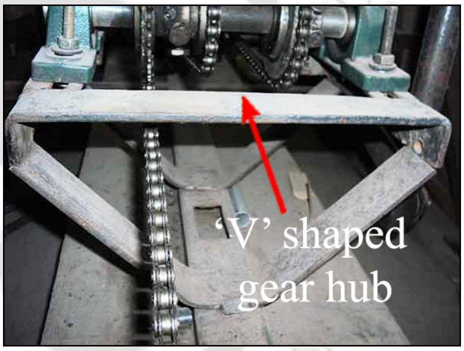
(a): Arrangement of sprockets before being machined.



(b): Arrangement of sprockets after being machined.



(c): Gear hub along the Jackshaft.



(d): 'V' shaped gear hub

(e): Chain drive on gear hub

Figure 4.14: Gear hub and chain assembly.

Source of Photographs: Author

But after assembling the chain into the sprockets and the crank had some alignment problems causing the chain to break when the pedal is rotated at higher speed than a specified speed. The distance between the two sprockets [**Figure 4.14 (a)**] is reduced by machining the bolted section of one of the sprockets hub and fixed and tightened with the same set of bolts on the second sprocket [**Figure 4.14 (b)**]. This modification was chosen because the free play of both the sprocket is on the same side and, therefore, the motion of sprocket will not restrict the motion of the other.

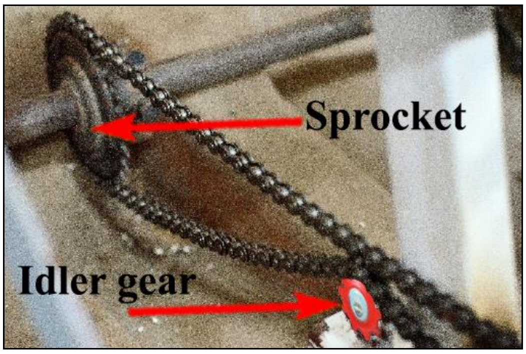
For propelling the amphibian ambulance, the chain drive along with sprockets was utilised [**Figure 4.14 (e)**]. The fundamental operation of this mechanism is that it comprises of a tandem cycle frame, where two riders give the required movement compounded to the rear wheels. It consists of two cranks assembles which are coupled to three sprocket wheels via an endless chain that connects with rear wheel axle [**Figure 4.15 (a)**]. The front crank transmits its motion to sprocket gear hub [**Figure 4.14 (c)**].

To propel the vehicle a chain drive mechanism was used. Front and rear rider applying forces through an individual set of the pedal was transmitted to a jackshaft held on a gear hub [**Figure 4.14 (c)**] with the help of bearing. One of the jackshafts is mounted on three sprockets, which are connected to front and rear crank and the rear axle which drives the vehicle. The degrees of freedom included in this upper limb model are those considered most significant in accounting for motion of the upper limbs performing arm-cranking tasks.

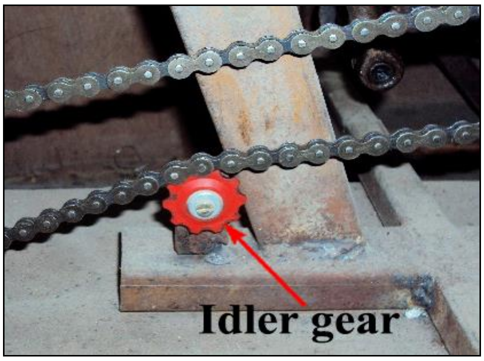
4.3.6 Simulation of idler gear

Idler sprockets are used to reduce the slack in the chain. In amphibian ambulance design the idler is used to compensate for the imposer placement of the rear axle gear housing causing the chain from the jackshaft to the sprocket [**Figure 4.15 (a)**] of the rear axle to clash with the chassis. The idler is mounted on the mainframe with the help of metal clamp.

The clamp was L- shaped and was welded to the mainframe. The idler was bolted to clamp [**Figure 4.15 (b)**]. The chains were finally mounted on the sprockets on the jackshaft and on the rear axle and checked for alignment of the sprockets and crank wheel. The detail dimension and breaking loads of roller chain is stated in **Table 4.2**. The idler was also checked for its motion to the sprockets.



(a): Rear free wheel sprocket and idler gear.



(b): Idler gear placed between rear free wheel gear and intermediate shaft.

Figure 4.15: Mechanism of Idler gear and sprockets.

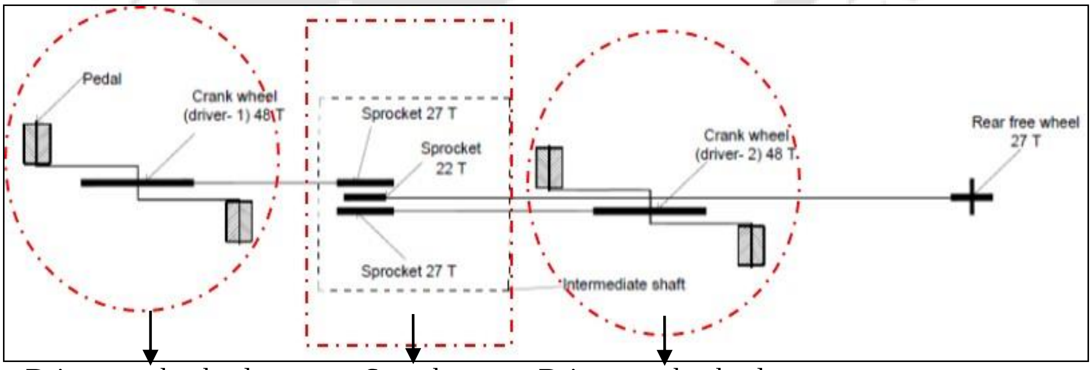
Source of Photographs: Author

4.3.7 Alignment of chain and sprocket

The gear ratio was reduced with the introduction of an intermediate shaft and two additional sprockets. Thus, **Table 4.3** and **Figure 4.16** provide details of the same.

Table 4.2: Dimensions and breaking loads of roller chain 06A (ANSI-40) (www.dimondchain.com, 2012).

ISO chain number	Pitch, p (mm)	Roller dia. dl (mm)	Width, b1 (mm)	Transverse pitch, p1 (mm)	Breaking load (min) N		
					Simple	Duplex	Triplex
08a (ansi-40)	12.70	7.98	7.85	14.38	13800	27600	41400



Driver crank wheel Sprocket Driver crank wheel

Figure 4.16: Systemic diagram of layout of gears and pinions for gear reduction.

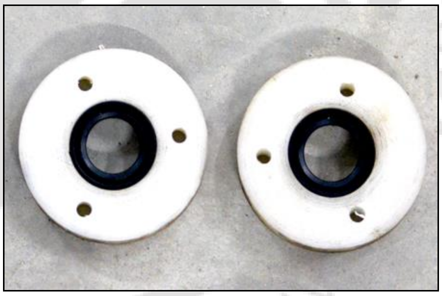
Table 4.3: Possible gear ratio with and without intermediate shaft.

Number of full pedaling	Teeth on crank wheel	Teeth on rear axle free wheel	Intermediate shaft		Gear Ratio	Distance covered in meter in 1 rotation of pedal	Number of pedaling to cover 1 Km	Pedaling per minute to achieve 10 Km per hour speed
			Teeth on driver wheel	Teeth on driven wheel				
1	48	18	-	-	2.667	5.96	168	28
1	48	20	-	-	2.4	5.96	187	31
1	48	22	-	-	2.182	4.88	205	34
1	48	27	-	-	1.777	3.97	252	42
1	48	~~27~~	~~27~~	~~22~~	~~2.182*~~	~~4.88~~	~~205~~	34
1	48	22	27	22	2.68	5.97	168	28
1	48	27	22	27	1.45	3.23	310	52
1	48	~~22~~	~~22~~	~~27~~	~~1.777*~~	~~3.97~~	~~252~~	42

4.3.8 Oil seal

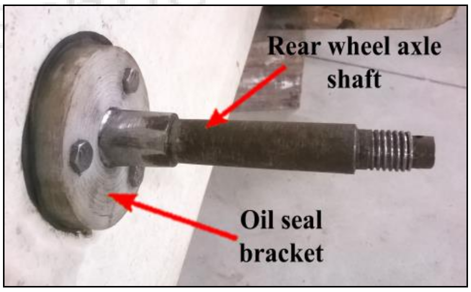
The catamaran type hull of the ambulance requires displacing of water to float and sail. This results in submerging the wheel shaft in water and yet the water outside the hull should not enter the catamaran type hull from any opening for wheel axle.

(a): An oil seal of 25 mm inner and 35 mm outer diameter.



(b): Oil seal mounted in bracket after machining.

(c): Rear wheel shaft before fixing the oil seal.



(d): Rear wheel shaft after fixing the oil seal.

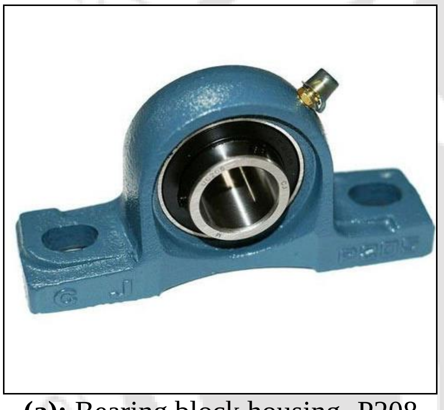
Figure 4.17: Oil seal with bracket at rear wheel shaft.

Source of Photographs: Author

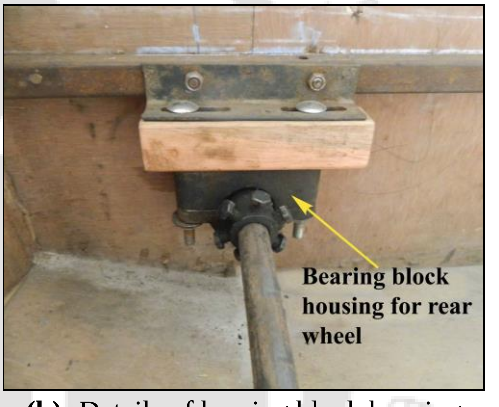
Thus, a conventional oil seal is shown in [**Figure 4.17 (a)**], which was fixed with nylon bracket [**Figure 4.17 (b)**] to the hull for the rear wheel shaft to provide water tight sealing to prevent water from outside the hull seeping in through the holes provided for the wheel axle shaft. The various stages of the oil seal which were fixed with the rear wheel shaft are shown in **Figure 4.17 (c)** and **Figure 4.17 (d)**.

4.3.9 Bearing block housing

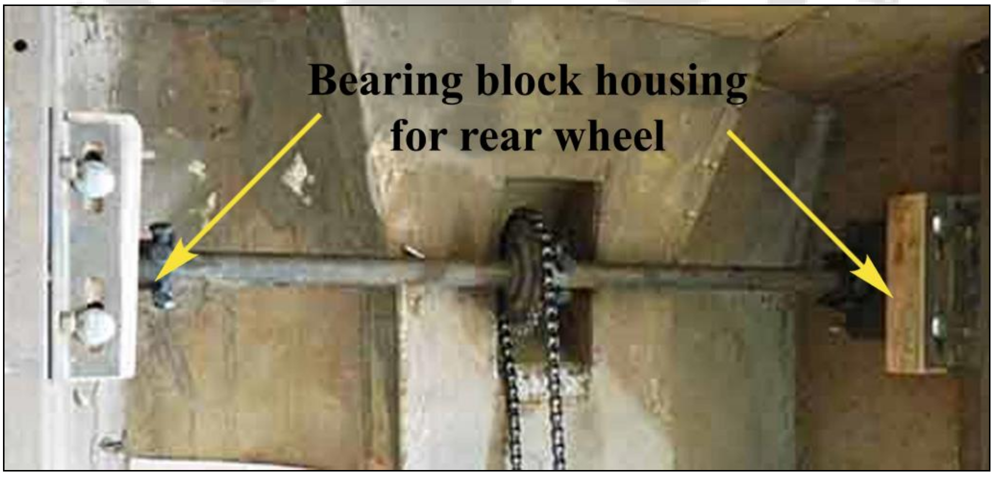
Two numbers of bearing block housing- P208 [**Figure 4.18 (a)**] and [**Figure 4.18 (c)**] were used to hold the rear wheel axle shaft of the amphibian ambulance. The bearing block housing mounted on a piece of structure and support (made of wood) is offset below to the rear wheel axle shaft and the bearing block housing mounted on the chassis of the amphibian ambulance [**Figure 4.18 (b)**].



(a): Bearing block housing- P208



(b): Details of bearing block housing mount on the chassis.



(c): Wheel shaft placed with two bearing block housing.

Figure 4.18: Bearing block housing for the rear shaft.

Source of Photographs: Author

4.3.10 Design of paddle wheel

Amphibian ambulance requires moving on water for which an appropriate water propulsion system needs to be integrated with the vehicle. Since the vehicle has been designed as a low speed human powered one, it was thought to be prudent that rotary type screw propeller requiring high RPM will not be an appropriate one. Drawing from the inspiration of duck's feet, paddle wheel was selected to be the best solution in the context of use. The paddle wheel is a device for conversion of motion of a shaft to linear motion of a fluid and vice versa. In the linear-to-rotary direction, paddle wheel is placed in a fluid stream to convert the linear motion of the fluid into rotation of the wheel. This rotation can be used as a source of power, or as an indication of the speed of flow.

Paddle wheel

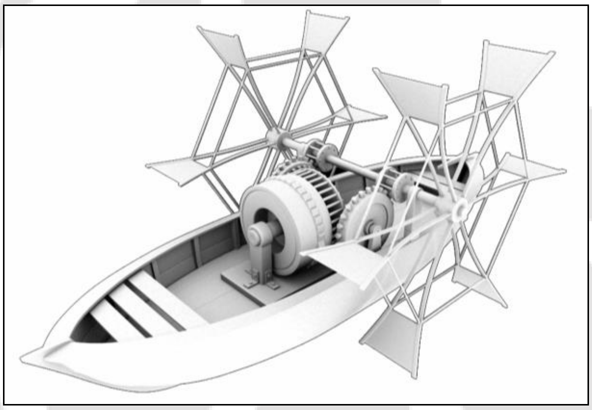
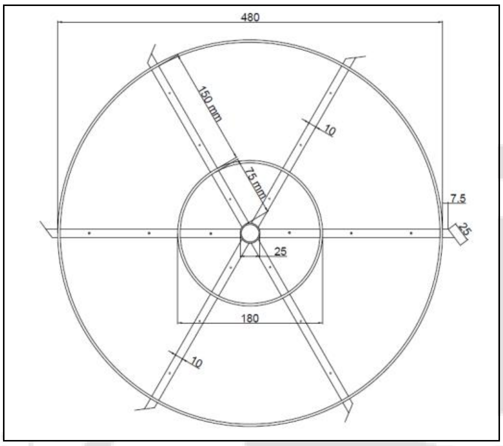


Figure 4.19: Da Vinci's feathering paddle boat (SimplyMaya, 2012).

A paddle wheel is a form of waterwheel used from ancient times. Italian Renaissance man Leonardo da Vinci invented this paddle boat (**Figure 4.19**). These type of paddle wheels were used for harbour craft that needed to move through narrow channels and docks.

In the present case, it is a steel framework where outer edge of the wheel is fitted with required numbers of paddle blades (also called floats or buckets) spaced regularly at the peripheral. The lower part or bottom of the wheel is kept submerged in water and when the paddle wheel is rotated in the water, it produces thrust to propel the vessel. In this type of simple paddle wheel, where the paddles are fixed around the periphery, some amount of thrust power is lost due to churning of the water as the paddles enter and leave the water surface. To obtain higher efficiency, ideally, the paddles should remain vertical while under water. More advanced paddle wheel designs feature feathering methods that keep each paddle blade closer to vertical while in water to increase efficiency. This ideal condition can be achieved by use of levers and linkages connected to a fixed eccentric which is fitted slightly forward of the main wheel centre. This mechanism is coupled to each paddle via a rod and lever. The profile of the eccentric is designed to keep the paddles almost vertical for the short duration of time and paddles are in the water provide ideal linear thrust rather than churning the water.



(a): CAD drawing of radial paddle wheel design.

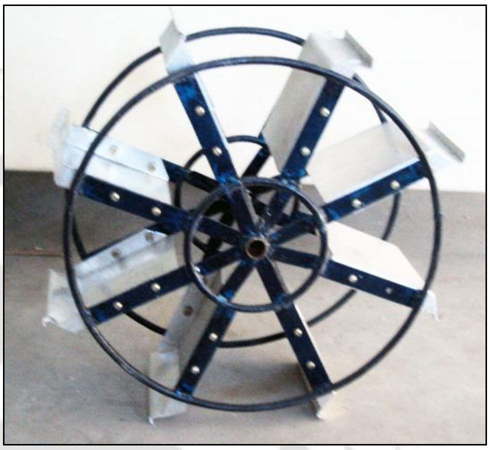
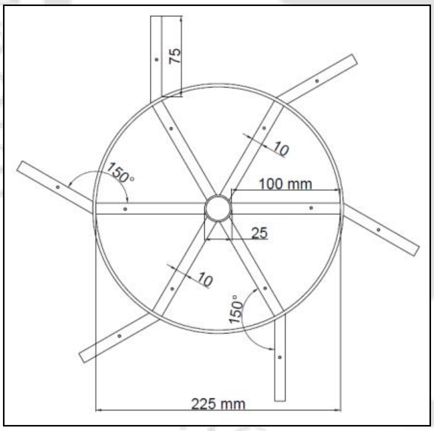


Figure 4.20 (b): Radial paddle wheel is suitable for low speed sail boat.



(c): Design of feathering paddle wheel using CAD.

(d): Feathering paddle wheel design with angular paddle.

Figure 4.20: Propulsion system for amphibian ambulance in water.

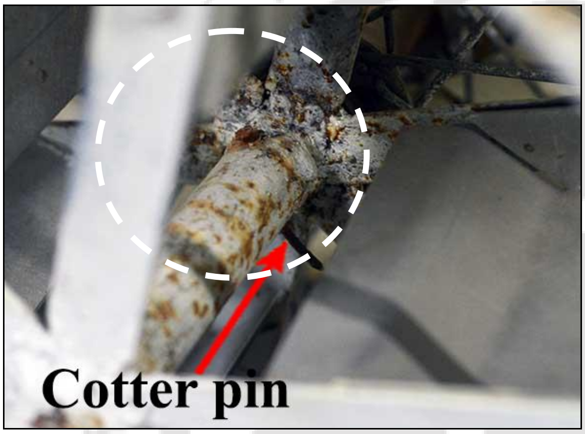
Source of Photographs: Author

Instead of using two rear sides paddle wheel drive for separate water propulsion system, 27.5 cm diameter joinery was designed for the paddle wheels for easy attachment and removal on to the existing rear wheel shafts without removing the existing rear wheels used for movement on land. Thus, the paddle wheels used as propulsion system in water are integrated with the rear drive shaft. This facilitates efficient transfer of power from the foot pedals to the propulsion system and thus the amphibian ambulance is able to move forward and reverse in water.

To minimise splashing, the upper part of the paddle wheel is normally enclosed in an enclosure called as paddle box. However, to keep the design simple, feathering paddle wheel is not considered but instead design of the paddle wheels have been changed from straight [**Figure 4.20 (b)**] to angular ones [**Figure 4.20 (c)**]. In fact, initially paddle wheels for the amphibian ambulance were straight [**Figure 4.20 (a)**] which after initial trial was modified to angular ones [**Figure 4.20 (d)**].

4.3.11 Mounting and removal of the paddle wheel

The paddle wheels of the amphibian ambulance are fitted to the rear wheel shaft.



(a): Cotter pin placed in the wheel shaft for fixing the paddle wheel.

(b): Removing paddle wheel from the wheel shaft with anti-clock wise rotation.

(c): Removing the paddle wheel from the wheel shaft.

Figure 4.21: Process of removal of paddle wheel from the rear wheel shaft.

Source of Photographs: Author

A cotter pin was inserted on both sides into the hole of the rear shaft axle until the head of the cotter pin rests against the rear shaft axle where fixed the paddle wheel is shown in **Figure 4.21 (a)**. The feathering paddle wheel was mounted to the rear wheel, which in turn was mounted to the rear wheel shaft axle. The paddle wheels have directional and positional movement on the wheel shafts axle. Directional movement means that the paddle wheels are made to rotate only in one direction, whereas positional movement means that the paddle wheels are designed to mount only a certain corner of the wheel shaft axle of the amphibian ambulance.

Removing and installing the paddle wheel and rear wheel, it is important to tighten the lug nut and cotter pin down off using a pattern and torquing them to specifications. Failure to do, both wheel and paddle wheel come off the amphibian ambulance while driving on land and in water. In this case the paddle wheel attached on wheel shaft with anti-clockwise rotation [**Figure 4.21 (b)**]. The process of removing the paddle wheel from the wheel shaft axle is also followed anti-clock order [**Figure 4.21 (c)**].

4.3.12 Removal of the rear wheel

The rear wheel of the amphibian ambulance was adopted from the Dipbahan tricycle rickshaw. For the removal of the sets of wheels, amphibian ambulance is required to be moved to a flat surface and a wedge shaped piece of wood or similar item is required to be placed in front of and at the back of the wheel that is diagonally opposite across from the one being changed to keep the vehicle from rolling. After that, a jack can be placed below the vehicle and the vehicle raised slowly [**Figure 4.22 (a)**]. It is to be ensured that the vehicle does not roll away as the wheel taken off. Dull wrench (double open end spanner) or ring wrench can be used to loosen wheel and remove hub nut. Once wheel to be replaced is removed and a spare wheel fitted, the operation can be reversed, vehicle lowered from the jack and jack stored in its proper location in the vehicle’s toolbox. At this stage, the various process of removing the rear wheel from the wheel shaft with anti-clockwise rotation is shown in **Figure 4.22 (b)** and comes out the rear wheel from the wheel shaft axle [**Figure 4.22 (c)**].

(a): Wooden stool used as a jack.

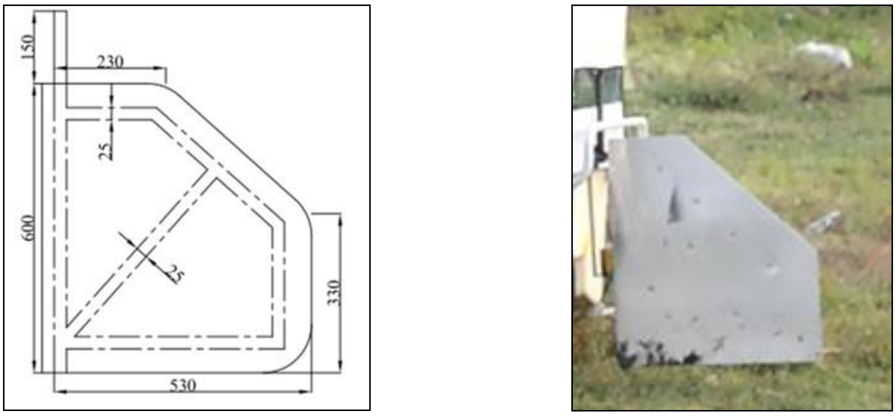
(b): Removing rear wheel from the wheel shaft with anti-clock wise.

(c): Removing the rear wheel from the wheel shaft.

Figure 4.22: Process of removing rear wheel from the wheel shaft.
Source of Photographs: Author

4.3.13 Design of rudder and rudder steering

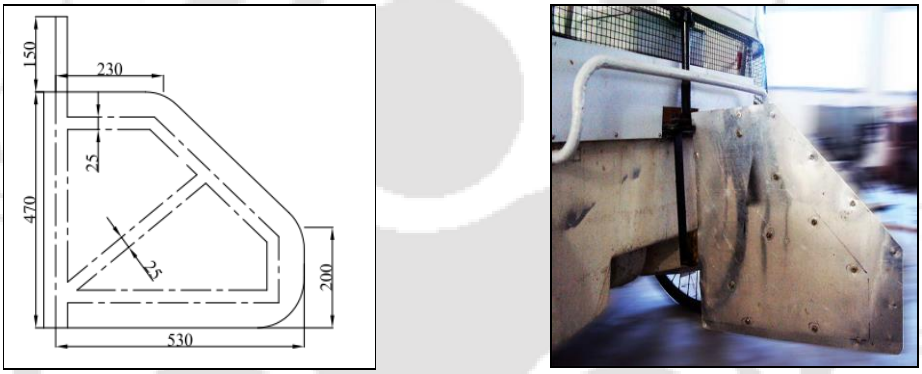
The rudder of the amphibian ambulance was placed in the rear end of the vehicle, outside the catamaran type hull. The vehicle steers utilising the rudder in water. A rudder is a vertical, blade like appendage which is mounted on the rear end of the catamaran type hull. The rudder works by deflecting the water flow. When the rudder moves in the direction of lower pressure, the vehicle turns. A detail drawing in CAD is shown in [**Figure 4.23 (a)**] along with physical prototype which is shown in [**Figure 4.23 (b)**]. During the initial testing of the amphibian ambulance in water the size of the rudder was found to be bigger than necessary and was touching the bottom of a shallow water body and it was modified later [**Figure 4.24 (a)**] and [**Figure 4.24 (b)**].



(a): CAD drawing of rudder as per the low speed sail boat.

(b): Prototype of the rudder as per low speed sail boat.

Figure 4.23: Initial design of the rudder.



(a): Modified CAD drawing after field trial.

(b): Modified rudder after field trial.

Figure 4.24: Modification of rudder design after trial.
Source of Photographs: Author

The whole rudder steering mechanism is a cable driven cross- bar system. This type of system is commonly used in catamaran type sailboat. This system is not fully safe as a push- pull system because of the safety as the system depends on the cable tension.

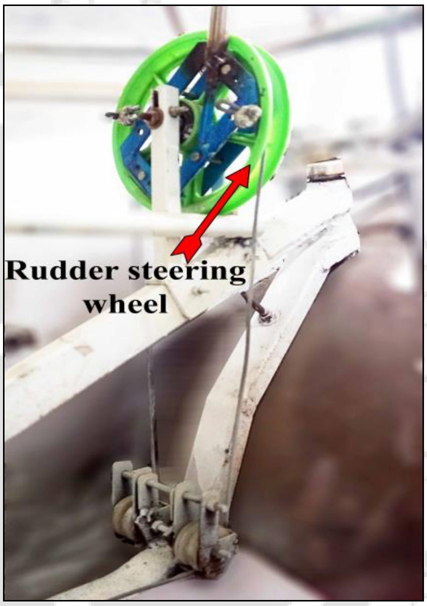
The rudder assembly is made out of following components.

- The rudder is associated with a T- shaped quadrant plate [**Figure 4.25 (d)**], which is pivoted along with a 35 mm hollow bar.
- The quadrant plate integrates a tiller arm for the wire cable and wire cable is actuated with the rudder steering pilot drive unit [**Figure 4.25 (b)**] which is placed on pedestal head between main front wheel steering and the rider saddle.

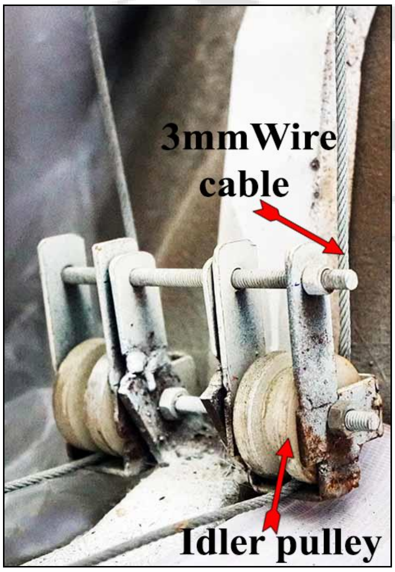
- A 15 mm hollow stainless steel bar (650 mm) [**Figure 4.25 (a)**] is placed with nut and bolts with the rudder steering pilot drive which can easily operate the pilot drive from the front rider saddle.
- The full mechanism of the rudder steering is shown schematically [**Figure 4.25 (e)**].

The cable system driving on idler pulley [**Figure 4.25 (c)**] runs a push pull system. Total 12 units of idler pulley are placed in equal distance.

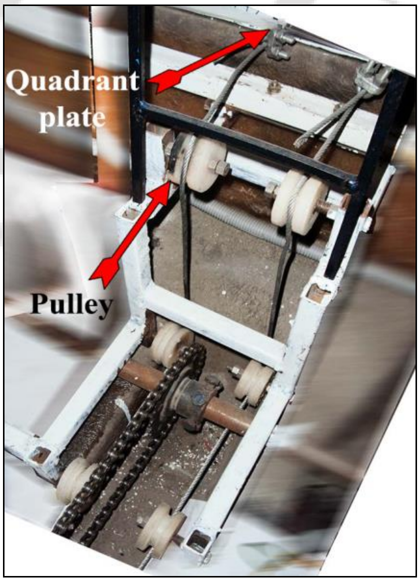
(a): Steering pilot drive (green coloured wheel) on the pedestal head.



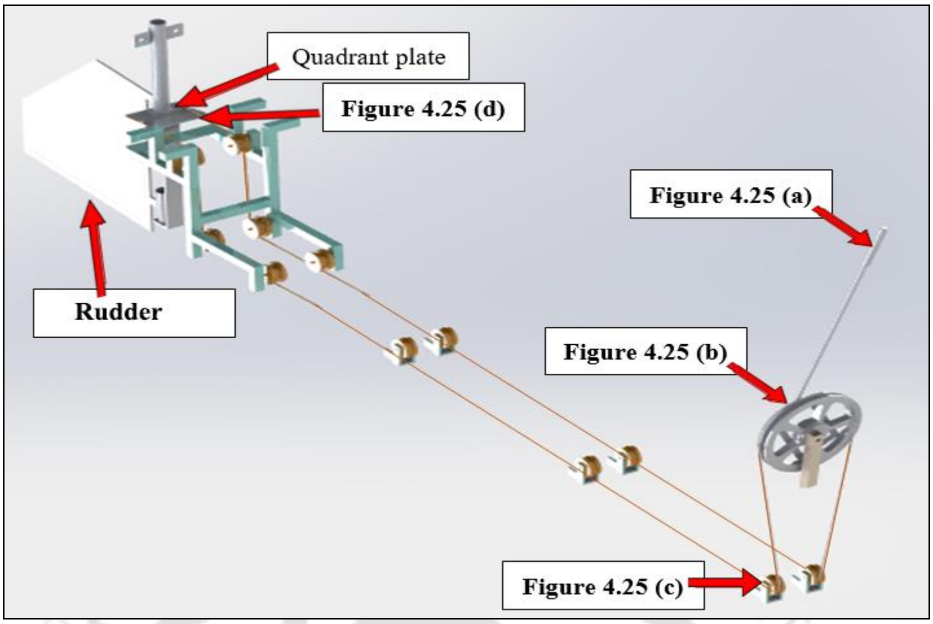
(b): 3mm wire cable wrapping around the rudder steering wheel.



(c): Wire cable runs through the idler pulley.



(d): Wire cable connected with the tiller arm of quadrant plate.



(e): Full mechanism of rudder and rudder steering.

Figure 4.25: Various sub-systems of the rudder steering.

Source of Photographs: Author

Test for ease of rotation of the rudder

During the field trial in water, the rudder of the amphibian ambulance was turned smoothly from stop to stop. The movement is maximum 35-degree to either side of centre which is desirable for smooth action in water. During the trial in water it has been checked that when the rudder moves towards the left direction, amphibian ambulance turns right direction [**Figure 4.26 (a)**] and vice versa [**Figure 4.26 (b)**].

(a): When rudder moves left direction, amphibian turns right direction.

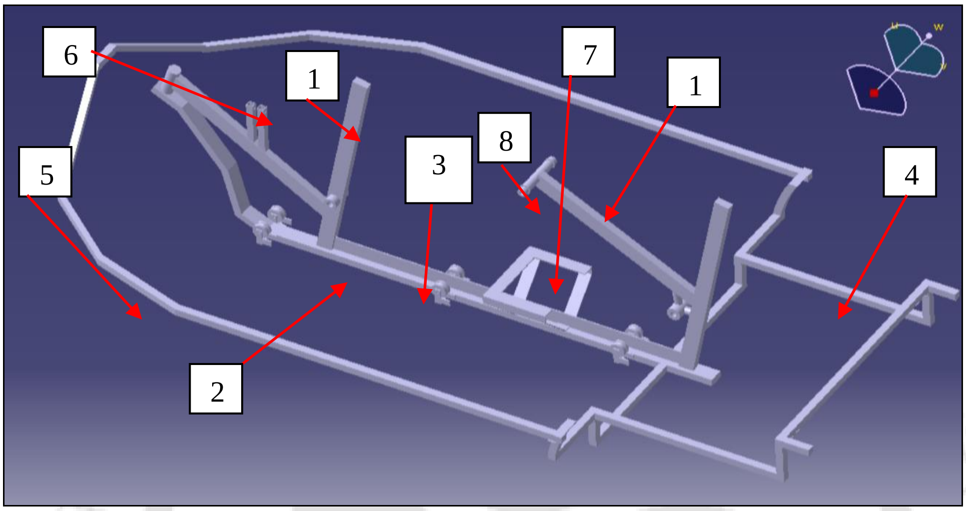
(b): Amphibian ambulance turns left direction.

Figure 4.26: Test of rudder movement.

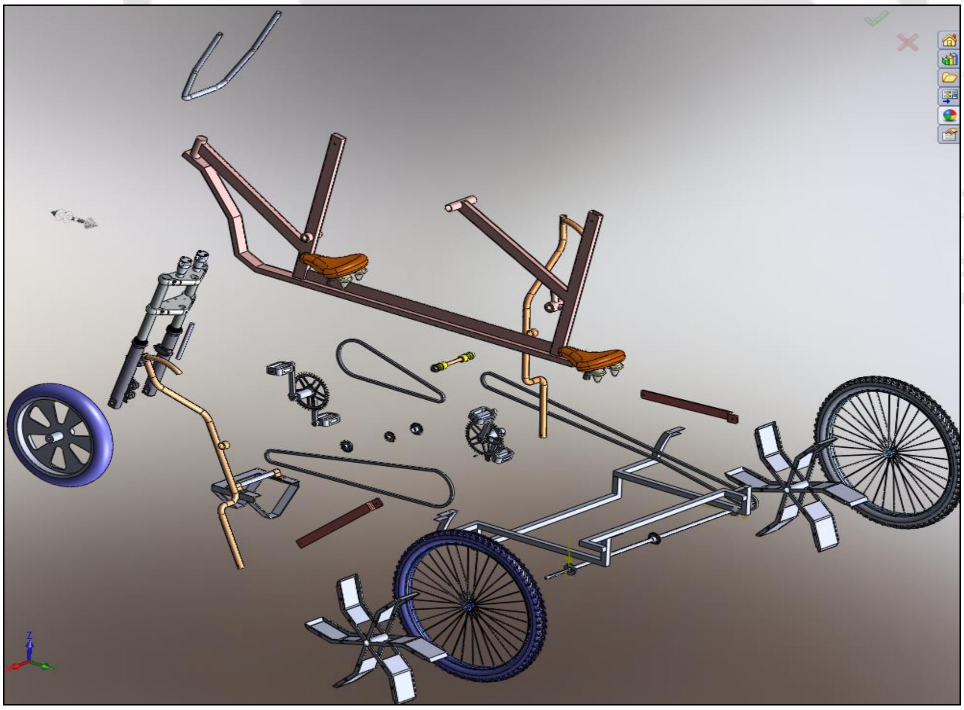
Source of Photographs: Author

4.3.14 Design of physical life to match anticipated service life

There are propulsion and transmission system, tyre and tubes, sprockets and chains, brake pads, foot pedal, propeller, rudder etc. Chassis and mainframe is an integrated piece made out of following components and mentioned as components in [**Figure 4.27 (a)- Figure 4.27 (b)**].



(a): Integrated mainframe and chassis



(b): Exploded view of systems and subsystem in the amphibian ambulance.

Figure 4.27: CAD modelling of integrated mainframe and chassis.

1. Four pieces of M.S. (50 x 25 mm) rectangular tubular sections of 2 mm thick are used for prototyping the saddle frame of the rider and attendant.

2. One piece of M.S. (50 x 25 mm) rectangular tubular section of 5 mm thick flat bar is used at the bottom part of the chassis main frame.
3. One flat bar of M.S. (40 x 5 mm) flat bar of 150 mm in length is used for strengthening the chassis main frame.
4. Three pieces of M.S. (25 x 25 mm) square tubular section of 2 mm thick are used for block bearing attachment bracket.
5. Three pieces of M.S. (33 x 35 mm) square tubular section of 3 mm thick are used alongside the catamaran type hull.
6. One small piece of M.S. (15 x 15 mm) square tubular section of 2 mm thick is used for making the pillar of rudder steering wheel.
7. One L- section of M.S. (25 x 25 mm) of 3 mm thick bar is used for manufacturing the V- shaped gear hub.
8. One round tubular bar of 35 mm diameter is used for handlebar in the attendant position.
9. Two sets of bottom bracket with spindle are placed in the shell in the tandem tricycle chassis.

All these components were adopted from the tricycle rickshaw and expected to meet the target life of the product which is shown in **Figure 4.28**.

Figure 4.28: Integrated mainframe and chassis placed in the amphibian ambulance.

Source of Photographs: Author

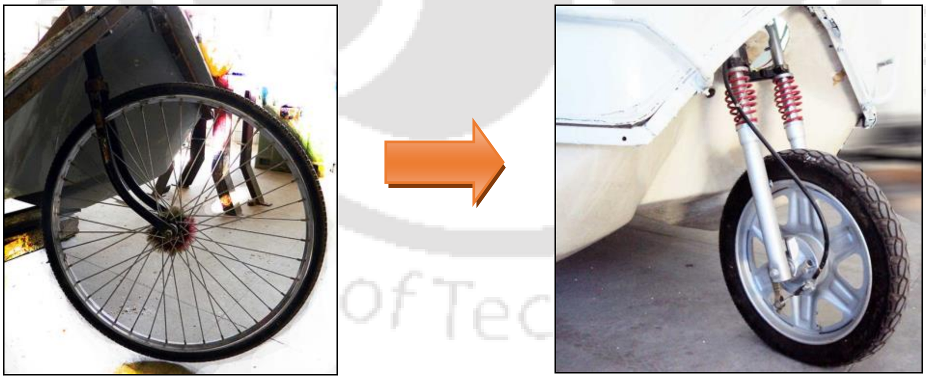
4.4 Design for consumption

4.4.1 Design for maintenance

After completion of the assembly of different parts of the drive system and joining it to the main frame, the system is checked for its maintenance. Two riders occupied the two saddles provided there and accelerated it at the same time with front rider steering the vehicle and the rear rider utilising his hands to steer the handlebars of the tandem tricycle mechanism of the drive system. The working of the drive system is checked for the various speed of the revolution of the pedals, and handlebars are checked for maximum travel and it tried to find out if the most extreme travel speed is inside the scope of the back rider.

4.4.2 Design for reliability

The amphibian ambulance is an innovative design. Therefore, use of every part and sub-systems were considered and designed as per the research and development standards. Various sub-systems and components in their manufacture and fabrication process were standardised. Standard parts were selected from existing tricycle rickshaw component manufacturing units and front wheel assembly was sourced from traditional tricycle rickshaws front wheel and steering system along with braking system [**Figure 4.29 (a)**].



(a): Front steering before modification (from traditional tricycle rickshaw).

(b): Front steering after modification (from E rickshaw).

Figure 4.29: Front steering before being modified and after modification
Source of Photographs: Author

Once amphibian ambulance was prototyped, this was tested on land. The reliability of product was improved through field trial when failure of mechanisms was identified and modified through the actual design and development process. Thus front wheel steering system was modified from initial design that used traditional tri-cycle rickshaw’s front wheel and steering system along with braking system [**Figure 4.29 (b)**] to one from available E rickshaw since initial design could not bear the load of the amphibian ambulance and the steering was difficult.

4.4.3 Design for convenience in use (considering human factors)

The anthropometric data are concerned with methods of designing machines, operations, and workplace. So, they coordinate the capabilities and limitation of human operators. Hence, equal importance was given to human part and man- machine framework.

- Fitting the assignment to man.
- Expanding wellbeing and diminishing chances of mishap and adverse effect.
- Expanding efficiency of man-machine operation.
- Expanding productivity
- Expanding human comfort
- Improving effort required to work the machine.

In the vehicle, there are three components, the rider, attendant, and patient. The objectives set for the ambulance to achieve were as under:

- Features of the ambulance should go along with relevant ergonomics criteria for making progress towards meeting different necessities. Simply it should provide easy facility for the riders and the patient to get in and out of the ambulance effectively. During operation, sitting ought to be comfortable. The anthropometric ergonomic data for a newly designed amphibian ambulance were stated in **Table 4.4**.
- It should provide safety protection to a rider, attendant, and patient.
- Keeping the present day riverine healthcare transportation needs the new appropriate design and technology be used for amphibian vehicles.
- It ought to provide appropriate space for the user to carry first-aid equipment.

Table 4.4: Anthropometric ergonomic data for a newly designed amphibian ambulance (Chakrabarti, 1997).

Parameters	Percentile		Preferable/ recommended	Amphibian ambulance
	5th percentile combined	95th percentile combined	Man and women combined	
Heights from sitting surface				
Normal sitting- Top of the head, sitting in normal relaxed posture.	715	886	805 - 50 50th percentile 857- 75th percentile	990 distance from seat to hood
Erect sitting - Top of the head, sitting in erect stretched posture.	738	901	824 - 50th percentile	990 distance from seat to hood
Eye- Inner corner of the eye.	623	796	723 - 50th percentile	
Cervical (trunk) - Most prominent spinouts process of the seventh cervical vertebra.	531	667		
Mid shoulder- Uppermost point	499	630	566 - 50th percentile 594 - 75th percentile	430 seat back height
Acromion- Most lateral point on the superior surface of the acromion process of the scapula.	475	603		430 seat back height
Upper Lumber- Uppermost point of the first lumber vertebra	246	352	298 - 50th percentile 317 - 75th percentile	430 seat back support
Lower lumber- Lower most point of the first lumber	72	159	72 - 50th percentile	430 seat back support
Tip of shoulder blade- Tip of the shoulder blade (scapula).	350	470	411 - 50th percentile	430 seat back support
Elbow rest- Lower most part of the elbow.	150	268	210 - 50th percentile 234- 75th percentile	190 hand rest

Table 4.4: Anthropometric ergonomic data for a newly designed amphibian ambulance (Chakrabarti, 1997).

Parameters	**Percentile**		**Preferable/ recommended**	**Amphibian ambulance**
	5th percentile combined	95th percentile combined	Man and women combined	
Heights from floor				
Knee height- Uppermost point on the knee (at lower thigh).	456	563	590 - 50th percentile	
Popliteal height- Popliteal angle point at the underside of the thigh immediately behind the knee, where the tendon of biceps femoris muscle inserts into the lower leg.	374	466	399 - 50th percentile 439- 75th percentile	430 seat height
Vertical upward arm reach from seat surface- Maximum vertical distance from the seat surface to the tip of the middle finger when the hand is raised upward vertically to the highest position attainable without strain.	1120	1414		
Lengths				
Buttock to knee length seating- Horizontal distance from the most posterior point on the uncompressed buttocks to the most anterior point on the knee (Knee at right)	479	613		820 clearance between the passengers and the puller's seat
Buttock to popliteal length, normal seating- Horizontal distance from the most posterior point on the uncompressed buttock to the back of the lower leg at the knee, i.e. the popliteal angle point (knee at right angle).	394	509	451 - 50th percentile	513 seat depth
Buttock to leg length, normal seating- Horizontal distance between the most posterior point on the uncompressed buttocks and the trip of the longest toe, when the legs are placed on the floor with the knee at an angle 90 degrees.	540	779	779 - 95h percentile	855 floor board length

Table 4.4: Anthropometric ergonomic data for a newly designed amphibian ambulance (Chakrabarti, 1997).

Parameters	Percentile		Preferable/ recommended	Amphibian ambulance
	5th percentile combined	95th percentile combined	Man and women combined	
Buttock to leg length while raised on toe- Horizontal distance, perpendicular to the trunk, between the most posterior point on the uncompressed buttock and trip of the longest toe, when legs are extended horizontally and the maximum height keeping the toes on the floor.	559	759		
Buttock to leg length while raised on toe- Horizontal distance, perpendicular to the trunk, between the most posterior point on the uncompressed buttock and trip of the longest toe, when legs are extended horizontally and the maximum height keeping the toes on the floor.	559	759		
Buttock to extended (rested on the floor) leg comfortable length- Horizontal distance, the most posterior point on the uncompressed buttock and the tip of the longest toe, when the legs are extended to the maximum keeping the heels and toes on the floor.	739	1069	979 - 75th percentile 905 - 75th percentile	855 floor board length
Buttock to leg, full extended length- Horizontal distance between the most posterior point on the uncompressed buttocks and the tip of the legs are lifted from the floor, extended horizontally and stretched forward to the maximum perpendicular to the trunk.	941	1199		855 floor board length
Bi-deltoid breadth- Maximum horizontal distance across the shoulders, breadth measured to the protrusions of the deltoid muscle.	349	479	417 - 50th percentile 443 - 75th percentile	815 Double seat width

Table 4.4: Anthropometric ergonomic data for a newly designed amphibian ambulance (Chakrabarti, 1997).

Parameters	Percentile		Preferable/ recommended	Amphibian ambulance
	5th percentile combined	95th percentile combined	Man and women combined	
Hip breadth- Maximum horizontal distance across the hips.	269	406	406 - 95th percentile	815 Double seat width
Elbow to elbow (relaxed)- Horizontal distance across the lateral surfaces of the elbows when in maximum relaxed position, spreading sideways.	389	632	495 - 50th percentile 539 - 75th percentile	815 Double seat width
Knee to knee (relaxed) - Horizontal distance parallel to the long axis of the foot, from the back of the longest toe.	252	529	419 - 75th percentile	815 Double seat width
Foots length- Distance parallel to the long axis of the foot, from the back of the heel to the hip of the longest toe.	215	271	244 - 50th percentile	355 Double seat width
Foot breadth- Maximum horizontal distance, whenever found, across the foot, perpendicular to its long axis.	77	104	92 - 50th percentile	815 Double seat width
Seat inclination			0- 5°	5°
Leg inward			10°	10°
Stretcher	1771	1850	1700- 95th percentile	
Door Entry/exit	2350	1500		

- The dimension value for lumber support is arrived at the following formula: Lumber support recommended= (50th percentile Mid Shoulder height- 50th percentile (566-298)/2+298= 234+ 298= 432 mm ≈430 to 435

- As per the ergonomics criteria used in this thesis, some dimensions are based to accommodate 50th percentile population for both man and woman and some of these are for 75th percentile.

4.4.4 Balancing weight

First version of functional prototype of the amphibian ambulance was tested in the IIT Guwahati campus internal road. The ambulance was initially tested in the workshop of Department of Design, IIT Guwahati. Its weight was 225 Kg. The ambulance was dragged with a spring balance under different loading conditions and the results are compiled below **Table 4.5**:

Table 4.5: Comparative pulling force required to move the amphibian ambulance measured using spring balance.

Sl. no	Specification	Weight
1.	Weight of the ambulance (without person)	225 Kg
2.	Weight of the ambulance with persons	450 Kg
3.	Spring balance reading for dragging the empty vehicle	15 Kg
4.	Spring balance reading for dragging the vehicle with two persons (front rider and attendant)	15 kg
5.	Spring balance reading for dragging the vehicle with three persons (75 Kg x 3 nos.)	17 Kg

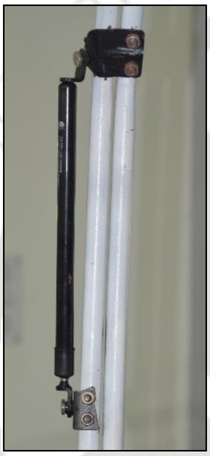
The results show that the vehicle is easier to drive. The amphibian ambulance inherently is stable during operation on the road due to the arrangement following by the 95th percentile anthropometric data and riding positions giving a proper CG. The findings are as under:

- The operation of the ambulance was found to be easy and comfortable by 95th percentile man as well woman.
- When the steering wheel is difficult to turn because of a problem with the front wheel steering system. The vehicle and its front wheel assembly has been installed from common tricycle rickshaw and the weight on the wheel is putting too much force for users to move singlehandedly.
- The brake assembly for front wheel did not properly work because the vehicle has too much momentum while driving the vehicle downhill.

4.4.5 Door opening latch

The design of the amphibian ambulance entry and exit door opening system that opens upward is shown in [**Figure 4.30 (b)**]. The upward opening system provides easier access for the stretcher to the vehicle in space, and in turn, allows less parking areas, and wider door opening by using more swinging configuration for the amphibian ambulance.

It gives more advantage for ambulance since they have much smaller exist opening than larger vehicles. It can also be able to open/ close the door without having hard push or slamming the doors [**Figure 4.30 (b)**]. It is safer and less costly. In case of a rollover emergency egress will be easier and more safe for the patient and riders. The uniquely designed door has one main component i.e., oil less spring shock absorbers [**Figure 4.30 (a)**] and [**Figure 4.32 (b)**]. The shock absorbers were sourced from the Maruti Alto car. Testing and validation of the ambulance door system at different operating positions is carried out and results prove that the system is reliable. A door handle is placed in the outer side of the door [**Figure 4.30 (c)**], the detail is shown in **appendix D**, p. 199.



(a): Alto car oil less spring shock absorber

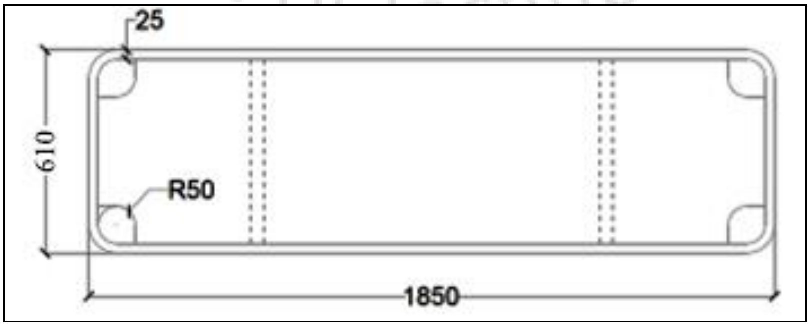
(b): Oil less **s**pring shock absorber used as door closure for vertically opening door.

(c): Door handle placed in the outer side of the door.
Figure 4.30: Door opening latches
Source of Photograph: Author

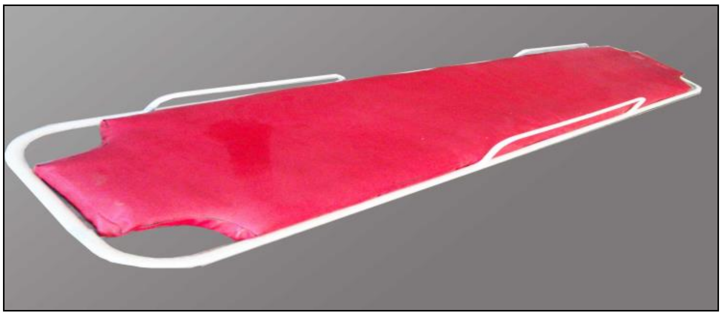
4.4.6 Stretcher design

The stretcher is main mobility aid for *Dola* amphibian ambulance. The stretcher including the mattress weights approximately 10 Kg and the overall dimensions of the stretcher are 1850 x 610 mm, which is enough for 95th percentile [**Figure 4.31 (a)**] of Indian people, and it is shown in **Figure 4.31 (b)**. The stretcher is rectangular with 50 mm diameter fillet corner, made from a 25 mm M.S tube. The stretcher mattress is made from rexine cloth and cotton foam [**Figure 4.31 (c)**] and two pieces of 35 mm sized rectangular flat bars are placed behind the stretcher top, that are welded to the outer frame. Four sliding pulley were fixed below the stretcher making them easily accessible in the amphibian ambulance [**Figure 4.31 (d)**].

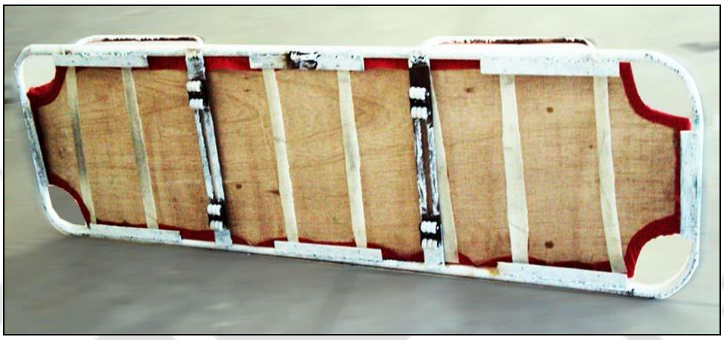
(a): A woman lying on the stretcher.



(b): CAD drawing of the stretcher.
(Note: All dimensions are in mm.)



(c): Top view of stretcher.



(d): Bottom view of the stretcher.

Figure 4.31: Design of the stretcher.
Source of Photograph: Author

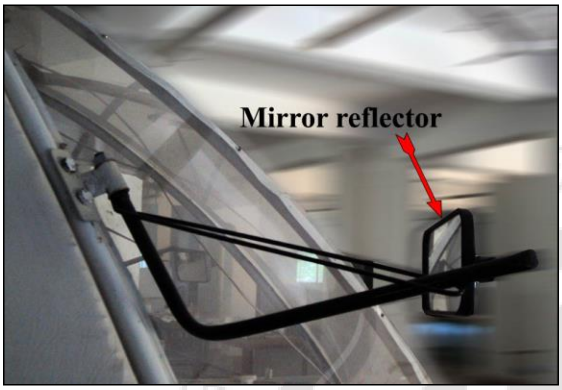
4.4.7 Design for aesthetic features

A product needs to be essentially aesthetic for enhanced acceptance and distribution (Chitale and Gupta, 1999). The aesthetic comes from a Greek word, is referred to as sensory perception and understanding or sensuous knowledge (Hekkert, 2006). In 18th century, German philosopher Alexander Gottlieb Baumgarten pointed out that the aesthetic had been part of philosophy. Perception of a new vehicle by a potential user usually happens from the outside to the inside through different levels of details. The first look catches the vehicle's body style and aerodynamic shape and proportion and their entry and exists in the vehicle. The set of objectives were set for the amphibian ambulance to be designed for aesthetic features and they are as follows:

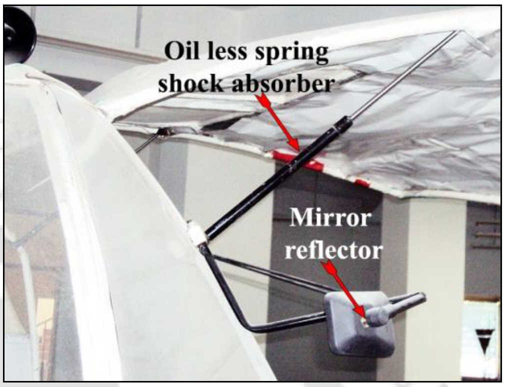
- It should have contemporary visual identity, massive and dynamic look.
- It should be expressed visually stronger but light in weight.
- Use of curvilinear form and colour to specify identity.
- It is a fully compact design where minimum requirements for carrying in an ambulance, such as fast aid box serve a patient in any situation.

- Flotation as well as wheel attached propeller driving on water for ease of transportation during any situation in riverine areas.

The outer line space structure of the amphibian ambulance forms a semi-ellipse, rods connecting the hood and each rod screwed with a transparent acrylic sheet for protection from wind and rain.



(a): Front mirror reflector with joining bracket.



(b): Front reflector and oil less spring shock absorber for entry- exit opening door.

Figure 4.32: Various aesthetic items of the amphibian ambulance.
Source of Photograph: Author

4.4.8 Design for operational economy

Since amphibian ambulance is a human powered vehicle several factors are mainly associated in terms of operational economy. The design has two principal components- lower half part is a catamaran type hull for floatation in water, which is made from FRP; and upper part is a tubular frame structure for protection from elements of nature. However, most of the components are locally available in the market commonly used for tricycle rickshaw and e- rickshaw. In the case of propulsion system on land and in water, it works very efficiently. The vehicle has a common propulsion and transmission system and serves for both land and water. Paddle wheel shaft assembly is connected to the main axle that in turn is connected to the pedals. Thus the paddle wheels rotate even when the vehicle is moving on land too. Based on these two aspects of propulsion of chain and sprocket system it is better and long lasting with an intermediate sprocket hub. In addition, it was noticed for each entry- exit door, two oil less spring shock absorber (telescopic) from the Alto car units fastened to a mounting bracket simply the upward and downward movement. Integrating cross trainer exerciser type peddling to assist the main rider by attendant facilitate ease of operation of the vehicle both on land

and water. This makes the newly designed amphibian ambulance work better in terms of operational economy.

4.5 Planning for retirement

The disposal of the product at the end of its life cycle is essential and require consideration during product development. For sustainable product development, reuse of different materials from retired product is another essential factor. Any consumer product needs to be retired because of either physical wear and tear or due to specialised outdated nature. Nothing much is possible about technical obsolescence but efforts can be made to reduce physical deterioration. In order not to incur extra cost for providing longer than useful life, a product should be designed to wear but physically at the same time, it becomes technically obsolete (Chitale and Gupta, 1999). An entire bargain between obsolescence and wear out is generally not possible because the elements of the design that contribute to a longer life of the product are also essential reliability and maintenance. To the product designer, the question whether to design to prevent physical deterioration or technical obsolescence is of fundamental important. An ambulance being a human powered vehicle of mass appeal, functionally useful, should be at a very low cost of ownership. Thus, designing to overcome physical deterioration played a more dominant role in the design of the Dola- amphibian ambulance. The impact on the amphibian ambulance is more immediate as an old structure or system must be replaced by a new one or by minimum disruption of normal operation, specifically concerning the retirement of a boat, tricycle trolley and other tricycles which are used in riverine areas. The values that are available when a product reaches a terminal point of service and influence of these values on design is the concern of the retirement phase of design. In case of the amphibian ambulance most of the metal components can be recycled safely and environment friendly way.

4.6 Design for safety

Designers need to cross- check product safety in a way to touch upon individual hazards within the context of overall usability (Li *et al.*, 2001). The amphibian ambulance must protect the users in an emergency situation from injuries in case of an accident where another vehicle passing on road hits it.

Various tests were done to find possible risks to determine the proper precautions when riding the vehicle on land and water. Safety considerations are shown in **Table 4.6**.

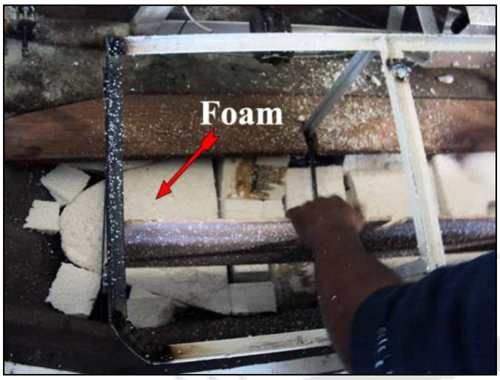
Table 4.6: Safety considerations for amphibian ambulance.

Sl. No.	Factors of risk	Precaution
1.	Vehicle could sink	Non- structured foam is placed in the void area of catamaran type hull and the buoyancy is tested properly. If water gets into the hull still it will float due to its bottom chamber creating enough buoyancy. Ensure riders can swim.
2.	Users could fall off the vehicle	Rider must always wear a buoyancy aid, while in water. Ensure rider can swim.
3.	Users could get their foot stuck in the chain	Make sure to enclose the chain to prevent the rider from sticking their foot anywhere near it.
4.	The transmission and propulsion could fail	Carry a set of oar on the amphibian ambulance when in water.
5.	Rider could flip the cycle over and not be able to get back on	Mechanical winch is placed in the rear end of the vehicle. Throw the rope to the bank of water body to pull the vehicle to safety.
6.	Rider could turn too fast, causing the vehicle to flip	Limit the steering to a specific angle (45 degree) and turning radius 2.9 m of turning to prevent the vehicle from getting out of control.

4.6.1 Buoyancy for anti- sinking using non- structured plastic foam in case of ambulance sinks

In the catamaran type hull of the amphibian ambulance, foam is used for flotation purposes in case of sinking situation in water. Foam is the form of non- structured plastic; it is available in blocks or sheets. The density of the foam refers to the weight of the foam per cubic foot of material. In addition, high density of foam does not allow it to absorb large quantity of water over a long period while using in water.

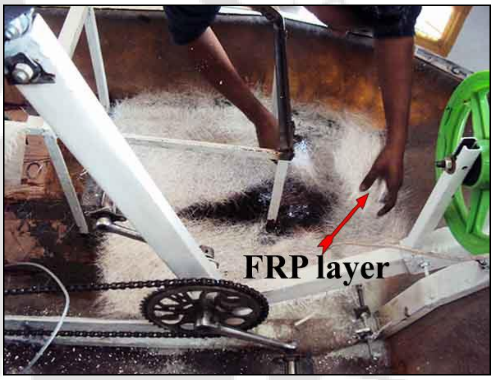
In the catamaran hull, the Pour- in- place foams in blocks were used in void areas for flotation of the amphibian ambulance. This type of blocks is not easily cut into pieces, since the hull is an irregular shaped area. After cutting of blocks, the pieces of foam were placed in all void areas filled with using Fevicol glues [**Figure 4.33 (a)**]. This type of foam is quite friable and crumbles easily, which causes a loss in bond and breakdown of the foam in high vibration. Usually this type of foam is found in powerboat. After finishing the stage of Figure 4.33 (a), a piece of 4 mm thick plywood was installed on the foam [**Figure 4.33 (b)**] for fixing the gaps between void areas of catamaran hull [**Figure 4.33 (c)**] then applied FRP on the plywood for fixing the gaps of void areas of the amphibian ambulance [**Figure 4.33 (d)**].



(a): Foam used in the void area of the hull.

(b): 4 mm thick plywood placed on the void area after putting pour- in-place foam.

(c): Fixing the gaps between void areas of the catamaran hull**.**



(d): Applying FRP on the plywood for fixing the gaps of void areas.

Figure 4.33: Filling the void with buoyant material in the hull.
Source of Photographs: Author

4.7 Assembly of functional prototype of the amphibian ambulance

4.7.1 Field trial of the amphibian ambulance

Once the functional prototype is ready, it is extensively tested by the user on land for its performance, stability, convenience, and comfort on road [**Figure 4.34 (a)**], [**Figure 4.34 (b)**], [**Figure 4.34 (c)**] and [**Figure 4.34 (d)**]. At this stage, a group of diverse background persons participated and consist of 10 persons (individual, students of mechanical engineering background, workers and security personals).

Smoothness in accelerating the ambulance, pedalling, comfortable sitting arrangement and the separation between the arms while holding the handlebars are some of the ergonomics factors checked for effective integration of the drive system. The mobility of the vehicle on land was found to be very good because of the effective steering mechanism, steadiness and comfortable seat position of both riders and stretcher position. In spite of the fact that the designed amphibian ambulance is heavier than a Dipbahan tricycle rickshaw or tandem tricycle, the intermediate gear hub facilitates the user with a comfortable move. On land, the vehicle is driven by rear side wheel sprocket. The ambulance does not drag to either side and there were no issues encountered with stability. The turning radius of the vehicle is essentially 2.9 metres. This is achieved by turning the rear wheel to its peripheral point.

(a): A person is riding the amphibian ambulance on land.

(b): Two persons operating the amphibian ambulance on land.

(c): Two persons sat comfortably before riding the amphibian ambulance.

(d): The front wheel fork was broken while being used by two persons in the second time.

Figure 4.34: Different views of the prototype during operation on land.
Source of Photographs: Author

Table 4.7: Standard items outsourced from existing - tricycle industry (price as on 01.05.2013) in Guwahati).

Sl. no	Description	Rate per unit ₹	Quantity	Amount ₹
1.	10 gauge wheel rim of 28” x 1 ½”	300.00	2 nos.	600.00
2.	10 gauge spokes 40 nos. x 2	5.00	80 nos.	400.00
3.	10 gauge back hub	120.00	1 pair	240.00
4.	Heavy duty tyre 28” x 1 ½”	320.00	3 nos.	960.00
5.	Rubber nylon tube	150.00	2 nos.	300.00
6.	Screw racer	80.00	1 set	80.00
7.	Ball racer	80.00	1 set	80.00
8.	¼ steel ball	16.00	1 packet	16.00
9.	Main axle	35.00	1 no.	35.00
10.	06 socket	70.00	2 nos.	140.00
11.	06 bearing	200.00	1 pair	400.00
12.	06 bearing block/housing	70.00	1 pair	140.00
13.	BB socket black	20.00	1 no.	40.00
14.	BB axel black	45.00	1 no.	45.00
15.	BB cup black	20.00	1 set	40.00
16.	Gear crank- 48T	190.00	2 sets	380.00
17.	Foot pedal	100.00	2 pedal	200.00
18.	Cotter pin	15.00	2 nos.	30.00
19.	5/4 ball centre	20.00	1 packet	40.00
20.	22 teeth sprocket	130.00	1 no.	130.00
21.	Freewheel plate 29 teeth	130.00	1 set	130.00
22.	Freewheel socket	40.00	1 no.	40.00
23.	Heavy duty chain	300.00	3 nos.	900.00
24.	10” seat pillar	45.00	2 nos.	90.00
25.	Seat pillar socket	15.00	2 nos.	30.00
26.	Saddle	130.00	2 nos.	260.00
27.	Heavy duty frame cup	160.00	1 set	160.00
28.	Frame socket	300.00	4 nos.	1200.00
29.	Rear side shaft axle	350.00	1 no.	350.00
			Total: A=	5906.00

Table 4.8: Items procured from e-rickshaw for the manufacturing of functional prototype (price as on 01.05.2015 in Guwahati).

Sl. No.	Description	Rate per unit ₹	Quantity	Amount ₹
1.	E- rickshaw front wheel assembly			7120.00
	Socket Jumper	1700.00	1 no.	
	Handle	500.00	1 no.	
	Handle bearing	280.00	1 no.	
	Handle T fork	1300.00	1 no.	
	Pneumatic tube	250.00	1 no.	
	Tyre	850.00	1 no.	
	Handle grip	200.00	1 no.	
	Front axle	290.00	1 no.	
	Front rim drum	490.00	1 no.	
	Front rim	1200.00	1 no.	
	Brake cable	150.00	1 no.	
	Rexine cloth for stretcher (Red)	150.00	1 metre	150.00

Sl. No.	Description	Rate per unit ₹	Quantity	Amount ₹
	Rexine cloth for hood (White)	150.00	15 metre	2250.00
2.	Aluminium mesh	90.00	8 metre	720.00
3.	Blue revolving light	500.00	1 unit	500.00
4.	Ambulance siren	200.00	1 unit	200.00
5.	Auto front light	300.00	1 unit	300.00
6.	Signal light (both side)	350.00	1 Pair	350.00
7.	Door wheel for stretcher	70.00	2 Pairs	140.00
8.	Red oxide primer colour	80.00	1 Litre	80.00
9.	Duco thinner	240.00	1 Litre	240.00
10.	Vihux putty with hardener for front facade	190.00 per can	200 gm	190.00
11.	3mm wire rope	40.00	10 metre	400.00
12.	Oil seal (R= 25 x35) mm	35.00	2 piece	70.00
13.	Screw (22 x 30 x 7mm)	2.00	43 piece	86.00
14.	Pop rivet	2.00	36 piece	72.00
15.	M.S. nut bolts	5.00	36 piece	180.00
16.	M.S. nut bolts (½”x ½”)	3.00	12 piece	36.00
17.	12 Volt battery 8 amh		1 unit	1450.00
			Total: B=	14,498.00

Table 4.9: Items procured from various sources (price as on 01.05.2013 in Guwahati).

Sl. No.	Description	Rate per unit ₹	Quantity	Amount ₹
1.	M.S. tube 22 mm diameter, TATA Steel pipe	500.00	4 pieces	2000.00
2.	Square hollow pipe			
3.	Stainless steel for frond riders steering	450.00	1 piece	450.00
4.	M.S. square hollow pipe			2000.00
5.	M.S. flat			750.00
6.	Welding electrodes	350.00	1 packet	350.00
7.	Grinding blades	40.00	4 nos.	160.00
8.	Nuts and bolts	100.00	3 kg	300.00
9.	NC- Nitro Callouse based Duco Automotive putty	128.00	500 gm	128.00
10.	Red Oxide primer	80.00	1 litre	80.00
11.	Duco paints (white)	250.00	3 litre	750.00
12.	Duco thinner	270.00	3 litre	810.00
13.	Alto car dickey oil less spring	270.00	4 nos.	1080.00
			Total: C=	8,858.00

Table 4.10: FRP making works for fabrication of designed ‘*Dola’* ambulance.

Sl. No.	Description	Rate per unit ₹	Quantity	Amount ₹
1.	Dies making	140.00	110 kg	15400.00
2.	Hull making	140.00	43 kg	6020.00
3.	Resin	120.00	50 kg	6000.00
4.	Latex Gel coat	110.00	10 litre	1100.00
5.	Putty FRP	200.00	2 kg	400.00
6.	Sand paper (water paper)	10.00	20 nos.	200.00
			Total: D=	29,120.00
			Total (A+B+C+D)=	58,382.00

E: An overhead of 15% is required over the above amount to cover indirect cost of supervision etc. Profit is not considered at this stage, since it is an experimental stage.

Total: E= 15% (A+B+C+D)=	8757.00
Grand total (A+B+C+D+E)=	67,139.30

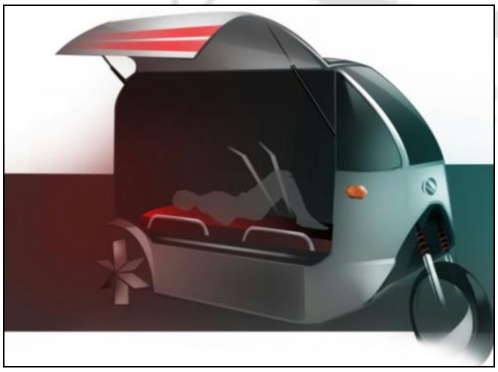
• Cost of standard items from existing rickshaw industry as percentage of total cost of material	40%
• Cost of standard items brought out from various sources as percentage of total cost of material	52%
• Labour cost as percentage of total cost of production	60%

Table 4.11: Labour charges for fabrication of designed '*Dola*' ambulance on job work basis.

Sl. No.	Description	Rate per vehicle ₹	Amount ₹
1.	Nylon pulley with material (₹ 120 per piece)	10 nos.	1200.00
2.	Bending	350.00	350.00
3.	Cutting and grinding	450.00	450.00
4.	Welding and grinding	900.00	900.00
5.	Painting	400.00	400.00
6.	Fitting of wheels with spokes, balancing	100.00	100.00
7.	Fitting of gears, axle, chains, handle, fork	130.00	130.00
8.	Stitching and fitting of hood, flap, back cover, stretcher cover etc.	3000.00	3000.00
9.	Fitting saddle	40.00	40.00
		Total: F=	6,570.00
		Grand total (A+B+C+D+E+F)=	73,709.30

The various categories of cost as percentage of total cost (**₹ 73,709.30**) indicated above provides vital clue about a process [**Table 4.7- Table 4.11**]; working capital requirement and capital investment required in addition depended on SME for the success of the products.

4.7.2 Modified version of the amphibian ambulance



(a): A digital rendering of second version of functional prototype on land.

(b): A digital rendering of second version of functional prototype in Water.

Figure 4.35: Digital rendering of the second version of functional prototype.

Based on the feedbacks received from the first version of functional prototype and their field-testing, it was decided about the next version of prototype. At this stage, the concept is developed from various iteration using CAD modelling and digital sketches which are shown in **Figure 4.35**.

4.7.3 Operation on land

Once the design and development was completed, it was prototyped. The newly designed amphibian ambulance was found to be functionally satisfactory while tested on land and it is shown in **Figure 4.36**.

(a): Modified version of prototype trial in the IIT Guwahati campus.

(b): Side view of modified version of prototype on land.

Figure 4.36: Trial on land of the amphibian ambulance.
Source of Photographs: Author

The braking system of E- rickshaw was tested at different speeds to determine time and distance it takes to stop the ambulance. In addition, the ambulance is recommended for travel to a distance less than 3 km (in which case it will cover most of the target in riverine area). During trial, it has been used for distance of up to 6 km. The amphibian ambulance can travel at an approximate speed of 9 km/h on road. It also accommodates patients with a diversity of conditions, including cholera, malaria, obstetrics, and orthopaedics.

4.7.4 Operation in water

The amphibian ambulance can travel at an approximate speed of 10 km/h on road and 3km/h in water. It has been checked during the modified version of functional prototype type in water is shown in **Figure 4.37 (a)**.

(a): Trial of modified version of functional prototype in water.

(b): Front view of modified functional prototype in water.

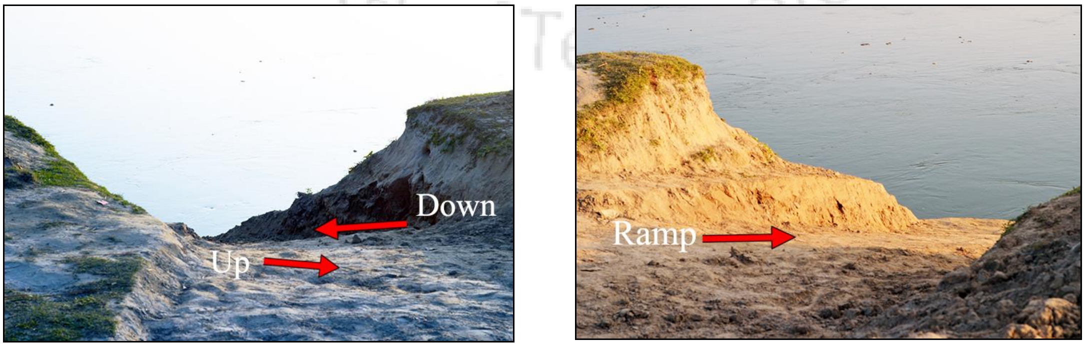
Figure 4.37: Various scenarios of field testing of modified functional prototype in water.
Source of Photographs: Author

Testing of the Amphibious Vehicle on water verified the calculations for the buoyancy of the vehicle and the float line to maximize the efficiency of the paddle wheel. The calculations were used to calculate the volume of flotation required. The ambulance settled level in water, with the water line unchanged from that in the preliminary buoyancy test [**Figure 4.37 (b)**]. The float line of the catamaran type hull of amphibian ambulance shows in **Figure 4.38**. The green line is maximum flotation, yellow line is the average flotation while accommodating three persons with medical equipment and red line is the dangerous line. The result is that the paddlewheel is positioned in its intended position relative to the water in such a manner that each blade is just fully submerged at bottom centre and the paddlewheel's efficiency is maximised.

Figure 4.38: Float line of the catamaran hull.

4.7.5 Transition from land and water and vice versa

Usually, for the transition of the ambulance from land to water in the riverine areas, a ramp is made at the bank of the water body from land (**Figure 4.39**). In this regard, to check the ability of the amphibian ambulance for making a transition between land and water has been tested using the temporarily man-made ramp with minimal slop in a water body in IIT Guwahati campus. It was found that, the ambulance made forward movement at reduced speed to minimise the impact on flotation while hitting the water surface.

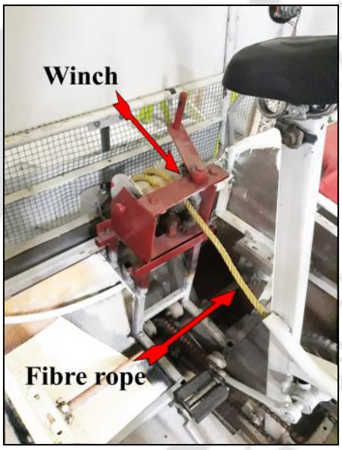


(a) **(b)**

Figure 4.39: Man made ramp to the water level.

This is done using the necessary amount of front wheel braking system of the amphibian ambulance. The transition back on the land is done similarly with the rear wheel. The present design of amphibian ambulance is propelled by paddle wheels till the rear wheel reaches the land. Since the main power supplies by the rear wheel provide the necessary forwarding power to exit the lake. As the amphibian ambulance approaches the ramp, the amphibian ambulance does not have enough forwarding drive to climb the entire ramp. To facilitate the ambulance to come up, a winch [**Figure 4.40 (a)**] is attached to the rear end of the amphibian ambulance, behind the attendant's saddle [**Figure 4.40 (b)**]. It helps the vehicle wheel drive gets into trouble in the muddy water. It assists the ambulance get out from this situation. The scenario shows in the **Figure 4.40 (c)**. A winch is a mechanical device that is used to pull in (wind up) or let out (wind out) or otherwise adjust the 'tension' of a wire rope (cable). It is very useful in a rural environment as is able to pull a vehicle across a horizontal or semi- vertical surface.

(a): Locally available Winch



(b): Position of the Winch behind the attendant's saddle.

(c): Rider trying to pull out the ambulance from a water body using winch.

Figure 4.40: Winch is for pulling up the vehicle while it gets stuck in mud.
Source of Photographs: Author

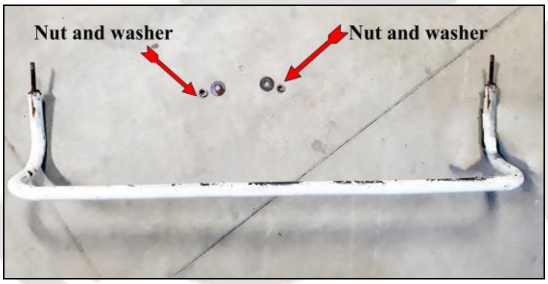
Sometimes winch does not work properly. Therefore, two safety handles are attached with nut and bolts on the front side of the amphibian ambulance. These two safety handles assist for pulling out the vehicle from the muddy water as shown in **Figure 4.41 (a)** and **Figure 4.41 (b)**.

(a): Safety handle

(b): A Safety handle is used for holding and pulling the vehicle when it gets stuck in muddy water.

Figure 4.41: Safety handle and its uses of the amphibian ambulance.
Source of Photographs: Author

And also an alternative holding bar [**Figure 4.42 (a)**] is attached to the rear end of the amphibian ambulance to pull off the ambulance when it gets stuck in muddy water as shown in the **Figure 4.42 (b)**.



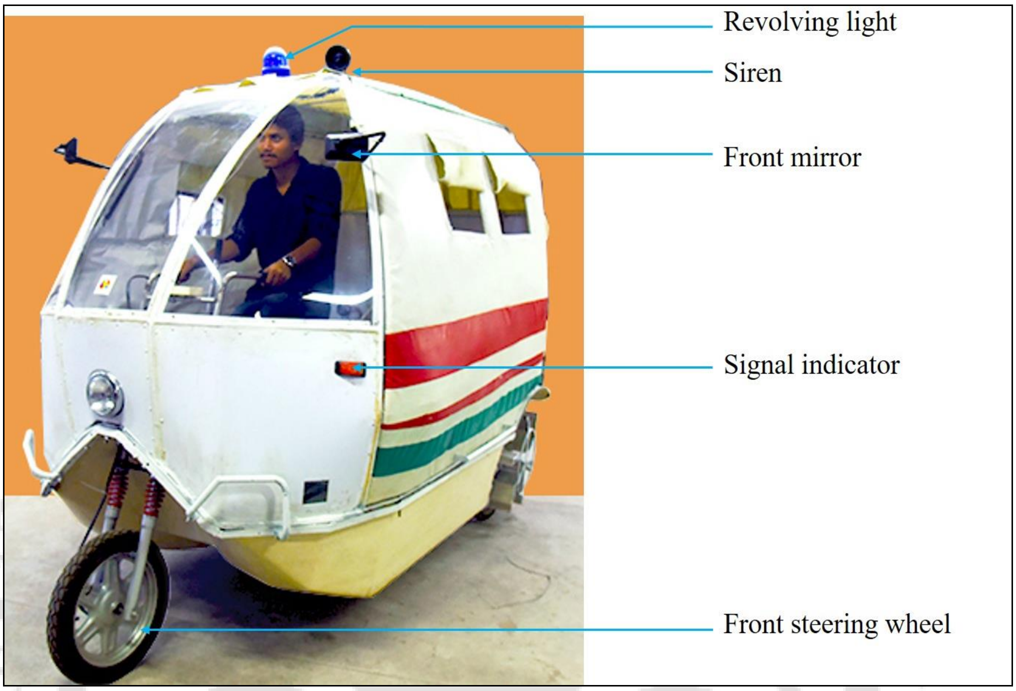
(a): Rear holding bar

(b): An alternative holding bar is used for pulling up the ambulance.

Figure 4.42: Holding bar and its uses of the amphibian ambulance.
Source of Photographs: Author

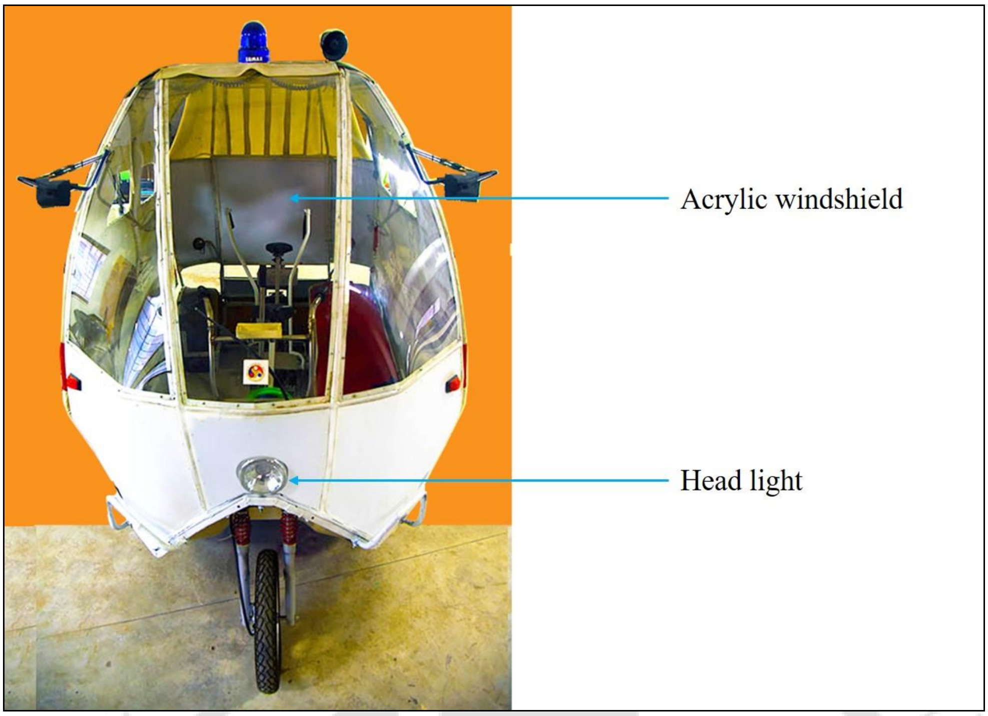
4.9 Final functional prototype construction of the *Dola* ambulance

The third modified version of functional prototype [**Figure 4.43 (a)- 4.43 (d)**] of amphibian ambulance was tested in the IIT Guwahati campus.



(a): Front three quarter view of final functional prototype.

(b): Rear three quarter view of final functional prototype.



(c): Front View of final functional prototype.

(d): View during the trial in water at IIT Guwahati campus.

Figure 4.43: Different views of final functional prototype.
Source of Photographs: Author

Based on analysis of the data available from product test programme of the third modified version of prototype which validated the predictions made easier. Data from the field trial during third version of functional prototype in both situations on land and in water were recorded and analysed from the point of view of their usefulness for implementing as a design specification which is explained in Chapter 5.

Chapter 5: Detailed Product Test Programme, Data Collection and Analysis

In this chapter, the experimental setup used to carry out the experiments is explained. It has been mentioned in Chapter 1, that aim of the research work is to design an amphibian ambulance for meeting the specific needs of people living in riverine areas which can provide health care transportation both on land and in water. To assess its acceptance by the user for its performance and efficiency, it was required to be evaluated through actual field trials. For the design evaluation of the amphibian ambulance, twelve experimental tests were carried out.

Objectives of these tests were to assess the followings:

Users' perception regarding:

i. Ease of use of the newly- designed amphibian ambulance to drive while driving on land and in water by two persons pedalling simultaneously and compare.

ii. The newly- designed amphibian ambulance in terms of user- friendliness and compatibility while driving on land and in water by two persons and compare.

iii. The comfort issue of the newly- designed amphibian ambulance while riding on land and in water by the rider and compare.

iv. The comfort issue of the newly- designed amphibian ambulance while riding on land and in water by the attendant and compare.

v. The feeling of safety of the amphibian ambulance while riding on land and in water by the rider and the attendant and compare.

vi. The ease of use (entry/exit) of the newly- designed amphibian ambulance while the vehicle is on land and in water by the rider and the attendant and compare.

vii. The front visibility of the newly- designed amphibian ambulance while riding on land and in water by the rider.

viii. The protection from the natural elements issue of the newly- designed amphibian ambulance while driving on land and in water by the rider and the attendant and compare.

ix. The effect of navigation of the amphibian ambulance while driving on land and in water and compare.

x. The space requirement of patient to lie on the stretcher while operating the amphibian ambulance on land and in water.

xi. The visual appearance of the vehicle as an ambulance while operating on land.

xii. The visual image of the vehicle as an amphibian ambulance while operating on land and in water.

5.1 Materials and methods

5.1.1 Questionnaire preparation

Questionnaire were prepared with a Semantic differentiate scale regarding riders' perception of the vehicle on land, riders' perception in water, patients' perception and publics' perception based on **Figure 5.1**.

5.1.2 Experimental design

A two-month prospective cross-sectional study on the amphibian ambulance to look at participants' perception at IIT Guwahati campus and Amingaon primary health centre was carried out. A total 27 participants were interviewed with a set of questionnaires (**Table 5.1**- **Table 5.**4) regarding their perceptions for the ambulance and were asked to rate the ambulance as per their perception [**Figure 5.2**].

Figure 5.1: Field trial of final functional prototype.

Each participant drove approx. 600 metres for evaluating the factors like easy of driving, user friendly and compatibility, comfort of riding, feeling of safety, easy to access into the ambulance, front visibility, issue of protection from the natural elements and it's easy to navigate issue while the vehicle is on land and in water.

Figure 5.2: Test for loading and unloading the patient with stretcher in the ambulance.
Source of Photographs: Author

5.1.3 Details of the responders' demographical profile

Among 27 participants, 24 were males and 3 were females (**Figure 5.3**), with the age group ranging up to 45 (Age 16 to 45) of total participants, details are shown in **Figure 5.4**.

Gender	Frequency	Percent
Male	24	89
Female	3	11
Total	27	100

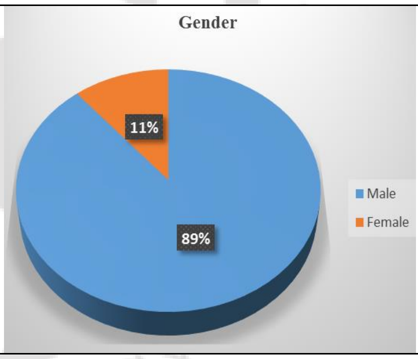


Figure 5.3: Descriptive statistics of gender of the respondents.

Age group	Frequency	Percent
16-25	2	7
26-35	17	63
36-45	7	26
Above 45	1	4
Total	27	100

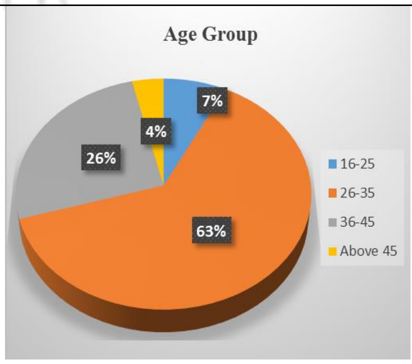


Figure 5.4: Descriptive statistics of age of the respondents.

5.1.4 Experimental details- objective measurement

The following observations questionnaires and results were aimed to find out that the vehicle can run on land and in water. The 5-point Semantic differentiate scale evaluation was made where value of 1= poor, 2= fair, 3= good, 4= very good and 5= excellent (**Table 5.1- Table 5.4**).

Table 5.1: Questionnaires for riders' perception on land.

Q	Statement	Semantic differentiate scale				
1	The vehicle is easy to drive with two persons pedalling simultaneously on land	1	2	3	4	5
2	Design is user friendly and its compatibility for use by two persons on land	1	2	3	4	5
3	Rider's comfort to ride the ambulance on land	1	2	3	4	5
4	Attendant's comfort to ride the ambulance on land	1	2	3	4	5
5	Feeling of safety in the ambulance while driving on land	1	2	3	4	5
6	The vehicle is easy to access (entry/exit) on land	1	2	3	4	5
7	Front visibility during driving on land	1	2	3	4	5
8	Protection from the elements of weather on land	1	2	3	4	5
9	Navigability on land	1	2	3	4	5

Table 5.2: Questionnaires for riders' perception in water.

Q	Statement	Semantic differentiate scale				
10	The vehicle is easy to drive with two persons pedalling simultaneously in water	1	2	3	4	5
11	Design is user- friendly and compatibility for use by two persons in water	1	2	3	4	5
12	Rider's comfort to ride the ambulance in water	1	2	3	4	5
13	Attendant's comfort to ride the ambulance in water	1	2	3	4	5

Q	Statement	Semantic differentiate scale				
14	Feeling of safety in the ambulance while driving in water	1	2	3	4	5
15	The vehicle is easy to access (entry/exit) in water	1	2	3	4	5
16	Front visibility during driving in water	1	2	3	4	5
17	Protection from the elements of weather in water	1	2	3	4	5
18	Navigability in water	1	2	3	4	5

Table 5.3: Questionnaires for patient's perception on land and in water.

Q	Statement	Semantic differentiate scale				
19	The patient's comfort	1	2	3	4	5

Table 5.4: Questionnaires for public's perception.

Q	Statement	Semantic differentiate scale				
20	Visual appearance of the ambulance while driving on land	1	2	3	4	5
21	Visual appearance of the ambulance while sailing in water	1	2	3	4	5

5.1.5 Data analysis and result

To interpret the result of the experimental data, the paired sample t-test was conducted. The paired sample t-test is a statistical procedure used to determine whether the Mean difference between two sets of observations is zero (Solutions, 2017). It was initiated by identifying the type of variables i.e., dependent variable and test variable. In the second case the experimental data was analysed through One-way ANOVA, it was tried to compare two Means from two independent (unrelated) variables.

Procedure followed to 'analysis- 1' the statistical data using SPSS software

- Checking the dependent variables and test variable.
- There are three tables: Paired samples statistics, Paired samples correlations and Paired Samples T-Test.
- Paired samples statistics gives univariate descriptive statistics (mean, sample size, standard deviation, and standard error) for each variable entered.

- Paired samples correlation shows with a two- tailed test of significant nature for each pair of variables entered.
- Paired samples test gives the null hypothesis test results.

Procedure followed to 'analysis- 2' the statistical data using SPSS software

- Checking the one independent variable and one factor.
- Descriptive statistics (mean, standard deviation, and standard error) for each variable entered.
- One-way ANOVA test gives the null hypothesis test results.

5.2 Findings of experiments

Findings and interpretations of the above experiments are provided in sections 5.2.1 to 5.2.12.

5.2.1 Experiment no. 1: *Users' perception regarding ease of use of the newly- designed amphibian ambulance to drive while driving on land and in water by two persons pedalling simultaneously and compare.*

Findings and interpretation of paired sample t-test for experiment no. 1 (**Table 5.7**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *easy to drive* issue or factor while driving on land and in water by two persons pedalling simultaneously. Paired samples statistics and correlations are stated in **Table 5.5** and **Table 5.6**.

Table 5.5: Paired Samples Statistics for experiment no. 1.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	The vehicle is easy to drive with two persons pedalling simultaneously on land	3.33	27	1.038	.200
	The vehicle is easy to drive with two persons pedalling simultaneously in water	3.56	27	.934	.180

Table 5.6: Paired Samples Correlations for experiment no. 1.

		N	Correlation	Sig.
Pair 1	The vehicle is easy to drive with two persons pedalling simultaneously on land and the vehicle is easy to drive with two persons pedalling simultaneously in water	27	.556	.003

Table 5.7: Paired Sample test for experiment no. 1.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The vehicle is easy to drive with two persons pedalling simultaneously on land – The vehicle is easy to drive with two persons pedalling simultaneously in water	-.222	.934	.180	-.592	.147	-1.237	26	.227

Interpretation of experiment no. 1

H_{01}- Null hypothesis: There is no significant difference in the rider's perception in the context of 'ease of drive' with two persons pedalling simultaneously on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.227> 0.05) and concluded that there is no significant difference of ease of drive with two human pedalling simultaneously on land and in water.

5.2.2 Experiment no. 2: *Users' perception regarding the newly-designed amphibian ambulance in terms of user- friendliness and compatibility while driving on land and in water by two persons and compare.*

Findings and interpretation of paired sample t-test for experiment no. 2 (**Table 5.10**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *user friendly and compatibility factor* while driving on land and in water by two persons. Paired samples statistics and correlations are stated in **Table 5.8** and **Table 5.9**.

Table 5.8: Paired Samples Statistics for experiment no. 2.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Design is user- friendly and compatible for use by two persons on land	3.44	27	.698	.134
	Design is user- friendly and compatible for use by two persons in water	3.70	27	.953	.183

Table 5.9: Paired Samples Correlations for experiment no. 2.

		N	Correlation	Sig.
Pair 1	Design is user- friendly and compatible for use by two persons on land and design is user friendly and compatible for use by two persons in water	27	.437	.023

Table 5.10: Paired Samples Test for experiment no. 2.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Design is user friendly and compatible for use by two persons on land – Design is user friendly and compatible for use by two persons in water	-.259	.903	.174	-.616	.098	-1.492	26	.148

Interpretation of experiment no. 2

H_{02}- Null Hypothesis: There is no significant difference in the riders' perception in the context of user friendly and compatibility for use by two people while driving on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.148> 0.05) and concluded that there is no significant difference in the vehicle in its user friendly and compatibility for use by two people on land and in water.

5.2.3 Experiment no. 3: *Users' perception regarding the comfort issue of the newly- designed amphibian ambulance while riding on land and in water by the rider and compare.*

Findings and interpretation of paired sample t-test for experiment no. 3 (**Table 5.13**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *comfort* while riding on land and in water by the rider. Paired samples statistics and correlations are stated in **Table 5.11** and **Table 5.12**.

Table 5.11: Paired Samples Statistics for experiment no. 3.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Comfort to ride the ambulance on land	3.37	27	1.043	.201
	Comfort to ride the ambulance in water	3.59	27	1.083	.209

Table 5.12: Paired Samples Correlations for experiment no. 3.

		N	Correlation	Sig.
Pair 1	Comfort to ride the ambulance on land and comfort to ride the ambulance in water	27	.615	.001

Table 5.13: Paired Samples Test for experiment no. 3.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Comfort to ride the ambulance on land - Comfort to ride the ambulance in water	-.222	.934	.180	-.592	.147	-1.237	26	.227

Interpretation of experiment no. 3

H_{03}- Null Hypothesis: There is no significant difference in the riders' perception in the context of riders' comfort while riding the ambulance on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.227> 0.05) and concluded that there is no significant difference of riders' comfort while the ambulance is on land and in water.

5.2.4 Experiment no. 4: *Users' perception regarding the comfort issue of the newly- designed amphibian ambulance while riding on land and in water by the attendant and compare.*

Findings and interpretation of paired sample t-test for experiment no. 4 (**Table 5.16**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *comfort* while riding on land and in water by the attendant. Paired samples statistics and correlations are stated in **Table 5.14** and **Table 5.15**.

Table 5.14: Paired Samples Statistics for experiment no. 4.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Attendant's comfort to ride the ambulance on land	3.48	27	.893	.172
	Attendant's comfort to ride the ambulance in water	3.74	27	.764	.147

Table 5.15: Paired Samples Correlations for experiment no. 4.

		N	Correlation	Sig.
Pair 1	Attendant's comfort to ride the ambulance on land and attendant's comfort to ride the ambulance in water	27	.472	.013

Table 5.16: Paired Samples Test for experiment no. 4.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Attendant's comfort to ride the ambulance on land - Attendant's comfort to ride the ambulance in water	-.259	.859	.165	-.599	.081	-1.568	26	.129

Interpretation of experiment no. 4

H_{04}- Null Hypothesis: There is no significant difference in the attendant's perception in the context of his/her comfort while riding the ambulance on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.129> 0.05) and concluded that there is no significant difference of attendant's comfort while riding the ambulance is on land and in water.

5.2.5 Experiment no. 5: *Users' perception regarding the feeling of safety of the amphibian ambulance while riding on land and in water by the rider and the attendant and compare.*

Findings and interpretation of paired sample t-test for experiment no. 5 (**Table 5.19**).

Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *feeling of safety* while riding on land and in water by the rider and attendant. Paired samples statistics and correlations are stated in **Table 5.17** and **Table 5.18**.

Table 5.17: Paired Samples Statistics for experiment no. 5.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Feeling of safety in the ambulance while driving on land	3.56	27	1.121	.216
	Feeling of safety in the ambulance while driving in water	3.63	27	.926	.178

Table 5.18: Paired Samples Correlations for experiment no. 5.

		N	Correlation	Sig.
Pair 1	Feeling of safety in the ambulance while driving on land and feeling of safety in the ambulance while driving in water	27	.465	.014

Table 5.19: Paired Samples Test for experiment no. 5.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Feeling of safety in the ambulance while driving on land - Feeling of safety in the ambulance while driving in water	-.074	1.072	.206	-.498	.350	-.359	26	.722

Interpretation of experiment no. 5

H_{05}- Null Hypothesis: There is no significant difference in the riders' perception in the context of safety in the ambulance is on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.722> 0.05) and concluded that there is no significant difference of rider's safety while riding the ambulance is on land and in water.

5.2.6 Experiment no. 6: *Users' perception regarding the ease of use (entry/exit) of the newly- designed amphibian ambulance while the vehicle is on land and in water by the rider and the attendant and compare.*

Findings and interpretation of paired sample t-test for experiment no. 6 (**Table 5.22**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *easy to access factor* (entry/exit) by the rider and the attendant while the vehicle is on land and in water. Paired samples statistics and correlations are stated in **Table 5.20** and **Table 5.21**.

Table 5.20: Paired Samples Statistics for experiment no. 6.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	The vehicle is easy to access (entry/exit) on land	4.00	27	.734	.141
	The vehicle is easy to access (entry/exit) in water	4.00	27	.620	.119

Table 5.21: Paired Samples Correlations for experiment no. 6.

		N	Correlation	Sig.
Pair 1	The vehicle is easy to access (entry/exit) on land and the vehicle is easy to access (entry/exit) in water	27	.423	.028

Table 5.22: Paired Samples Test for experiment no. 6.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The vehicle is easy to access (entry/exit) on land – The vehicle is easy to access (entry/exit) in water	.000	.734	.141	-.290	.290	.000	26	1.000

Interpretation of experiment no. 6

H_{06}- Null Hypothesis: There is no significant difference in the riders' perception on land and in water in the context of 'ease of access' to the ambulance.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 1.0> 0.05) and concluded that there is no significant difference of ease of access to the ambulance is on land and in water.

5.2.7 Experiment no. 7: *Users' perception regarding the front visibility of the newly- designed amphibian ambulance while riding on land and in water by the rider.*

Findings and interpretation of paired sample t-test for experiment no. 7 (**Table 5.25**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *front visibility* while riding on land and in water by the rider. Paired samples statistics and correlations are stated in **Table 5.23** and **Table 5.24**.

Table 5.23: Paired Samples Statistics for experiment no. 7.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Front visibility during driving on land	4.07	27	.874	.168
	Front visibility during driving in water	4.04	27	.854	.164

Table 5.24: Paired Samples Correlations for experiment no. 7

		N	Correlation	Sig.
Pair 1	Front visibility during driving on land and front visibility during driving in water	27	.975	.000

Table 5.25: Paired Samples Test for experiment no. 7.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Front visibility during driving on land – Front visibility during driving in water	.037	.192	.037	-.039	.113	1.000	26	.327

Interpretation of experiment no. 7

H_{07}- Null Hypothesis: There is no significant difference in the riders' perception in the context of front visibility of the rider during driving the ambulance on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.327> 0.05) and concluded that there is no significant difference in terms of front visibility of the rider during driving the ambulance is on land and in water.

5.2.8 Experiment no. 8: *Users' perception regarding the protection from the natural elements of the newly- designed amphibian ambulance while driving on land and in water by the rider and the attendant and compare.*

Findings and interpretation of paired sample t-test for experiment no. 8 (**Table 5.28**). Comparison of two different contexts using the newly designed amphibian ambulance in perceiving the *protection from the natural elements* factor while driving on land and in water by the rider and the attendant. Paired samples statistics and correlations are stated in **Table 5.26** and **Table 5.27**.

Table 5.26: Paired Samples Statistics for experiment no. 8.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Protection from the elements of weather on land	4.00	27	1.000	.192
	Protection from the elements of weather in water	4.22	27	.974	.187

Table 5.27: Paired Samples Correlations for experiment no. 8.

		N	Correlation	Sig.
Pair 1	Protection from the elements of weather on land and protection from the elements of weather in water	27	.592	.001

Table 5.28: Paired Samples Test for experiment no. 8.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Protection from the elements of weather on land - Protection from the elements of weather in water	-.222	.892	.172	-.575	.130	-1.295	26	.207

Interpretation of experiment no. 8

H_{08}- Null Hypothesis: There is no significant difference in the riders' perception in the context of protection from the weather while driving the ambulance on land and in water.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.207> 0.05) and it is concluded that there is no significant difference for weather protection of the ambulance on land and in water.

5.2.9 Experiment no. 9: *Users' perception regarding the effect of navigation of the amphibian ambulance while driving on land and in water and compare.*

Findings and interpretation of paired sample t-test for experiment no. 9 (**Table 5.31**).

Comparison of effect of navigation of amphibian ambulance while driving on land and in water. Paired samples statistics and correlations are stated in **Table 5.29** and **Table 5.30**.

Table 5.29: Paired Samples Statistics for experiment no. 9.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Navigability on land	3.81	27	1.001	.193
	Navigability in water	4.04	27	1.091	.210

Table 5.30: Paired Samples Correlations for experiment no. 9.

		N	Correlation	Sig.
Pair 1	Navigability on land and navigability in water	27	.499	.008

Table 5.31: Paired Samples Test for experiment no. 9

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Navigability on land - Navigability in water	-.222	1.050	.202	-.638	.193	-1.100	26	.282

Interpretation of experiment no. 9

H_{09}- Null Hypothesis: There is no significant difference in the riders' perception on land and in water in the context of navigation.

A Paired sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (Two- tailed sig.: 0.282> 0.05) and concluded that there is no significant difference of navigability of the ambulance while driving on land and in water.

5.2.10 Experiment no. 10: *Users' perception regarding the space requirement of patient to lie on the stretcher while operating the amphibian ambulance on land and in water.*

Findings and interpretation of One-way ANOVA test for experiment no. 10 (**Table 5.33**). Comparison of space requirement of stretcher regarding patient comfort of the amphibian ambulance in the context of gender (male and female). The descriptive statistics of users' are stated in **Table 5.32**.

Table 5.32: Descriptive statistics of rating on level for experiment no. 10.

The patient's comfort								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Male	24	3.71	.955	.195	3.31	4.11	2	5
Female	3	4.00	1.000	.577	1.52	6.48	3	5
Total	27	3.74	.944	.182	3.37	4.11	2	5

Table 5.33: One-way ANOVA test for experiment no. 10.

The patient's comfort					
	Sum of Squares	df	Mean Square	F	Sig
Between Groups	.227	1	.227	.247	.624
Within Groups	22.958	25	.918		
Total	23.185	26			

Interpretation of experiment no. 10

H_{10}- Null Hypothesis: There is no significant difference in the patient's perception on land and in water in the context of gender.

A dependent sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (sig.: 0.624> 0.05) and concluded that there is no significant difference of gender and patient's perception on *patient's comfort* while lying on the stretcher of the vehicle on land and in water.

5.2.11 Experiment no. 11: *Users' perception regarding the visual appearance of the vehicle as an ambulance while operating on land.*

Findings and interpretation of One-way ANOVA test for experiment no. 11 (**Table 5.35**). Comparison of visual appearance of the vehicle as an ambulance while operating on land in the context of gender. The descriptive statistics of users' are stated in **Table 5.34**.

Table 5.34: Descriptive statistics of rating on level for experiment no. 11.

Visual appearance of the ambulance while driving on land								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Male	24	4.29	.859	.175	3.93	4.65	2	5
Female	3	4.67	.577	.333	3.23	6.10	4	5
Total	27	4.33	.832	.160	4.00	4.66	2	5

Table 5.35: One-way ANOVA test for experiment no. 11.

Visual appearance of the ambulance while driving on land					
	Sum of Squares	df	Mean Square	F	Sig
Between Groups	.375	1	.375	.532	.473
Within Groups	17.625	25	.705		
Total	18.000	26			

Interpretation of experiment no. 11

H_{11}- Null Hypothesis: There is no significant difference in the public perception of visual appearance of the vehicle as an ambulance on land in the context of gender.

A dependent sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (sig.: 0.473> 0.05) and concluded that there is no significant difference of gender and public perception of *visual appearance* of the vehicle as an ambulance while on land.

5.2.12 Experiment no. 12: *People perception regarding the visual appearance of the vehicle as an amphibian ambulance while operating on land and in water.*

Findings and interpretation of One-way ANOVA test for experiment no. 12 (**Table 5.37**). Comparison of visual appearance of the vehicle as an amphibian ambulance while operating in water in the context of gender. The descriptive statistics of users' are stated in **Table 5.36**.

Table 5.36: Descriptive statistics of rating on level for experiment no. 12.

Visual appearance of the ambulance while sailing in water								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Male	24	4.25	.794	.162	3.91	4.59	2	5
Female	3	4.33	.577	.333	2.90	5.77	4	5
Total	27	4.26	.764	.147	3.96	4.56	2	5

Table 5.37: One-way ANOVA test for experiment no. 12.

Visual appearance of the ambulance while sailing in water					
	Sum of Squares	df	Mean Square	F	Sig
Between Groups	.019	1	.019	.031	.863
Within Groups	15.167	25	.607		
Total	15.185	26			

Interpretation of experiment no. 12

H_{12}- Null Hypothesis: There is no significant difference in the public perception of visual appearance in water in the context of gender.

A dependent sample detail has been conducted for a significant level of 0.05.

The null hypothesis is accepted (sig.: 0.863> 0.05) and concluded that there is no significant difference of gender and public perception on *visual appearance* of the vehicle as an amphibian ambulance while operating on land and in water.

5.3 Validation of hypothesis- H1

The first hypothesis formulated in Chapter 1, section 1.8 is that *"If an appropriate transportation (in the context of easy to access, user friendly, comfort, safety, navigability and general appearance) is designed for riverine areas in Assam, it can facilitate delivery of healthcare services."* It has been fully established after conducting a number of exhaustive experiments numbering twelve in different phases, as described in experiment no. 1 (section 5.2.1), experiment no. 2 (section 5.2.2), experiment no. 3 (section 5.2.3), experiment no. 4 (section 5.2.4), experiment no. 5 (section 5.2.5), experiment no. 6 (section 5.2.6), experiment no. 7 (section 5.2.7), experiment no. 8 (section 5.2.8), experiment no. 9 (section 5.2.9), Experiment no. 10 (section 5.2.10), experiment no. 11 (section 5.2.11) and experiment no. 12 (section 5.2.12). The interpretation of various experiments as mentioned is also given. Findings from above interpretations of (experiment no. 1 to experiment no. 9) clearly indicate that the newly designed vehicle is an amphibian vehicle. It was also found to be user- friendly, compatible and easy to drive by two people while running on land and in water. From the interpretation of experiment no. 10, it has been found that the stretcher (details in **section 4.4.6**) of amphibian ambulance is comfortable to lie while the vehicle operates in both situations. It has also been found that the visual appearance of the vehicle is appropriate as an amphibian ambulance while running on land and in water (details in **section 4.9**).

Based on the basic data response from the experimental group it is found that all respondents have given rating above 3 for all the questions and this indicates acceptability of the amphibian ambulance as an appropriate means for transportation in riverine areas in Assam. This is evident from mean of scores in **Table 5.5** to **Table 5.36**. Thus amphibian ambulance is acceptable and satisfies the hypothesis 1.

The next chapter contains the study about the contextual guidelines for support of innovation in India and western country to formulate a strategy to introduce the amphibian ambulance as an innovation. The study can provide way to follow in present context to make the effort of introduction of the innovation successful.

Chapter 6: Institutionalisation of Innovation

This chapter elaborates the significance of successful innovations for people through design support. The present research aims at providing a systemic guideline of the process of institutionalisation taking place in India.

The concept of the innovation system emphasises the fact that the flow of science, technology and information among people, enterprises and institutions are needed in order to turn an idea into a successful innovation in the market. The concept was extended to aspects of regional and cluster development in 1980 by two European economists, Christopher Freeman and Bengt-Åke Lundvall (Freeman, 1990; Lundvall, 1992), called the 'National System of Innovation (NIS)'. In addition, a new model of innovation, the 'Triple Helix', was initiated by Professor Henry Etzkowitz in 1993 and Professor Loet Leydesdorff in 1995.

India has a large informal economy where most of the people are associated with low labour productivity and poverty. In addition, it is the first country which recognises the innovative ability of the informal sector and support innovation of the informal sector. The term 'informal sector' made the concept of the informal economy given by Organisation for Economic Co-operation and Development (OCED). The informal sector is considered as the activities of individuals and group of individuals (communities, households), producing goods and services for the market and use them within people's own household or community without material gain. According to the report of 'National Commission for Enterprises in the Unorganised Sector (NCEUS)' mentions that the informal employment in India is 58% in the agricultural sector, 75% in the industrial sector, and 72% in services, mostly in underdeveloped enterprises and labour intensive employment - workers mainly having low-skill levels and low level of wages (Olga, 2015).

By contrast, Schumacher, in his book 'Small is Beautiful: Economics as if people mattered', evangelised the local development of low- tech, labour intensive, environmentally sound technologies as an alternative to dependence on technology–transfer from developed countries. However, till date, there is no full-proof methodology for success in this effort. It is in this context that this research work is important and it discusses the various issues through two case studies which compare and contrast how grassroots innovators are supported in developing countries such as India and how the support is offered in Wales, UK. First case study is from India where grassroots innovation was developed into a commercial product with the design support of an Indian institution and second from Wales where design support was provided by PDR (the National Centre for Product Design and Development Research), Cardiff Metropolitan University and Welsh universities. Three key questions investigated in the case study research were: (1) what can be learned from comparing and contrasting the design support given to grassroots innovations in India and Wales? (2) how can people and local businesses benefit from collaboration with university research centres in India? (3) how could this design support be further improved to transfer the newly designed amphibian ambulance as a marketable product? This guideline will help to identify the design drivers for a new philosophy by the doctoral researcher towards embracing the challenge of low-income markets as a leverage for innovation of the amphibian ambulance.

6.1 Initiation of a system of institutional support for grassroots innovation

There is no universal definition of the grassroots innovator. For instance, some academics describe grassroots innovators as a creative network of activists who are locally based and assisted by a wide range of shared interests (Church, 2005). Some of the academicians recognise grassroots innovators by their origin, individuals coming from rural communities (Butkevicience, 2009). The grassroots innovators are the average people who tackle different issues they confront in troublesome circumstances in their everyday life. Bhaduri and Kumar define grassroots innovators as individual innovator who undertakes innovative efforts to solve localised problem, and who deals in a business firm in a formal organisation (Bhaduri and Kumar, 2011). In India, the National Innovation Foundation (NIF) began working in March 2000 as India's national activity to fortify the grassroots innovations and for remarkable traditional knowledge (TK) together with the Grassroots Innovations Argumentation Network (GIAN) after scouting and identifying grassroots innovators and their innovations. As mentioned earlier, the NIF, with the assistance of the Department of Science and Technology (DST), Government of India, gives full support to innovators as regards access to information mapping and assembling, learning creation and value addition and information application and dissemination. On the other hand, the Welsh Government's innovation team provides support for businesses in Wales to engage with universities and colleges. The Academic Expertise for Business (A4B) Programme is a programme of support aimed at unlocking the commercial potential of grassroots innovations and to provide an effective interface between academia and Welsh business start-up. Besides, A4B provides a mechanism of knowledge transfer, access to research, development, expertise, and facilities that are both small medium enterprises and a wide range of technology business start-up (Henderson, 2011).

6.2 Innovation ecosystem in rural India: Demand for technology

6.2.1 Grassroots Innovation Augmentation Network (GIAN)

As mentioned in the section 6.1, GIAN is the first technology business incubator focusing on incubating and commercialising of grassroots innovations in India. This organisation was set up on 1st March, 1997 in collaboration with *Society for Research and Initiatives for Sustainable Technologies and Institutions* (SRISTI) and Indian Institute of Management Ahmedabad (IIMA) for scaling up the grassroots innovation into commercialised products (www.gian.org, 2008). GIAN provides training to unaided, unqualified individual innovators from rural areas which have conceptualised a technological innovation. It provides a very limited grant up to ₹ 0.1 million individually in the initial stage of concept testing and prototype. Moreover, it also provides two basic funds: (1) Value Addition Research and Development (VARD) and (2) Micro Venture and Innovation Fund (MVIF) to support innovators and incubators. The VARD fund was created with the help of NIF to support prototype development and testing. GIAN has created another MVIF with the support of the Government of India, SIDBI (Small Industries Development Bank of India) of £4 million pounds in 2004 (Bulsara *et al.*, 2013). This fund is managed by NIF. Through this fund, GIAN supports pilot scale production and other commercial activities.

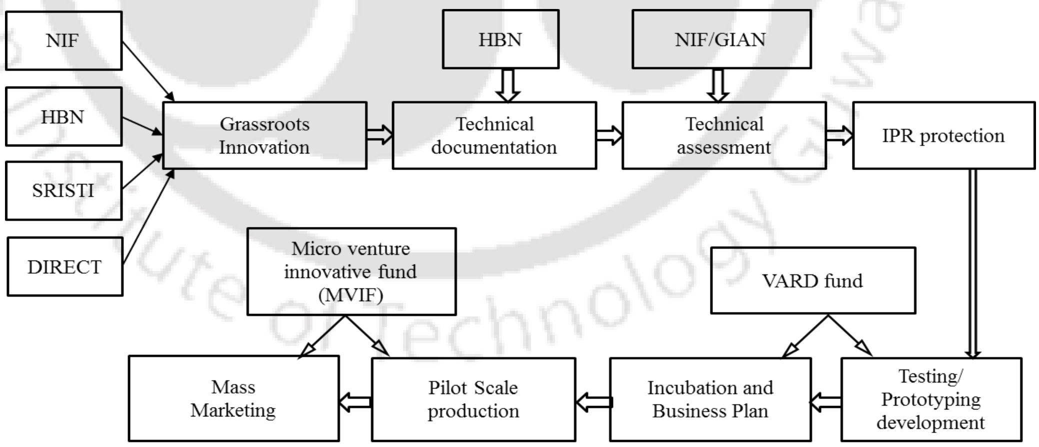
6.3 Techno incubation to techno business incubation

There are four main activities that are performed in India within the NIF which collaborates the Honey Bee Network (HBN), SRISTI and GIAN. These organisations have scouted and documented various activities relating to the commercialisation of innovations such as (1) the value addition and research and development (R & D); (2) the business development and micro venture; (3) IPR, trademarks, and copyright; (4) dissemination mechanism (Gupta, 2012).

The innovation process in Wales follows a broadly similar pattern. The Welsh government supports the creation and commercialisation of new products and processes and that increases efficiency in manufacturing through science and technology, and also helps identify, protect and exploit the IPR of local innovations.

6.3.1 Technology business incubation (TBI) framework in India

The main driver for TBI Centre is to encourage Start-up enterprise by the grassroots innovation and generate employment among Science and Technology (S and T) graduates with successful commercialisation. In India, NIF and other organisations like GIAN, Council for Science and Industrial Research (CSIR) provide support in terms of access to knowledge mapping to grassroots innovators with the help of DST, India. TBI process is shown in **Flow diagram 6.1.**



Flow diagram 6.1: TBI Process for scouting innovation in India (GIAN, 2008)

Innovation Steps are shown

i. **Scouting for innovations:** The scouting for innovation is done through NIF, HBN, SRISTI. NIF runs many chapters at various institutions in India. The

HBN is a network of individuals, innovators, farmers, scholars, academicians, policy makers, entrepreneurs and NGOs. Many innovators directly come with their innovations to GIAN.

ii. **PIC and Technical documentation:** PIC (Prior Informed Consent) is taken from innovators when they apply for support from GIAN. It has two forms: (1) PIC for Traditional Knowledge, and (2) PIC for Ideas and Technology Innovations. For the purpose of using traditional in any knowledge, innovation or practices produced by individual knowledge experts, healers, craft persons etc., alone or in groups or community a long time ago or several generations ago. Prior consent of the innovators is taken in an application format which is also available in local languages. It comes with explanatory notes also. This normally includes consent of the innovators for sharing their Innovation with other agencies, entrepreneurs, magazines, for IPR, for commercialisation of technology etc. As grassroots innovations come in raw form, detailed technical documentation is made by GIAN with the help of the HBN and other agencies if required.

iii. **PAS /Technology Assessment:** At this stage, PAS (Prior Art Search) for evaluation of technology is done in terms of possible patenting (IPR issues) through Patent database searches, through internet in the market and other information resources, to check whether it is really innovative. This is done by GIAN with the help of NIF.

iv. **Competitive Benchmarking:** This is done by GIAN with the help of NIF, Volunteers and summer interns. They check whether the Innovation has viability in the market in terms of competition or not. They carry out their check on similar kinds of products available in the market and try to know them at what price the resources those competitors have and try to match all these with their innovations. They check whether the innovation has market potential or not, and that it can be successful in the market or not.

v. **Go/ No Go Decision:** After competitive benchmarking, GIAN normally decides whether to support the innovations for commercialisation or not.

vi. **IPR protection:** At this stage, to protect the technology innovation in terms of IPR, the process of filling patent is started. GIAN uses a PAC (Patent Assistance Cell) to help innovators. PAC provides basic education related to patents to innovators and even the general public by means of disseminating information and workshops. The cell evaluates and searches for patent related information. It gives active support in filing a patent on behalf of the innovators with the help of a network attorney. GIAN even pays fees for filing a patent. All these services are given to innovators (incubates) of GIAN free of cost. But they take nominal charges from other individuals and organisations which may vary from ₹ 5000.00 to ₹ 30000.00. Normally they renew the patent for a few years but afterwards they expect innovators to renew the patent by paying a nominal fee. It also helps in technical documentation. Usually 1 to 2 months is taken for filing a patent and normally a patent is awarded in 1 to 2 years.

vii. **Testing and Prototype Development:** At this stage, the prototype model of the technology Innovation is developed. VARD created with the help of NIF to support mainly the testing and prototype development.

viii. **Incubation and Business plan:** Here the incubation support services, which also include preparing a business plan, are started.

ix. **Pilot scale production:** And then, a small quantity of product is produced to check the production viability and test the market.

6.3.2 Examples of commercialised grassroots innovations through NIF

The NIF along with the GIAN and other incubations partners have successfully licensed and commercialised a number of grassroots innovators' innovations in India. The procedure was shared with stakeholders as per the PIC frame under NIF. Some examples are shown below:

Bamboo Splinting Machine

Innovator Mr. Usman Shekhani developed a bamboo split making device which increases the productivity of bamboo labourers. GIAN-NE granted MVIF support him to commercialise the device. In the initial phase of commercialisation of his innovation, a total 100 units were exhibited at GIAN-NE India region for testing the market. As a result, 10,000 units have been sold by GIAN-NE with the collaboration of an NGO, Virasa, India.

Mini sanitary napkin making machine

Innovator Mr. A. Muruganantham developed a semi- automatic sanitary napkin making machine where can produce more than 800 sanitary pads every day. The machine is associated with three mechanised parts i.e. de-fibration, core forming and UV treatment. The cost of the machine is worth ₹ 1,00000 and cost of the sanitary pad produce at ₹ 1 per pad. NIF supported through MVIF for commercialisation of the machine. The innovator has already sold more than 60 units of machine in the market.

Treadle printing machine:

Treadle printing machine was designed and developed by an entrepreneur Mr. Ishan Baruah from Assam whom NIF supported MVIF for commercialisation his product. At present, five units of printing machines have been diffused in North East India.

Remote operated device for firecracker:

The fire-cracker machine, a remote-controlled device was developed by Mr. Balram Singh Saini. Usually, the machine used in various occasions such as marriage, festivals etc. The machine was granted MVIF by the NIF. In the initial stage, NIF provided financial support for prototyping his product.

Milking machine:

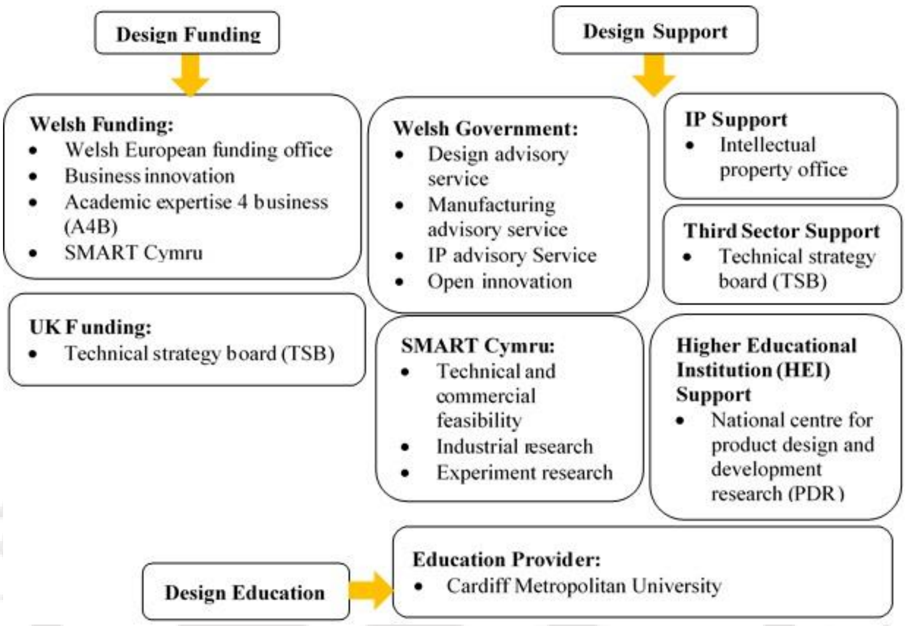
Innovator Mr. Raghav Gawda developed a manually operated low-cost milking machine for rural communities in developing countries. Currently, his machine is available in three models worth ₹ 10,000 to ₹ 22,000. The machine has been sold more 200 units to date.

Unique coupling device:

Innovator Mr. Deepak Das of Assam has developed power transmission device, which increases the efficiency of power transmission. The device can be assembled into any automobiles, pumps, and generators as couplers in power transmission equipment where energy is transferred from a drive shaft to another. GIAN-NE provided him financial support of worth ₹ 20,000 for promoting his device in the market.

6.3.3 Innovation ecosystem in Wales: design demand

Governments around the world are increasingly acknowledging the role and value of design (Design Council, 2010). In September 2013, the European Commission launched an 'Action Plan for Design-Driven Innovation'. In 2011, the UK Government stated that 'Design can be transformative for companies, through leading or supporting product and process innovation. In 2013, the Welsh Government recognised design as a driver of innovation for the private and public sectors in the 'Innovation Strategy for Wales'.



Flow diagram 6.2: Design Innovation Ecosystem for Cardiff (Whicher and Walters, 2014).

Based on interviewees from the Design Council, Welsh Government and a design education provider in Cardiff, Wales, the present scenario of the Design Innovation Wales, ecosystem is shown in **Flow diagram 6.2.**

The Welsh Government's Business Innovation programme provides innovation support to businesses in Wales. Fully integrated advice and specialist support is available to help smaller businesses take their first steps into innovation and R & D.

Business Innovation helps business to:

- Access funding for business innovation
- Create and commercialise new products and processes
- Increase efficiency in manufacturing through technology and process improvement
- Introduce design for new product development and manufacture
- Identify, protect and exploit your intellectual property (IP)

Welsh government provides micro loans up to million-pound at two stages for business: (1) tailored start-up, and (2) early stage finance to start the business grow up. In tailored start-up scheme the Welsh government provides three types of loans as stated in **Table 6.1**. Under the Innovate UK, the new name for the TSB is the UK's national innovation agency, and it contributes to businesses- led innovation of SMEs from small start-ups to global companies.

Table 6.1: Welsh Government funding

Micro loans	Tech ventures	Established SMEs
£1,000 - £50,000	£50,000 up to £2 million	from £50,000 upwards

The Innovate UK is a business-led organisation established by the Government. Its mission is to accelerate research, development and exploitation of technology and innovation for the benefit of UK business - building, economic growth and quality of life.

The Innovate UK provides funding for projects which are led by business. They support to stimulate R&D and innovation activity by encouraging businesses to develop innovative products, processes and services having future commercial potential. The provision of financial support by the Innovate UK is shown in **Table 6.2**.

Table 6.2: Innovate UK funding for SMEs business innovation (EU, 2003).

Applicant Business Size	Fundamental Research	Feasibility Studies	Industrial Research	Experimental Development
Micro/ Small	100%	70%	70%	45%
Medium	100%	60%	60%	35%

The Welsh Government's SMART Cymru team provides funding scheme and support to all innovators at different stages of a research and development (R & D) based innovation is shown in **Table 6.3**.

Table 6.3: SMART Cymru research and development.

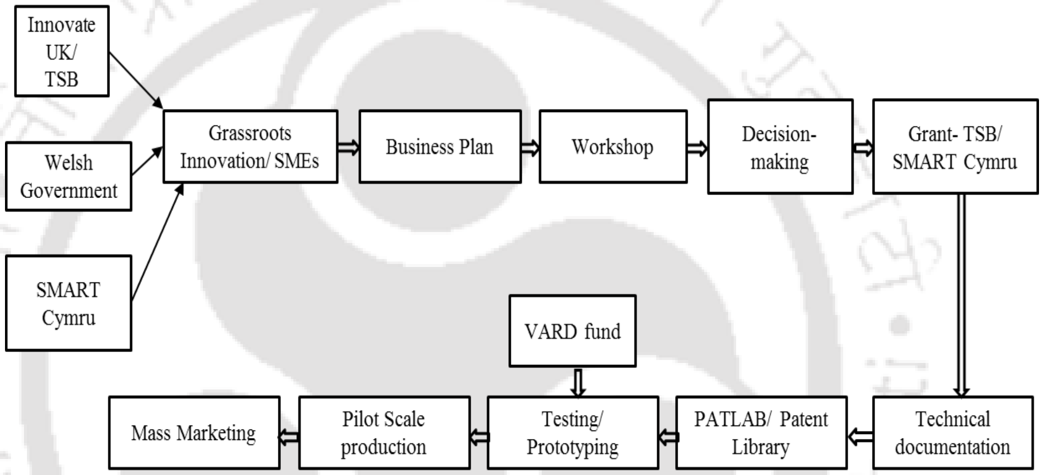
R& D Phase	Small Enterprise	Medium Enterprise	Large Enterprise	Limits
Technical and commercial feasibility	Up to 75%	Up to 75%	Up to 65%	£15,000
Industrial research	Up to 70%	Up to 60%	Up to 50%	£100,000
Experimental development	Up to 45%	Up to35%	Up to 25%	£200,000
Exploitation	Up to 50%	Up to 50%	Up to 50%	£20,000

6.3.4 TBI framework in Wales

The Technology business incubation framework in Wales is shown in **Flow diagram 6.3** and various in steps of the innovation in Wales are shown below:

- **Scouting for innovations:** Scouting for innovation is done by Innovate UK, Welsh Government and SMART Cymru.

- **Business plan:** Second stage of incubation support services, which include preparing a business plan.
- **Workshop:** Various workshop are organised by funding bodies. They provide many workshops to grassroots innovators and individuals for the purpose of testing their business ideas. They also provide start- up workshops. Moreover, they provide information regarding IPR, compliance, and design and manufacturing.



Flow diagram 6.3: TBI process for scouting the grassroots innovations in Wales.

- **Decision-making:** After making business plan, TSB and SMART Cymru decide whether to support the innovations for commercialisation or not.
- **Technical documentation:** Technical documentation is obtained from innovators when they apply for support from TBS and SMART Cymru.
- **PATLAB/Patent library:** At this stage, to protect the technology innovation in terms of IPR, the process of filling patent is started.
- **Testing and prototype development:** Next the prototype model of the technology Innovation is developed. VARD, created with the help of TBS and SMART Cymru, supports the testing and prototype development.
- **Pilot scale production:** At this stage, a small quantity of product is produced to check the production viability and for a test in the market.
- **Mass manufacturing:** Thereafter, product goes to mass manufacturing.

6.3.5 Examples of commercialised indigenous innovations in Wales, UK

Some examples of indigenous innovations in various sectors where Welsh Government innovation scheme helped to increase commercialisation. They are shown below:

Project Enduro:

The Enduro is a four-wheeled downhill mountain human-powered vehicle for the disabled person. The vehicle was designed and developed by Mr. Calvin Williams from Gower College Swansea in collaboration with the Trinity Saint David University of Wales, Swansea Metropolitan in 2015 under Academic Expertise for Business programme (A4B) (Business Wales, 2015). This project received financial support of over £500,000 from both Welsh Government and industry through European Regional Development Funding programme. In the present time, the project is into a commercialised venture of mountain vehicle in the world. In addition, the project has gained one of the significant innovations in Britain's supporting retailer and distributors.

Brick Fabrication KTP

A Pontypool based building manufacturer Brick Fabrication SME which was supported by Knowledge Transfer Partnership (KTP) with Cardiff University (Business Wales, 2016). KTP implemented the lean manufacturing principle and innovated techniques for improving overall operational efficiency and performance.

Adventa

Adventa was established in 1983 as a small family run business specialising in injection moulding. The Adventa provided print products for trade and wholesale customers. In 2015, Welsh Government provided financial support to develop a new high-speed glue machine that applies the back to back automatically and later the Aventa designed and developed a new product namely QuickPro Artrap, which works as a board construction of canvas wall art and patented fold- and- lock system. In addition, Welsh Government innovation funding supported Aventa in launching both products at Photokina exhibition in Cologne that was a global trade fair for the print media sector (Business Wales, 2017).

Rapidbuild

The RapidBuild is an accelerated-build technique that was developed by a builder Mr. Andy Roberts along with a small team of North Wales, UK in 2015 (Business Wales, 2016). The RapidBuild involves in the construction of a durable, block-work 'inner skin' of a house. It reduces build times up to 40% and increases the build quality of new houses than with conventional techniques. The company has received financial support from Welsh Government innovation, backed by EU funds. Financial feasibility study for Rapidbuild was done through construction research group BRE (Building Research Establishment) with the help of Welsh Government and also included rigours strength testing under various climate and weather conditions. The Rapidbuild technique was successfully examined through BRE's stringent testing criteria, including confirmation of the time and cost saving afforded by RapidBuild. The feasibility study served as a technical endorsement and allowed the company to make two specific patents which gaining credibility within an industry, which needs to adhere to stringent regulations and standards of health and safety. Support of Welsh Government funding not only establishing technical and commercial credibility but also an innovation with the potential to fulfill sustainable development in the housing sector.

6.3.6 Design support in Wales, UK

There are two reasons why an understanding of the innovation context in Wales is important: First, the Welsh economy faces a number of economic and labour market challenges, and the Welsh Government realised the need for new innovative approaches if Wales is to create a strong entrepreneurial culture and to provide a strong base for economic regeneration. The Welsh Government has been providing design support to SMEs in Wales through organisations such as Design Wales since 2000 and the National Centre for Product Design and Development Research (PDR) at Cardiff Metropolitan University since 1994. Design Wales initiated several design programmes for SMEs based in Wales and coordinated the EU-funded programme "SEEdesign"-Sharing Experience on Design Support for SMEs between 2005 and 2007. They have included 'Understanding computer-aided design', 'Design in the Food Sector', 'Brand Essentials' and the 'Service Design Programme'. The largest proportion of innovations in Wales (36%) contributing £465 Million to the economy, come from the creative industries both in employment and gross value added (Whicher, 2011). The designers were typically male and able-bodied, and a more recent survey of the UK design industry expressed concerns regarding lack of diversity within the design community itself (Wilkinson, 2014). The survey revealed that the average UK designer is male, white, and 38 years old, with only 7% of UK designers coming from an ethnic minority background (Wilkinson, 2014). Wales has historically been a powerhouse of public innovation. Instead of innovation and entrepreneurship policies, the mid-2000s was dominated by broader economic strategies (e.g. Winning Wales, WAG, 2002 and Wales: A Vibrant Economy, WAG, 2005) and higher education policy (e.g. Youth Entrepreneurship Strategy for Wales, WAG, 2002). Economic strategies emphasised innovation as a key to the overarching aim of turning Wales into a knowledge-based economy. According to recent trends presented by the Global Entrepreneurship Monitor Report (GEM) (Levie *et al.*, 2014), the rate of total early-stage entrepreneurship (TEA) in Wales was 5.4% which is significantly lower than the 7.0% recorded in 2012. In terms of youth entrepreneurship, results from the GEM data show that the TEA for those aged between 18 and 29 dropped from 8.6% in 2012 to 4.9% in 2013. Entrepreneurship is still not seen as a viable career by 93% of young people in Wales as young people move away from self-employment towards safer jobs (Evans, 2014).

According to the most recent statistics by the Welsh Government Knowledge and Analytical Services (2013), there were an estimated 219,400 enterprises active in Wales in 2013. The majority of these active enterprises were SMEs accounting for 99.3% of total enterprises in Wales in 2013. Between 2003 and 2013 the overall increase in enterprises active in Wales was largely due to the growth in the micro businesses (up to 35.5%). Moreover, Start-Up Britain (2015) has released the most recent data on new business registration. According to it 581,173 new UK firms were registered with Companies House in 2014. This represents a growth of 8% in just 12 months and beats the previous record of 526,446 businesses recorded in the previous year (Jones *et al.*, 2015). In Wales over 14,000 businesses were created in 2014. However, this accounted only for 2.5% of the total of new firms for the UK as a whole.

6.3.7 Design business support in Wales

The design is increasingly recognised by governments across Europe as a tool for innovating products, services, and systems. However, there are still challenges to the uptake of professional design services among SMEs (SEE platform, 2013). Nevertheless, demand for design is a fully integrated Design Council programme offering services for a wide range of businesses from high growth start-ups to more established businesses looking for new ideas for products and services (Design Council, 2007). However, in Wales, the Service Design programme was launched in January 2011 by Design Wales and Cardiff Metropolitan University to improve practical and use design-led service Innovation in the manufacturing sector and also for building a regional capacity for service design (SEE platform, 2014). The service design programme was a Knowledge Transfer Centre Project (KTC) funded by the Welsh Government's A4B (Academia for Business) projects. The Service Design KTC has supported industry in Wales to use service design and has provided training for Wales design agencies in service design methods and tools, including ethnographic research, ideation, rapid prototyping and user testing. The service design workshop by Design Wales is aimed at manufacturing companies who are first-time users of service design expertise and consists of three key components: (1) Capturing Experiences, (2) Customer Journey Mapping and (3) Service Blueprinting (Brooker, 2012). A 'Capturing Experiences' workshop investigates customer experience audit quality, and how to conduct research with customers and analyse competitors. Customer Journey Mapping is a core service design activity that highlights common problems within the company and identifies opportunities. Service Blueprinting is a technique that sets out the front and back of service operations as a visual map of someone's business (Brooker, 2012). There are numerous successful stories (PDR, 2014).

6.4 Interventions for grassroots innovation: case study

A case study analysed and described below is given to help provide an understanding of the motivations of two imaginative individuals who have invented, designed, developed and presented inventive products in India and Wales respectively. The people and their products are:

- Deepak Bharali's innovation, 'Chaneki', is an extra ornamentation device for the Jacquard loom to facilitate extra weft insertion.
- Frank Edwards- novel innovation, 'Synidor', is an intelligent mattress cover for bedsores.

Deepak's innovation, Chaneki was supported through National Innovation Foundation (NIF) with the help of Indian Institute of Technology Guwahati, a technical institution in Assam, India. On the other hand, Frank's indigenous innovation Synidor was supported by the Welsh Government Programme- Academic Expertise for Business (A4B). Both the case studies helped to explore commercial manufacturing facilities to the grassroots innovations in both India and Wales. Both of them are grassroots innovators.

6.5 Indian innovation: Chaneki

Chaneki means the printed design on graph paper followed by weavers to deliver it on cloth through the weaving process in Northeast India. Throughout the year, the weavers confronting basic issues while working with the Jacquard looms is shown in **Figure 6.1.** Firstly, the treatment of weft strings at different interims and the tying of bunches brought about drudgery and required a great deal of time and effort. A normal texture, comprising of 30 columns of lines with 14 consecutive designs, would have no less than 3 knots per design. This would mean a sum of 1260 knots and that would require nearly 10 hours of work, and the Weaver takes 30 seconds to make every knot. Besides, dealing with designs that need synchronous handling of at least five strings requires extraordinary aptitude that requires a couple of talented weavers.

Figure 6.1: A village woman is using existing Chaneki with Jacquard loom (Boruah and Das, 2017).

Thirdly, while taking care of expensive designs or when the crevice between the weft strings is too little, the weavers think that it is hard to slide their finger in handling the wefts. In order to generate speed, automate and chop down the dull procedure in routine errands, Deepak decided to make a devoted apparatus style attachment that can work in conjunction with standard Jacquard machine.

6.5.1 Concept generation of the Chaneki

The task of insertion of weft strings expected to make an assortment of design is done physically by tying knots, which is monotonous, lumbering and tedious. The string is additionally squandered in the association between one motif to another. The Chaneki facilitates texture efficiency help by more than 60% while wiping out the drudgery. This attachment to the Jacquard loom permits incompetent workers to enter the business and deliver extravagantly composed textures.

6.5.2 Product detailing of the Chaneki

The newly designed Chaneki [**Figure 6.3**] was produced as an attachment that can be fitted into any Jacquard loom. The Chaneki has three parts, a base frame that goes about as a shaft holder, the magnet bearing shaft, and the uniquely designed bobbin. The uniqueness lies in utilising the attractive magnetic clamping systems and uncommonly designed bobbin to accomplish its viability. The attachment facilitates the Jacquard loom to do automatic choice and helps in lifting of twist strings for design making. The magnet mounted shaft is fitted into the base casing. The magnets fluctuate relying on the designs that one has in every line. It is not at all like typical design making looms where every weft string is associated with a bobbin. These bobbins are put on the lower surface of the base frame, just in line at the top of the respective magnets attached on the shaft. Once the magnet and its delicate bobbins are stuck to the surface, the frame goes up against the top of the twist strings. As the Jacquard machine chooses and lifts the twist strings, the device is put on top of the twist strings. The device is set in a manner that the bobbins attached surface faces downwards and every bobbin falls in the middle of two arrangements of lifted twist strings.

As the magnet fitted shaft moves from one side to the other, it additionally drags along the bobbins appended to it from one side to the other. All the while, the concurrent intersection of all weft strings for design making happens. Once the weft string bobbins are intersected, the entire device is lifted to proceed with the typical loom weaving process. A similar procedure proceeds for all the weft string arrangements until the design making is finished.

6.5.3 Value addition of the Chaneki

The initial mock-up was made of wood in 2006. The NIF then provided support for the project by taking the help of a professor of industrial design at the Indian Institute of Technology Guwahati. Deepak and the professor made a number of mock-up models and after few of trials, they created a marketable version of the product [**Figure 6.2**]. In the entire process of development of the device, the development of the bobbin took most of the time. The result was the design of a new, special bobbin using a micro ball bearing [**Figure 6.3**].

Figure 6.2: After value addition of the Chaneki (Boruah and Das, 2017).

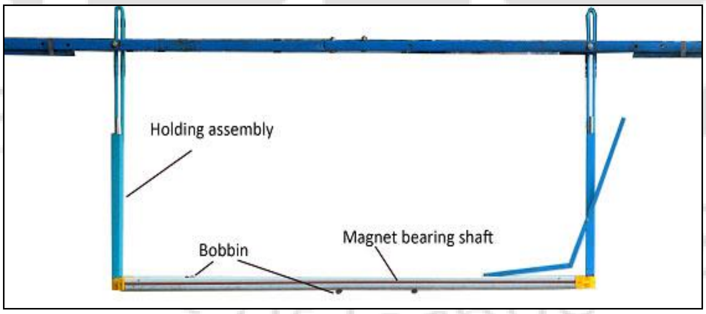


Figure 6.3: Commercial prototype of the Chaneki (Boruah and Das, 2017).

Another problem with the bobbin was that the art silk got uncoiled due to the elasticity and this created a problem in working, and so to avoid this, the innovator added a cup-shaped cover surrounding the bobbin keeping a hole for the art silk to pass through. Therefore, Deepak modified the shape of the bobbin with the help of design professor to solve the problem. Earlier Deepak used the magnet of a small sound speaker that is round in shape. Then he thought of replacing it with a magnet having a thread at the bottom so that it could be screwed.

(a): Bobbin without bearing. **(b):** Bobbin with bearing.

Figure 6.4: Value addition of the bobbin (Boruah and Das, 2017).

Figure 6.5: Pyramid shaped magnet (Boruah and Das, 2017).

But in consultation with the professor in design, was decided to use a pyramid shaped magnet (**Figure 6.5**) that will get itself clamped with the magnet bearing shaft [**Figure 6.6 (a)**].

(a): Bottom view of magnet bearing shaft.

(b): Top view of whole magnet bearing shaft.

(c): Bottom view of whole magnet bearing shaft.

Figure 6.6: Value addition of magnet bearing shaft (Boruah and Das, 2017).

In the first model, a weaver needs to keep the shaft over the weaving material, whereas in the new model the shaft dangles from the loom and is set close to the beater.

Whenever required, a weaver can pull it down and after the work is over a spring will pull the shaft to its original position. The professor in design instructed to utilise a pipe rather with respect to a metal sheet for the holding assembly (**Figure 6.7**). In light of the fact that the spring mechanism can be kept inside the pipe reducing the possibility of duplicating, yet if there arises an occurrence of the metal sheet it must be kept open.

(a): View of holding assembly.

(b): Magnet bearing shaft with holding assembly pipe.

(c): Sliding lever of magnet bearing shaft.

Figure 6.7: Value addition of holding assembly (Boruah and Das, 2017).

6.5.4 Diffusion of the Chaneki

To date, Deepak has sold around 1500 pieces throughout India. The device has been generally acknowledged by the weavers of various states of India. Globally, the device additionally has wide potential in the South Asian countries.

6.5.5 Role of technology business incubation

In the initial stage, Deepak invested ₹ 3.7 million from his own source for developing the concept and for making test models from wooden mock-ups. He went to NIF for discussions and then met a Professor of the Department of Design, IIT Guwahati. The professor and Deepak made different models with the help of the Department of Design, IIT Guwahati, India. After numerous iterations, the final design iteration was fabricated and successfully tested in IIT Guwahati. Then a Delhi-based plastic fabrication factory made the casings for the magnetic bobbins. At that point, NIF provided budgetary support of about ₹ 1.2 million, an 8% soft loan with a 10-year contract and later a ₹ 0.3 million premium free grant for market development. Deepak was given the venture finance from the Micro Venture Innovative Fund (MVIF). At present many government organisations are taking interest to introduce the product all over the country as a practically convenient product. Currently, the Central Silk Board in India provides a 75-80% subsidy for the cost of the device to the beneficiaries.

6.5.6 Financial support

The business improvement Bureau of the NIF bolsters the working of a value chain for grassroots developments to encourage their move into self-supporting economic endeavours. In 2008- 09 the NIF offered financial assistance from Micro Venture Innovation Fund (MVIF) of ₹ 0.235 million for institutionalisation and test advertising, and this money came from the Small Industry Development Bank of India (SIDBI). MVIF is a novel association, which was set up in October 2003 and it gives financial assistance to pioneers and entrepreneurs who are associated with NIF for innovation and commercialisation (Boruah and Das, 2017).

6.5.7 Problems, challenges and future

The NIF helped Deepak in many ways including documentation, publicity, patenting, and partial financial support for commercialisation. However, the significant problems confronted by Deepak for his development of Chaneki, are given below:

- **Procedural delay:** Deepak had to face the problem of postponement in commercialisation of his advancements with the assistance of NIF. Notwithstanding, it is essential to note that grassroots innovators get their advancements a crude shape that requires significant work and labour to get them to an appropriate level as an attractive product with the assistance of design establishments.
- **Limited funds:** Deepak realised that the NIF had not fully supported him for his innovation at the initial stage.

6.6 About the Wales innovator and his innovation

Frank Edwards was born in 1952 in Llandeilo, a Carmarthenshire town in Wales, UK.

When he reached the eight standards he dropped out of school. After dropping out his studies he started working in a Fibreglass shop in Cardiff. He made various boat models and later started to work on human anthropometric device including wheelchairs. These experiences inspired him to become an inventor and to date has 29 innovations.

6.6.1 Concept generation of the Synidor

The Synidor system was to help the anticipation of pressure ulcers by checking and cautioning of a fixed status of at-hazard patients. Bedsores happen on regions of the skin that are under pressure when a man has difficulty in moving, is incapacitated, unconscious, not able to sense pain or immobile. The assembly is attached to a fitted covered mattress sheet. Edwards built up the essential specialised plausibility of his thought by testing a basic stethoscope with a sphygmomanometer gadget and saw how these two gadgets functioned. This is an unmistakable instance of the transfer of a thought and innovation starting with one application then onto the next. The device could work for those patients who have pressure ulcer by between 20% and as much as 60%. The device incorporates a sensor that lies at the bottom of a patient's spine. If a patient has not moved for a certain period of time it alerts healthcare staff. The alarm can be set to go off at intervals of 30 minutes.

6.6.2 Product detailing of the Synidor

The Synidor system consists of two basic configurations. Detail sketch view is shown in **Figure 6.8**.

- Sensor assembly: attached to the full-length waterproof fitted mattress cover sheet.
- Patient Immobility Monitor (PIM) alarm unit: a battery driven remote caution unit that can be customised for the picked turning administration. At this point when inadequate movement is detected, unmistakable and alerts will trigger.

An astute bedding cushion cover is made by the provision of a strap across the bed or seat, which joins a proprietary sensor. Patient movements, however little, they may be being observed through the sensor appended to an electronic processor. By chance, no patient movement is identified in a predetermined time prescribed by the nurse or caretaker, the patient may be in danger of creating pressure ulcers and will require nursing mediation. The CAD view of the Synidor [**Figure 6.9**] and different views of the prototype are shown in **Figure 6.10**.

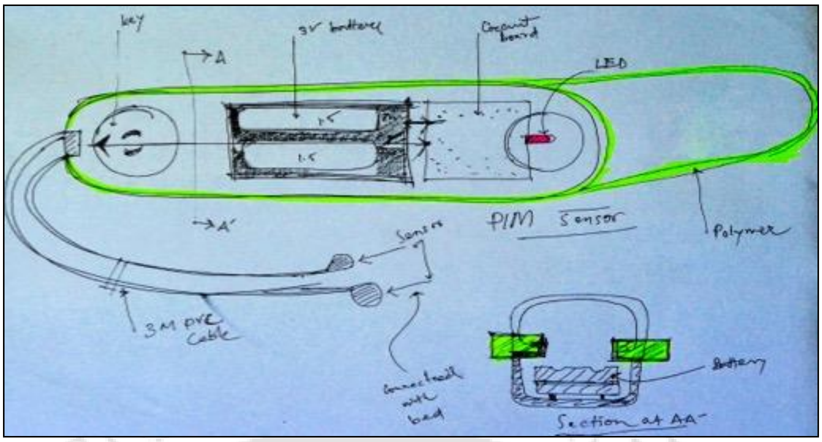


Figure 6.8: Internal sketch of the Synidor (Boruah and Das, 2017).

Figure 6.9: Prototype of the Synidor (Boruah and Das, 2017).

Figure 6.10: Different views of the Synidor (Boruah and Das, 2017).

The Synidor PIM caution unit should set as per the timing of the turning regime recommended for the patient by the medical attendant [**Figure 6.11**]. Once the setting had been chosen, the DATALINE cable is inserted into the base of the PIM alarm unit **Figure 6.10**.

Figure 6.11: Innovator of Synidor, Edwards demonstrating the product (Boruah and Das, 2017).

6.6.3 Role of technology business incubation

The Welsh Wound Network (WWN) exhorted Frank Edwards to make an alarm system for wheelchairs and sleeping bedding covers. The latest research has demonstrated that pressure ulcers in the UK cost £1.4-2.1 billion (₹ 124.27 billion approx.) every year. Straight to the point, Frank Edwards got bolster from the Assembly Government from the early feasibility stages by means of the Wales Innovators Network (WIN) for manufacturing. Edwards got the expertise at PDR, at Cardiff Metropolitan University to build up the casing for the alarm unit. PDR charged ₹ 1.2 million approx., and after many trials, the (Acrylonitrile Butadiene Styrene) made alarm unit was successfully tried for 6 weeks.

PDR collaborated with Glamorgan University for assistance in designing the electronics for the system. During those days Edwards worked at the Cardiff Medi-centre for 3 years (2007- 2010). His daughter designed the electronic circuit board at the University of Glamorgan. The system was initially tested by the Sunderland NHS Trust on his 80 years old mother. A China-based plastic injection moulding factory made 1000 pieces of casing unit for Synidor and 1000 pieces of circuit board were developed by an electric company, Newport, UK which cost ₹ 69 million approx.

Edwards received ₹ 18 million approx. from 49 investors in the UK. In total, the cost of innovation was £4 million.

6.6.4 Financial support

In 2009, the Welsh Assembly Government funded ₹ 14.8 million approx. Edwards innovation through its Academics Expertise for Business (A4B) programme, and the Welsh Assembly Government helped Edwards develop his business model.

6.6.5 Problems, challenges and future

In early November 2010, the Synidor was shortlisted in two award categories, as part of WWN's Nursing Times Product Awards, (1) for dignity, daily living and wound care and (2) pressure ulcer prevention category. Unfortunately, Synidor was not successful in either category but introduced in the event a brand new product for NHS (NHS,2010). Straight to the point, Edwards highlighted that he confronted difficulties amids the advancement of his development Synidor, on the other hand felt absence of appropriate instructions to a considerable extend.

6.6.6 Diffusion of the Synidor

In the first stage of commercialisation, two devices had been sold to Birmingham Hospital, two units to Hammersmith Hospital, one unit to the Home Watch Network in Cardiff, and one unit at Llantrisant Hospital. Synidor aimed at gaining 20% market share in the UK, North America and European territories in 5 years. Due to its highly unique nature, the inventor had kept the intellectual property guarded, even refusing to patent it as this would mean at possibility of the formula to be disclosed. This IP has been independently valued at £6.5million, based on its application in the UK market and it is therefore expected that the product can be successfully distributed globally.

6.7 Comparison between two innovations

Grassroots innovations focus on innovation by the poor in India (and elsewhere). However, the definition of grassroots innovations in the UK, does not exclusively relate to the poor. On the basis of the findings from the case study, it is possible to identify many similarities in concept development, the personal qualities of the individuals and innovation process which has been successfully introduced to the market as mentioned in **Table 6.4**.

In India, the most important factor is the creation of an investment fund to support enterprises and innovators that provide solutions to improve the lowest-income group. The grassroots innovators face stiffer difficulties regarding finance. Also at the initial stage of their start-up, it is difficult to hire skilled and capable people in the management team due to low salaries they can afford.

In Wales, the Welsh Government provides support for local innovations from initial ideas to the implementation of the final product or innovation including business innovation to help drive business success. The innovation specialists can identify how the business can be more innovative as well as how it can provide access to funding for business innovation advice and support that are available.

Table 6.4: Comparison between innovation in India and Wales.

	Chaneki- India innovation	**Synidor- Wales innovation**
Diffusion	2000 pieces sold Price/ piece= ₹ 2500/-	6 units sold in the UK Price/ unit= ₹ 54,000/-
Role of Technology Business Incubation	Highly expert man-power at technical institutions with innovation can help business incubation. This was evident in case of Chaneki.	Specialised Institution like PDR created to help in business incubation.
Financial support	At the initial stage Deepak had no financial support from Government	The Welsh Assembly Government funded ₹ 14.8 million through its Academics Expertise for Business (A4B) programme. He received funds
Problem, Challenge and Future	➢ NIF helped Deepak in documentation, publicity, patenting, and partial financial support for commercialisation *Product Awards:* (1) President's State Award in 2009. (2) Fifth National Biennial Awards in 2009. Problems: ➢ Long procedure for getting financial support- total number of innovations scouted by NIF is very huge. ➢ Limited Funds	➢ In November, 2010 the Synidor was shortlisted in two award categories, as part of WWN's Nursing Times *Product Awards:* (1) Dignity, daily living and wound care (2) Pressure ulcer prevention category. - Introduced new brand product at NHS. - Innovator specialist helped him develop Synidor into marketable product.

6.8 Validation of hypothesis- H2

The second hypothesis formulated in Chapter 1, section 1.8 is that *"Guidelines drawn from the study of support for innovation in India and western countries, may facilitate effectively for the introduction and sustainability of a designed product"*.

It has been observed that in India, only innovations from grassroots innovators are covered for design support which is also true for grassroots innovations in Wales, UK.

Findings from the study shows that the innovations in India should also be fostered through eight creative ways as given below and that will be a guideline to fulfil the challenge for successful commercialisation of the amphibian ambulance for the people of low-income groups.

i. *Empower the development of micro-venture finance:* The venture capital is basic in providing risk capital to subsidizing the entrepreneurs who emerge from all backgrounds. The government should expand the Micro Venture Innovation Fund.

ii. *Grow the common people pool of development by providing financial support to the innovators:* In 2011, the Honey Bee Network and NIF made the 'Grassroots Technological Innovation Acquisition Fund for providing of financial incentive encourages innovators to the programme and decrease barrios to diffusion.

iii. *Recognise, regard, and reward innovators where they live:* It is important to respect innovators.

iv. *Create community fabrication workshops in the homes of innovators:* To encourage innovators to share their work and to get growing innovators required in creating new things. The government should provide fabrication workshops inside the homes of innovators. These workshops, which are open to the community ought to have machinery and instruments that would otherwise be unavailable, especially in rural areas. The workshops likewise encourage a soul of collaboration that helps further production of the indigenous innovation.

v. *Build partnerships* amongst formal and casual science: A characteristic item research centre, Sadbhav-SRISTI-Sanshodhan, was made over 10 years' prior at SRISTI through a grant from a private altruist in Mumbai. It is presently supported by DST and other institutions. It takes a shot at the thoughts, innovations, and traditional knowledge of individuals in four regions agriculture, veterinary, human, and microbial diversity.

vi. *Prepare college students to address unsolved social issues:* Undergraduates, graduates, and Doctoral researchers should be encouraged to tackle genuine social issues.

vii. Promote indigenous innovation for condition suited cultivating and resource management. It perceives indigenous knowledge and easy-going experimentation among agriculturists, timberland occupants, pastoralists, and fisher folk.

viii. Organisations for support and headway of indigenous innovation are not dynamic, yet rather level, in light of systems administration standard. This is the similar principle they use for collaboration with organisations of the formal sector. It diminishes use of time and resources, making this collaboration faster and more effective.

This research followed all steps such as technical documentation, prototyping and testing common in both systems prior to commercialisation and should facilitate introduction of the amphibian ambulance commercially. In addition, collaboration with a start-up was carried out during prototyping and testing in absence of proper financial support. This process can facilitate introduction of the product in the market easily. Thus, it fulfils the hypothesis 2.

Chapter 7: Discussion, Conclusion and Recommendation

The mighty river Brahmaputra flows through the middle of the state of Assam from east to west distinctly dividing the valley into two parts, north bank and south bank. While flowing through its course, the river has been depositing huge amount of silt carried from upstream and this has resulted in huge riverine islands in the middle of the river and at the banks huge sandbanks. During monsoon, most of the times, these char areas are flooded and hence there is no permanent infrastructure in these areas. But because of fertile lands, a considerable population lives in these areas. In Assam, majority of the population inhabit the rural areas, and out of this rural population, 2.5 million people live in the riverine islands and sand banks mentioned above. Many places in these riverine areas are totally inaccessible by road in the absence of permanent road networks, since these riverine islands and many other areas are affected by the flood created by the river Brahmaputra and its tributaries in monsoons. This results in disruption of the health services of the people living in these areas. To provide health care facilities to the riverine areas, an NGO, Centre for North East Studies and Policy Research (C-NES) initiated innovative ideas for implementation to reach the poor and marginalised group by introducing boat based health services called boat clinics. This yielded positive results and later, Government of India collaborated with C-NES to expand boat clinic to make health services available to riverine rural communities in Assam under National Rural Health Mission. Although the government expanded boat clinics, people found it difficult to access them in emergencies, since patients cannot be easily transported by road to these boat clinics in the absence of proper road by traditional mode of transport.

The aim of this research was to facilitate a solution to provide transport to and from local health centres. Possibility of safely and comfortably carrying a patient and an outreach medical worker, emergency medical supplies for on-site treatment, can considerably reduce the time taken to get essential and emergency medical assistance to remote communities. It was felt that for remote riverine areas of Assam, providing access to rural health care facilities with existing socio-economic, road and environmental conditions, there is a need to design an amphibian ambulance along with related systems and was proposed to be undertaken as a part of this doctoral research.

Accordingly, an amphibian ambulance was conceptualised, designed, developed and prototyped in the Department of Design, Indian Institute of Technology, Guwahati. Prototype of the amphibian ambulance was further refined based on field trials carried out at IIT Guwahati campus and Amingaon primary health centre with participatory approach. The feedback received from these trials indicated that the vehicle was an efficient and appropriate solution compared to existing transportation mode in target areas. From the field trial it was also found that the vehicle was safe for operation as per the users' perception and it is user friendly, comfortable, easy to access, protected from natural elements and also sustainable for the riverine people, being fully amphibian in feature and satisfactorily worked on land and in water. This amphibian vehicle can be used in many other ways as an ambulance in the riverine areas and, thus, can be a sustainable activity for the rural population.

Once the design of the amphibian ambulance was found to be acceptable, next challenge was to find out way to introduce the same in the target area. Since the research work was without any financial support for its introduction in the contextual area, the study was done to find out appropriate way to achieve the same.

Though product innovation is one of the key strategic options available to SMEs in developing economies in order to compete better in today's global market, the contextual factors that affect the product's acceptance in the market was investigated. In this regard, it has investigated the factors that affect indigenous innovation during the Erasmus Mundus Interweave fellowship programme at Cardiff Metropolitan University, Wales for commercialisation of the newly designed amphibian ambulance. The design support for indigenous innovations at grassroots level is provided by the National Innovation Foundation (NIF), India. However, NIF does not provide financial support to science and technology background researchers. It provides financial support only to innovators who do not come from engineering background. But, in Wales, the Welsh Government provides support for all local innovators and also their ideas in the initial stage for the implementation of the final product including business innovation to drive business success. NIF and Government of India should come out with a mechanism to provide funding support from already established Government funded agencies like the District Industries and Commerce Centres (DICC), the Prototype Development and Training Centre (NSIC), New Delhi, and the Centre for Entrepreneurship Development (CED) for development of the newly designed amphibian ambulance. National Health Mission can adopt this context specific design innovation and should provide this facility to the riverine areas in the Brahmaputra valley.

Inhabitants of the riverine areas should be encouraged to support and accept this type of health care solutions. The acceptance by the community is essential for the success of amphibian ambulance.

7.1 Findings of present study

This research becomes relevant as it can provide and improve appropriate healthcare transportation system for riverine areas in Assam. From the various case studies and field surveys, it was evident that people travel to the boat clinic by walking and also reach them in whatever mode of transport available to them including the bullock carts, the horse carts, and the small boats if the person is immobile. The most common practice in riverine areas is that a patient is wrapped up with clothes to be carried by a strong person to the health centres. On several occasions, patients are also found to be transported in a handcart. Even in this case, where there are small water bodies without a bridge, it becomes impossible to cross them. Therefore, patients in many cases, never reach the health centres in time. Designing for the underprivileged section of the society is one of the basic requirements for indigenous design in Assam. This research is an attempt towards developing the current practice for meeting the local transportation needs of the poor population of remote riverine areas for accessing health centres. The solution of this type of problem can lead to a better healthcare system for the rural areas.

The design development in this research work has attempted to solve some of the shortcomings of accessing rural health services in remote riverine areas of Assam. The chapter discusses various aspects of the achievements of the research work, the problems have been solved through the 'Research by Design' and evaluation of the work achieved against targeted aims and objectives set at the beginning of the research, recommendation and scopes for further work in the research areas.

7.2 Contribution of the present research

The research has contributed to the knowledge in the area of contextual design and possible design and technology transfer of the amphibian ambulance to the potential market in Indian context, specifically considering the rural riverine areas in Assam.

The outcome of the research provides a solution to improve the current transportation system in remote riverine areas in Assam for accessing health care services. As mentioned earlier, context specific design and development of an innovative product is the best possible way to solve the problem of accessibility to health care services in rural riverine areas where proper road network does not exist. The newly designed and developed amphibian ambulance branded as *Dola* was prototyped and its manufacturing system management was evolved in the Department of Design, IIT Guwahati with participation from M/s Dipon Design Pvt. Ltd., a start-up under Technology Incubation Centre under IIT Guwahati located at North Guwahati, Assam.

Given fact that emergency service care can make an important contribution to reducing avoidable death and disability in low-income groups in developing countries, the designed and developed amphibian ambulance can play a very significant role. With better planning and co-ordination with boat clinics etc., within the present cost incurred for emergency care at present can achieve higher outcomes. This type of research can lead to filling up the gaps in accessing health care facilities in target areas including emergency care.

7.3 Suggestions and recommendation

The following are the suggestions for consideration while adopting and using the newly designed amphibian ambulance as a sustainable transportation mode:

a) Rider should preferably be a male person who can control the vehicle and attendant may be either a male or a female. However, physically fit strong female can also be a rider.

b) For the ease of use while transporting patients to and from health care facilities require crossing water bodies without bridges, the banks of these water bodies can be prepared by cutting it at a slope so that getting the amphibian ambulance into the water and getting it out of the water is easy. Wooden poles can be fixed at the banks where the wire ropes of the winch fitted in the ambulance can be tied and winched to get it in or out of the water very smoothly with less effort.

c) The winch fixed at the rear end of the amphibian ambulance should be used to get it out of a situation such as when the vehicle gets stuck in the muddy water.

d) A gasoline fuel engine or electric motor can be coupled with the transmission system of the ambulance to propel it by a propeller at the time of water mode operation.

e) Propeller should be possible to be disengaged while the vehicle is used only on land.

7.4 Limitation of the current research

Various limitations of this research can be summed up as under:

The research is based on a specific context. Being operated by human power, the vehicle is suitable for crossing still water bodies created by flash flood water or a small water bodies with still water. If there is strong current, the amphibian ambulance may not be effective.

Although the amphibian ambulance has been tested in and around IIT Guwahati, due to expensive logistics of taking it to actual target area, actual field trial in real life situation has not been done extensively. Thus actual performance is not available. Due to ease of prototyping, the various components of the amphibian ambulance have been fabricated in mild steel. They are heavy in weight and maintenance is required regularly, since mild steel gets rusted. To make the ambulance lighter in weight and easy to operate and free from rusting etc., many parts can be manufactured in aluminium tubular structure. This will increase the cost of the product and initial investment for machineries since welding aluminium requires special machineries like TIG/MIG welding which are not common. This will also limit repairing of the vehicle anywhere because of its aluminium components. However, ease of operating the ambulance will be higher when aluminium is used.

The research work being a mixed one, it was necessary to apply both qualitative and quantitative research methodology. The validation of the design of the amphibian ambulance has been done by both qualitative and quantitative assessment methodology. Therefore, subjective and objective responses mixed with direct observation formed the basis for result obtained in the research. Since number of participants for the experiments was less, the validity of the designed experiments depends on the feedback of the limited number of participants and outcome may vary with larger number of participants. This is one limitation of the research. This part may be considered in future research.

7.4.1 Future scopes

There are possibilities for further development of the design in different variation such as public transportation, as a means of recreational amphibian tricycle throughout India.

Another area for further research is regarding the conversion of this amphibian ambulance to an electric powered one using photovoltaic solar panels for charging the storage battery and then propelling the ambulance through electric motor.

In addition, the designed amphibian ambulance can be used in semi urban and urban areas at the time of flash flood. This has been the opinion of the people from Guwahati city who have seen this product in IIT Guwahati and they have found it to be justified. Guwahati city regularly gets flooded in monsoon due to flash flood.

7.4.2 Contextual design and appropriate technology transfer

For the contextual design and appropriate technology transfer for making the amphibian ambulance available in the target areas, different agencies, local NGOs, and local SMEs has been approached. Thus, there is a scope for future work for commercialisation in the target areas that can be explored.

Appendix- A

Calculation of pedaling based on **Figure 4.16** (page. 93).

Number of revolution of crank wheel given by= S_1 rpm

Number of revolution of sprocket wheel fixed with intermediate axel given by= S_1

Number of teeth of crank wheel given by T_1= 48 T

Number of teeth of sprocket wheel at rear axle given by T_2= 27 T

Then, $S_1/S_2 = T_2 / T_1$

Since, S_1 is 1, $S_2 = T_1 / T_2$ = 48/ 27= 1.78 i.e. for every rotation of the pedal by rider, the rear wheel will rotate by 1.78 turns.

Here gears ratio is T_1 / T_2 = 48/27= 1.78

Considering the diameter (d) of the rear wheel as 71 cm (28"), in one pedaling, the tri wheeler will travel a distance of $S_2 \times \pi \times d$= 1.78 × 3.14 × 71= 397 cm or 3.97 metre.

To travel one kilometre, numbers of pedaling required will be= 1000/3.97= 252 times.

For two stage gear reduction through introduction of intermediate shaft

Number of revolution of crank wheel given by= S_2 rpm

Number of revolution of sprocket wheel fixed with intermediate axel given by= S_1 rpm

Number of teeth of crank wheel given by T_1= 48 T

Number of teeth of driven sprocket wheel at intermediate shaft given by T_2= 22 T

Number of teeth of driver sprocket wheel at intermediate shaft given by T_3= 27 T

Number of revolution of sprocket wheel fixed to rear axle given by S_3

Number of teeth of sprocket wheel fixed to rear axle given by T_4= 27 T

Then, $S_1/S_2 = T_2 / T_1$

Since, S_1 is 1, $S_2 = T_1 / T_2$ = 48/ 22= 2.18

Again, $S_2/S_3 = T_4 / T_3$ or $S_3 = S_2 \times T_3 / T_4 = T_1 / T_2 \times T_3 / T_4$ (replacing S_2 with T_1 / T_2)

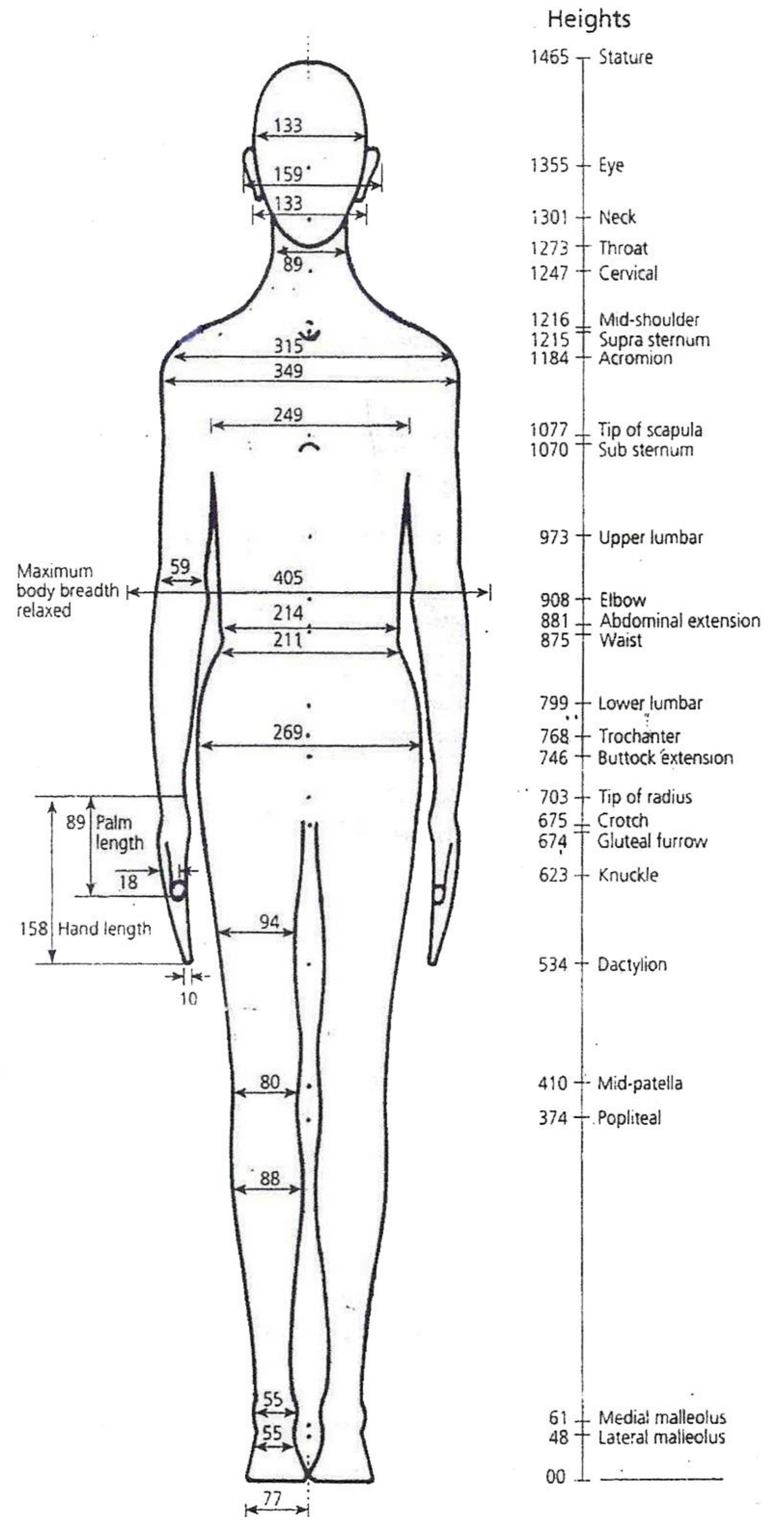
S_3= 48/22× 27/22= 2.18 x 1.22= 2.65

For every rotation of the pedal by rider, the rear wheel will rotate by 2.65 turns. Here gears ratio is $T_1 / T_2 \times T_3 / T_4$= 48/22× 27/22= 2.65

Considering the diameter (d) of the rear wheel as 71 cm (28"), in one pedaling, the tri wheeler will travel a distance of $S_3 \times \pi \times d$= 2.65 × 3.14 × 71= 593 cm or **5.93 metre.**

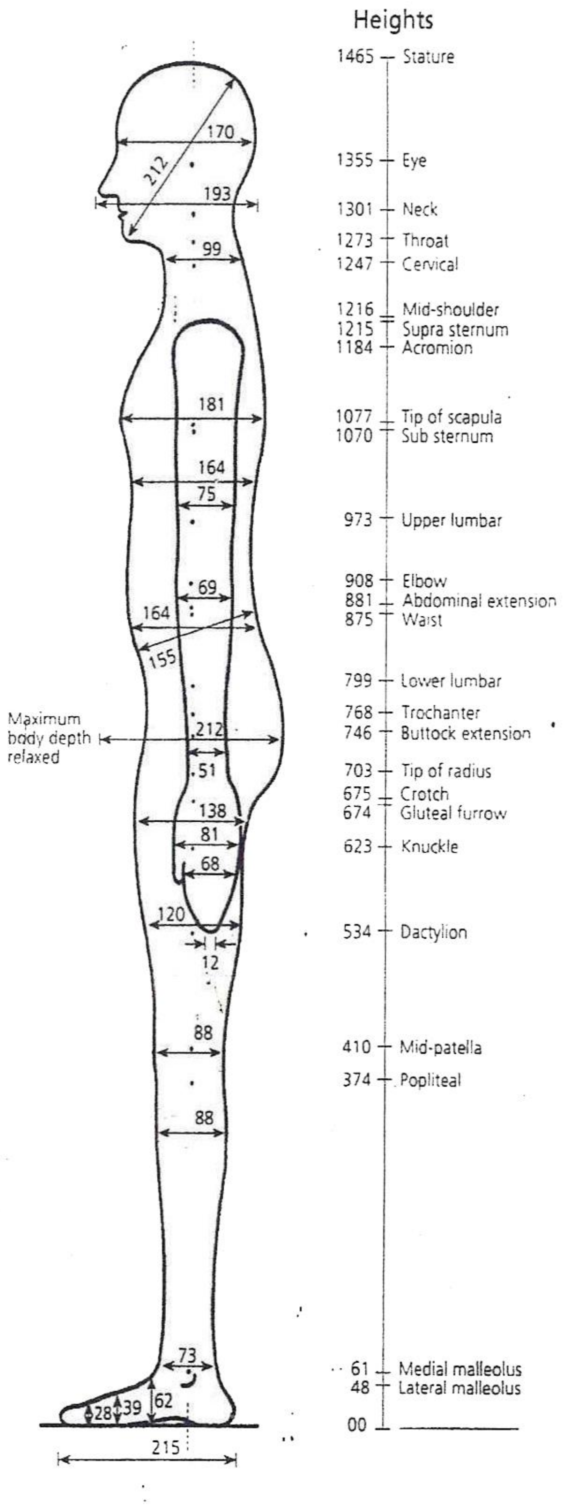
To travel one kilometre, number of pedaling required will be= 1000/5.93= 168 times.

Appendix- B



(Note: All dimensions are in mm.)

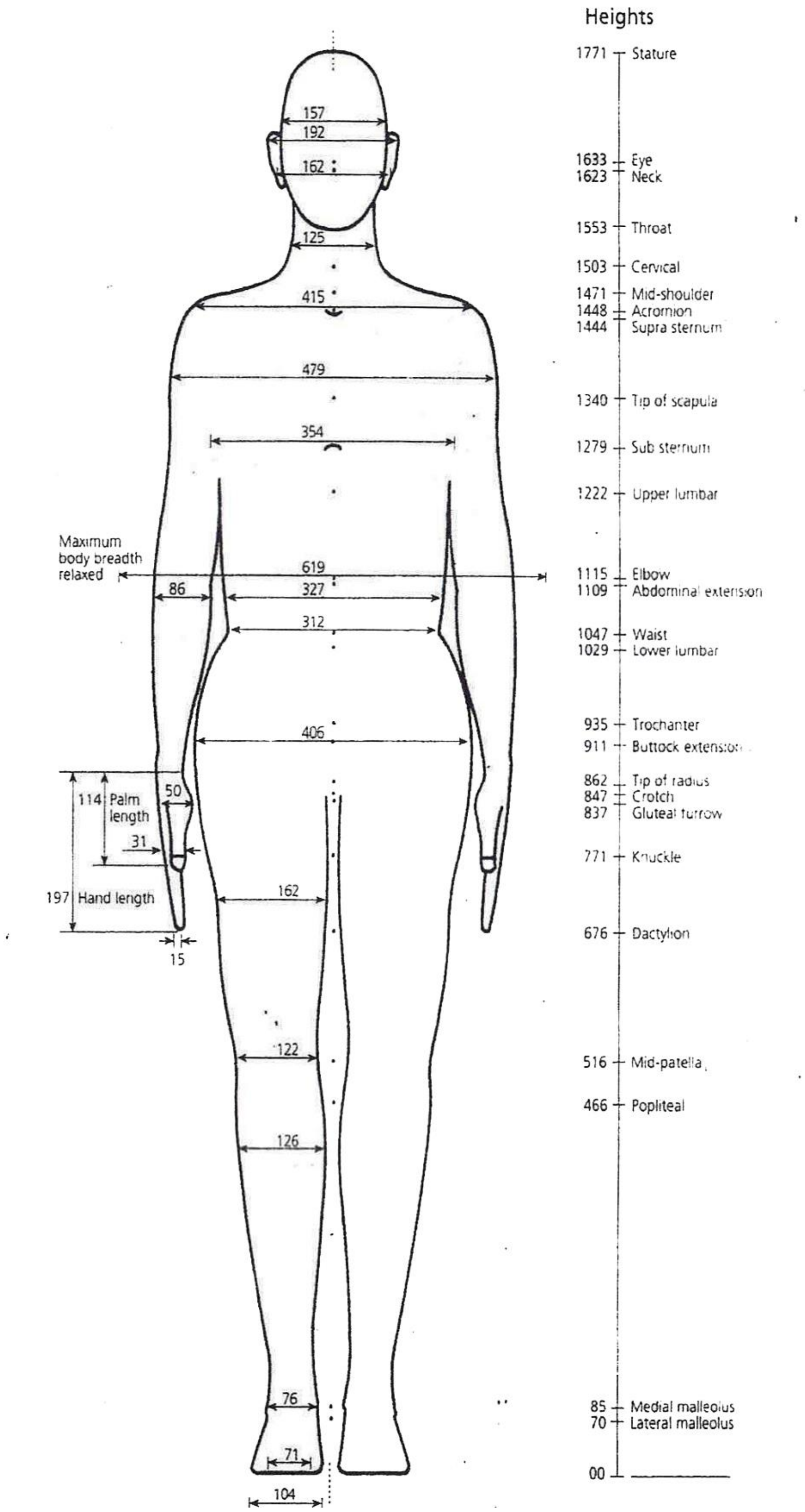
Figure App_B.1: 5th percentile Indian human body (front) dimensions; weight: 40 Kg; (Chakrabarti, 1997).



(Note: All dimensions are in mm)

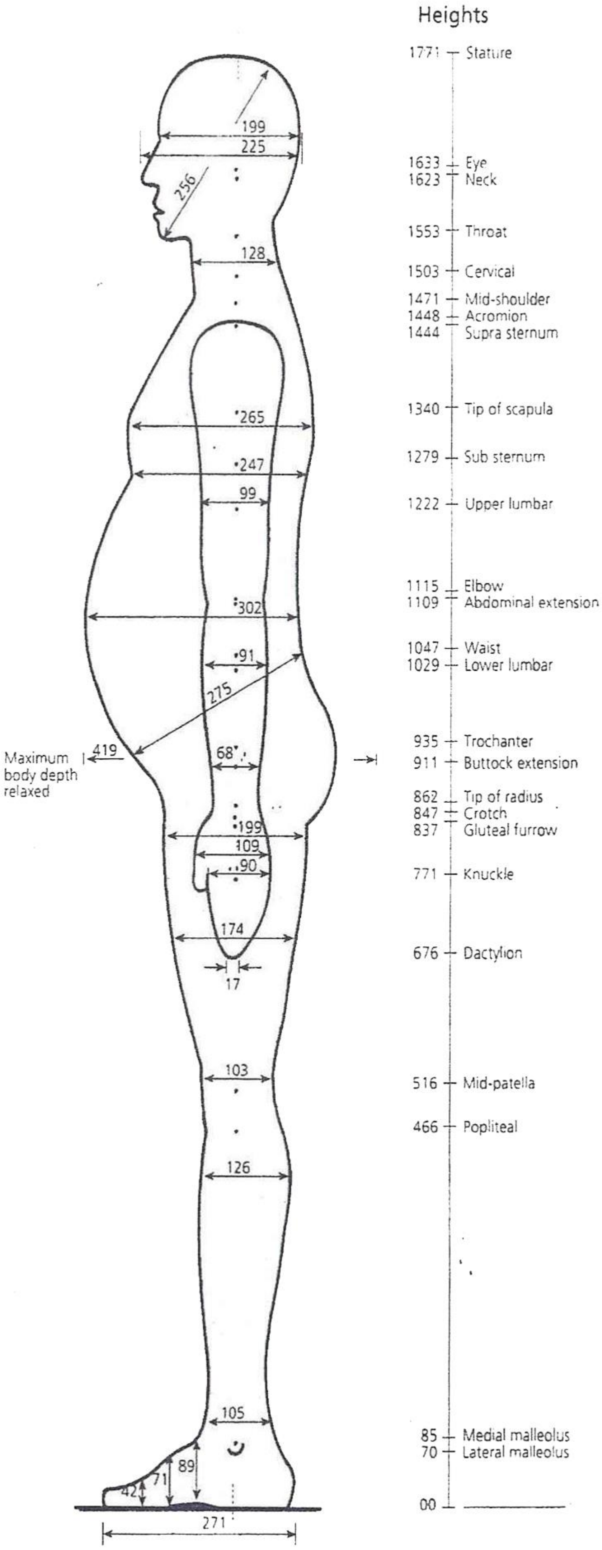
Figure App_B.2: 5th percentile Indian human body (side) dimensions; weight: 40 Kg; (Chakrabarti, 1997).

Appendix- B (continue)



(Note: All dimensions are in mm.)

Figure App_B.3: 95th percentile Indian human body (front) dimensions; weight: 74 Kg; (Chakrabarti, 1997).



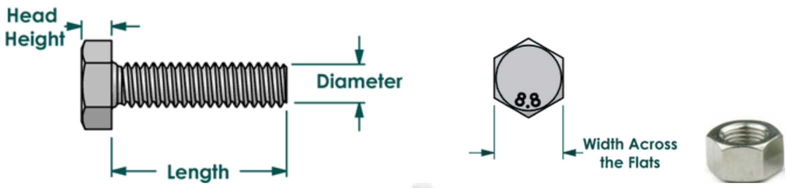
(Note: All dimensions are in mm.)

Figure App_B.4: 95th percentile Indian human body (side) dimensions; weight: 74 Kg; (Chakrabarti, 1997).

Appendix- C

1. Nuts and bolts

1.1 Hexagon nut and bolt (IS 4016)



Source: IS 1363 (Part 1): 1992, ISO 4016: 1988
Bureau of Indian Standards (BIS)
(Note: All dimensions are in mm.)

Sl. no.	Bolt				Bolt and nut		Description (Used in)
	Head height	Length	Dimeter	Width across the flats	Grade	Quantity	
1.	4.37	25	6.48	10.89	M6	6 nos.	Mudguard of the amphibian ambulance
2.	4.37	25	6.48	10.89	M6	4 nos.	Door latches in both sides
3.	3.6	34	5.52	10.89	M6	6 nos.	Rudder steering
4.	5.3	57	7.42	14.2	M8	12 nos.	Catamaran hull outer
5.	5.3	57	7.42	14.2	M8	2 nos.	Rear holding bar
6.	5.3	58	7.42	14.2	M8	1 no.	Rudder plate (rear side)
7.	5.3	58	7.42	14.2	M8	14 nos.	Internal sub-system
8.	5.3	58	7.42	14.2	M8	12 nos.	Pulley
9.	3.45	43	7.42	14.2	M8	16 nos.	Oil less spring for door opening
10.	3.45	43	7.42	14.2	M8	6 nos.	Oil seal

1.2 Spotted pan head screw bolt (IS 6101)

Source: IS 6101: 2005, ISO 1580: 1994
Bureau of Indian Standards (BIS)
(Note: All dimensions are in mm.)

Sl. no.	Bolt				Bolt and nut		Description (Used in)
	Head height	Length	Dimeter	Width across the flats	Grade	Quantity	
1.	3.625	17	5.52	10.89	M6	48 nos.	Paddle wheel
2.	3.625	17	5.52	10.89	M6	8 nos.	Rudder

Appendix- D

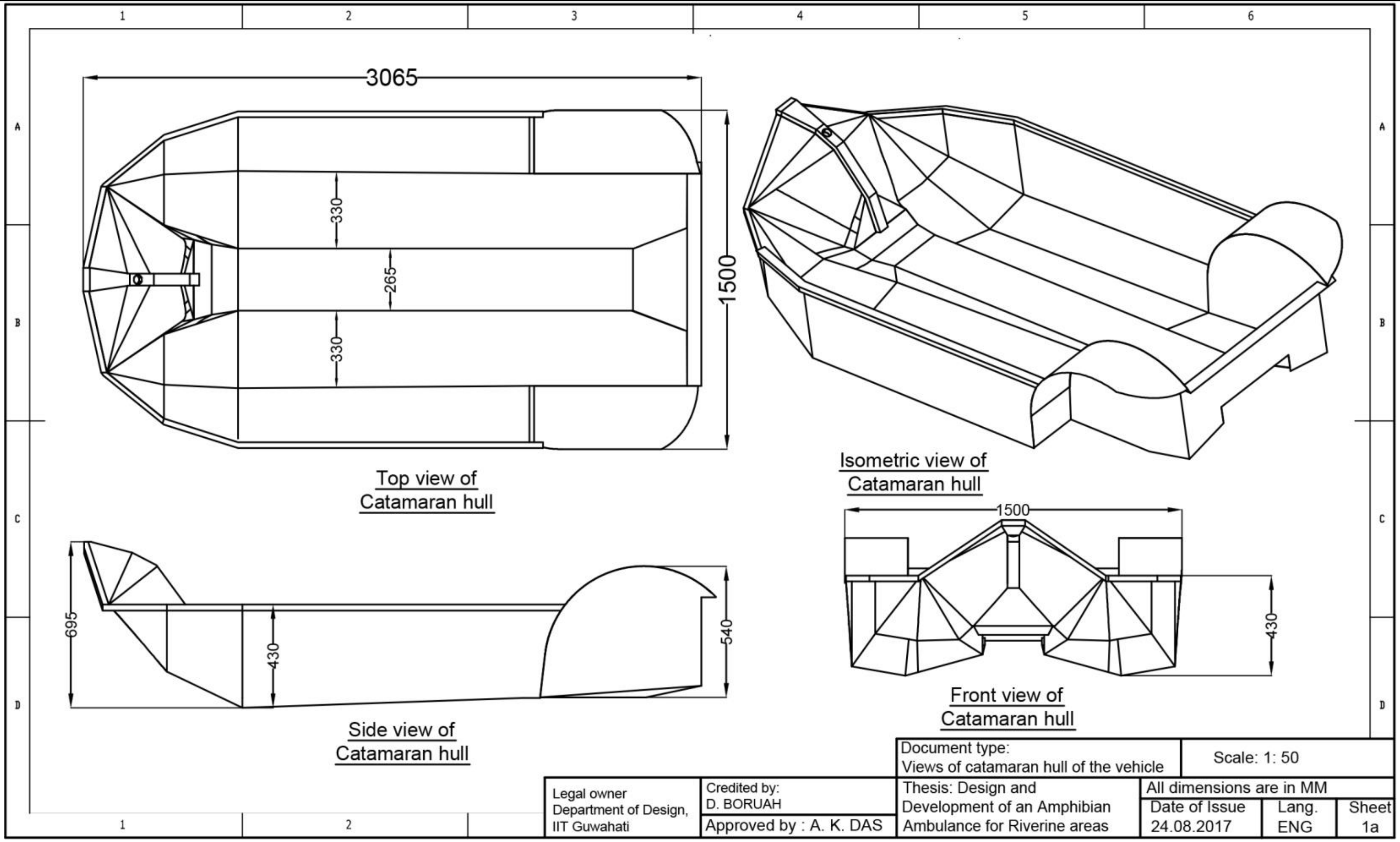
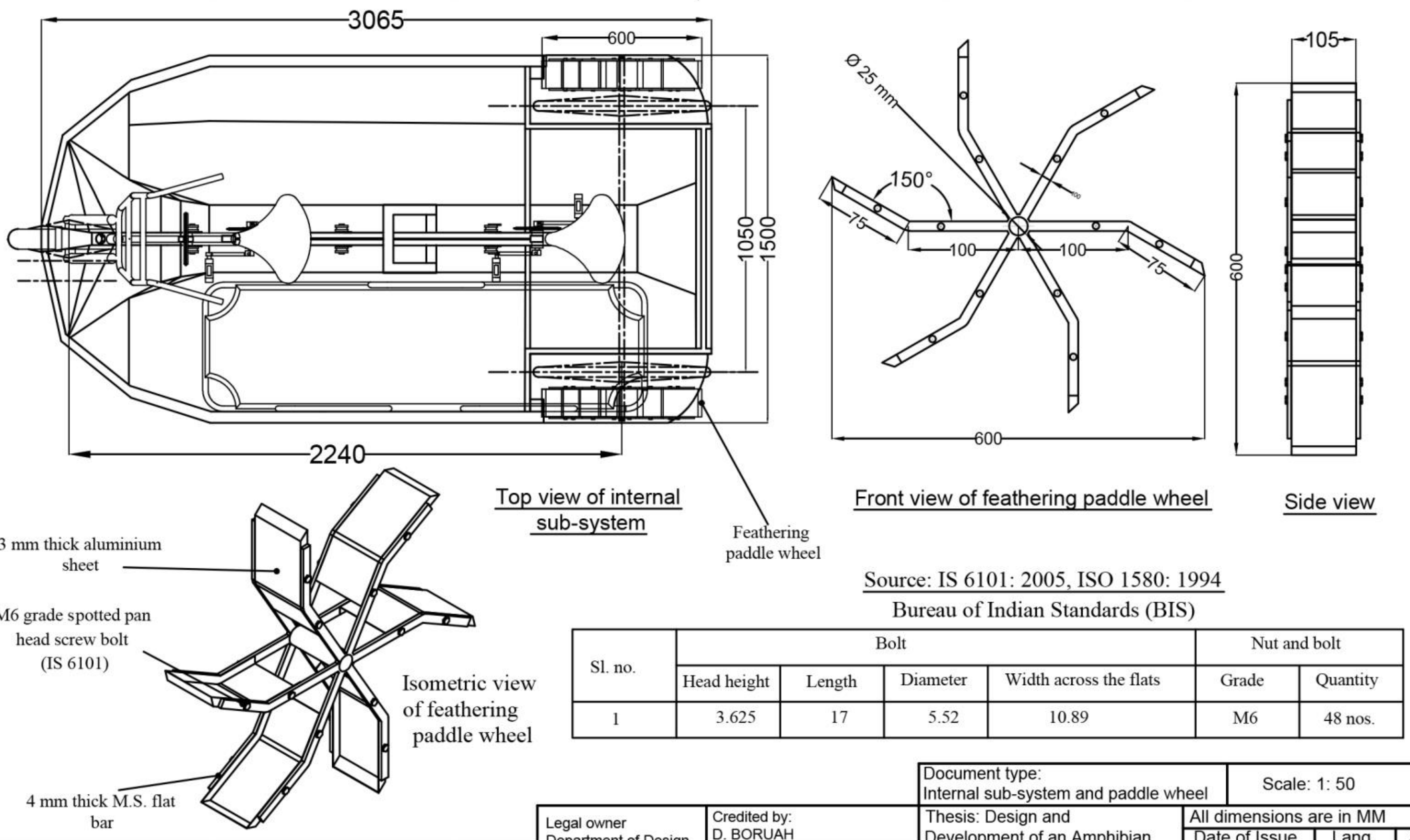


Figure App_D.1: Views of the catamaran hull of the amphibian ambulance.



Source: IS 6101: 2005, ISO 1580: 1994

Bureau of Indian Standards (BIS)

Sl. no.	Bolt				Nut and bolt	
	Head height	Length	Diameter	Width across the flats	Grade	Quantity
1	3.625	17	5.52	10.89	M6	48 nos.

			Document type: Internal sub-system and paddle wheel	Scale: 1: 50		
Legal owner Department of Design, IIT Guwahati	Credited by: D. BORUAH		Thesis: Design and Development of an Amphibian Ambulance for Riverine areas	All dimensions are in MM		
	Approved by : A. K. DAS			Date of Issue 24.08.2017	Lang. ENG	Sheet 1b

Figure App_D.2: Views of internal sub-system and paddle wheel.

Appendix- D (continue)

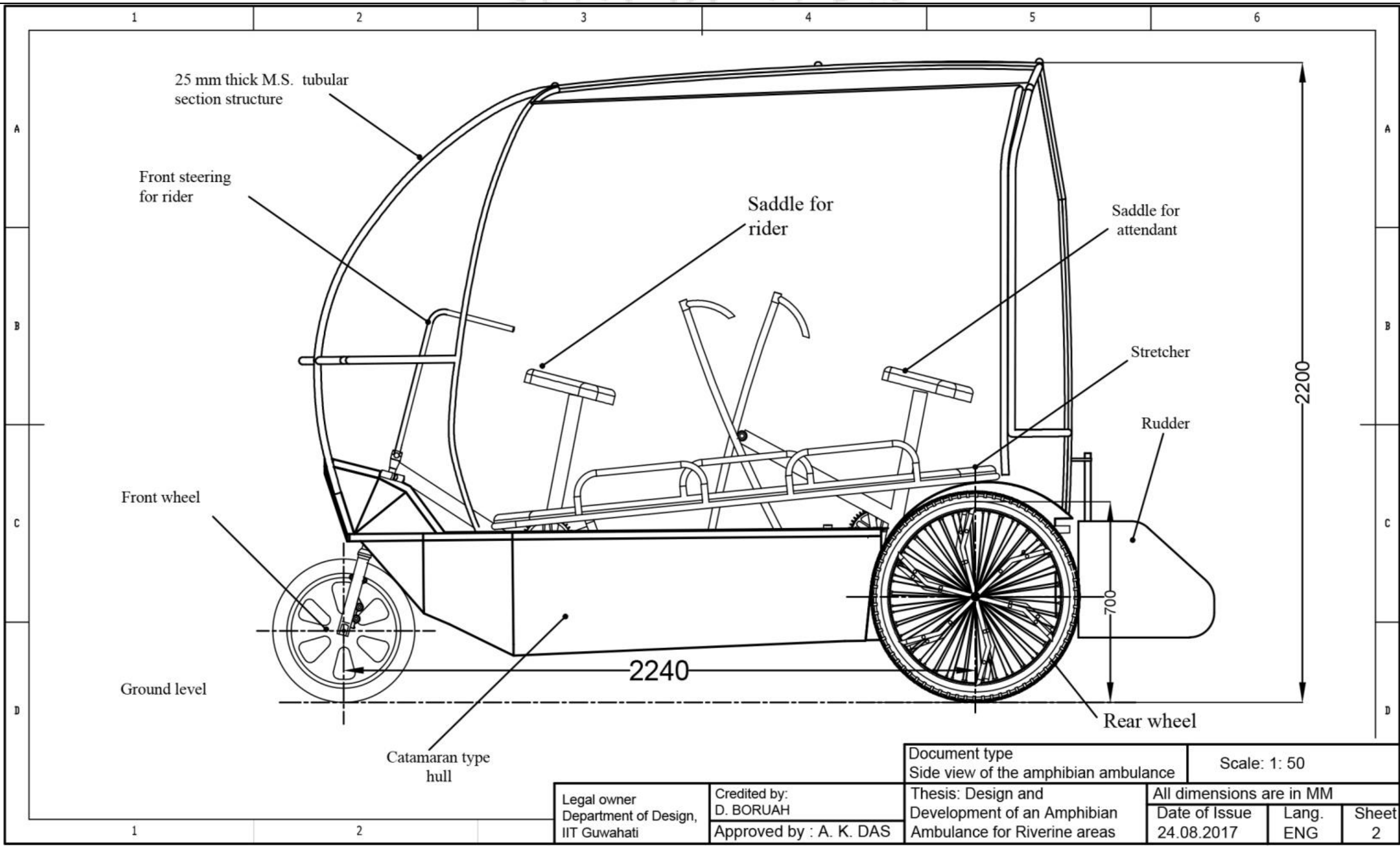


Figure App_D.3: Side view of the amphibian ambulance.

Appendix- D (continue)

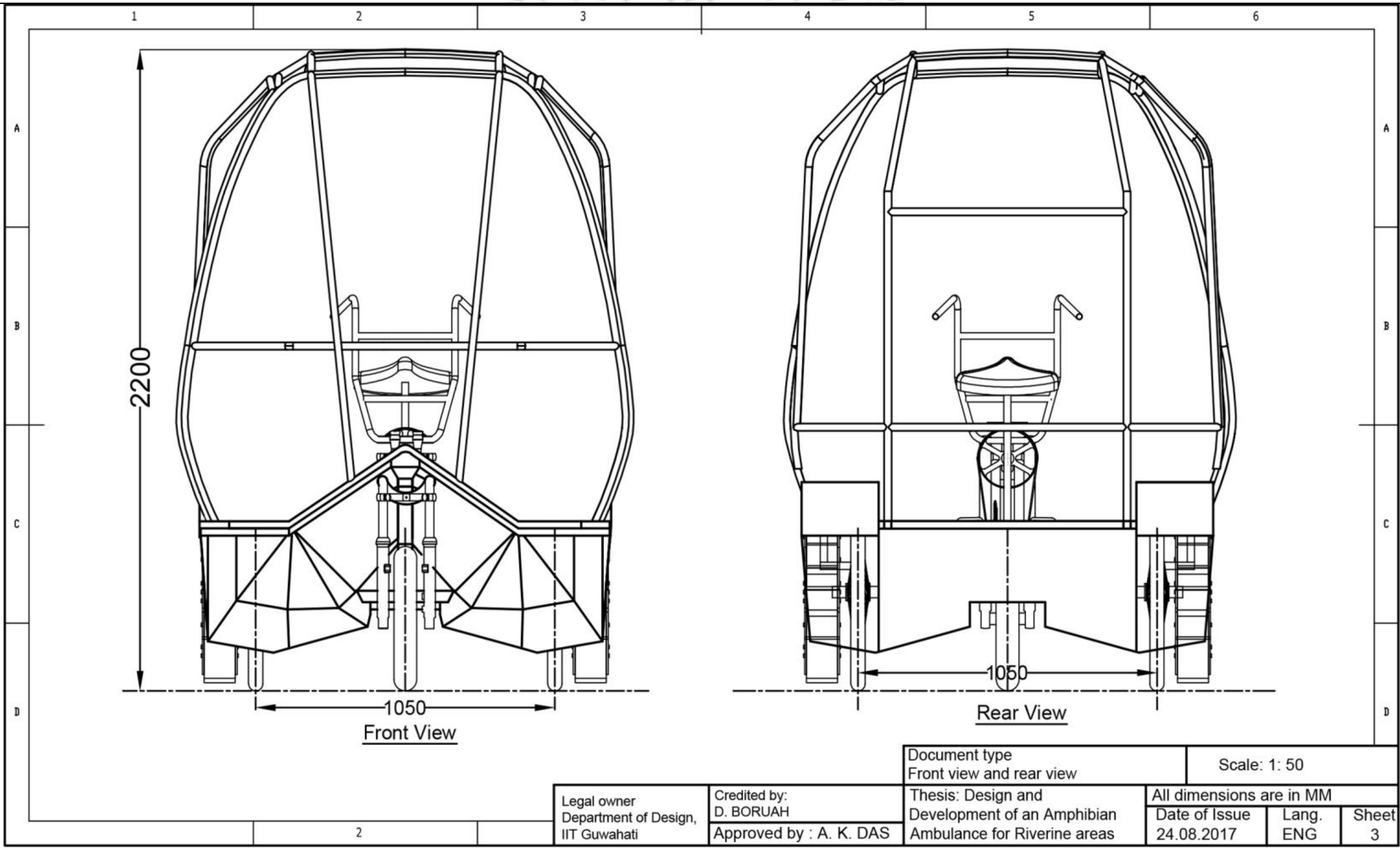


Figure App_D.4: Front and rear view of the amphibian ambulance.

Appendix- D (continue)

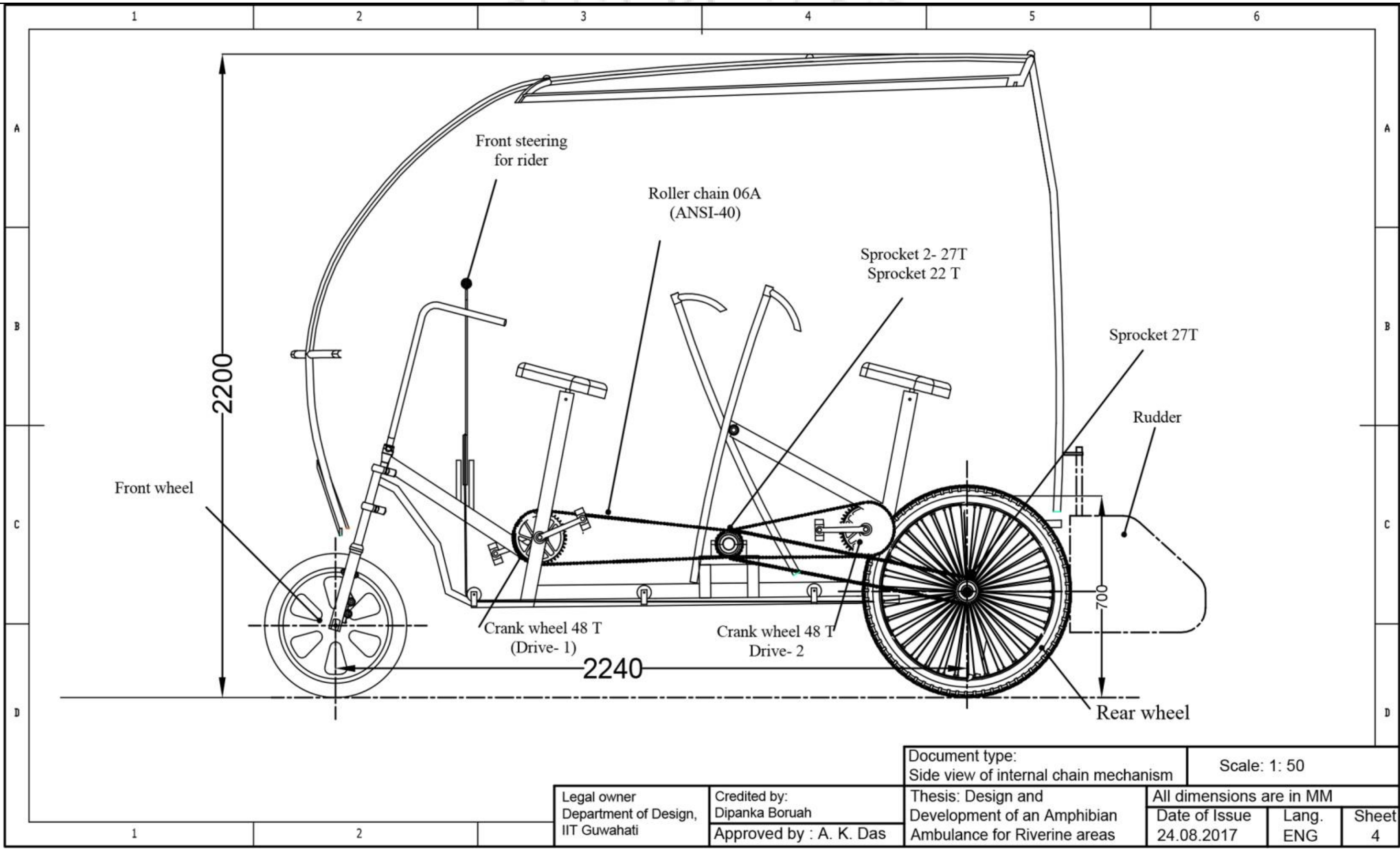


Figure App_D.5: Side view of internal chain mechanism of the amphibian ambulance.

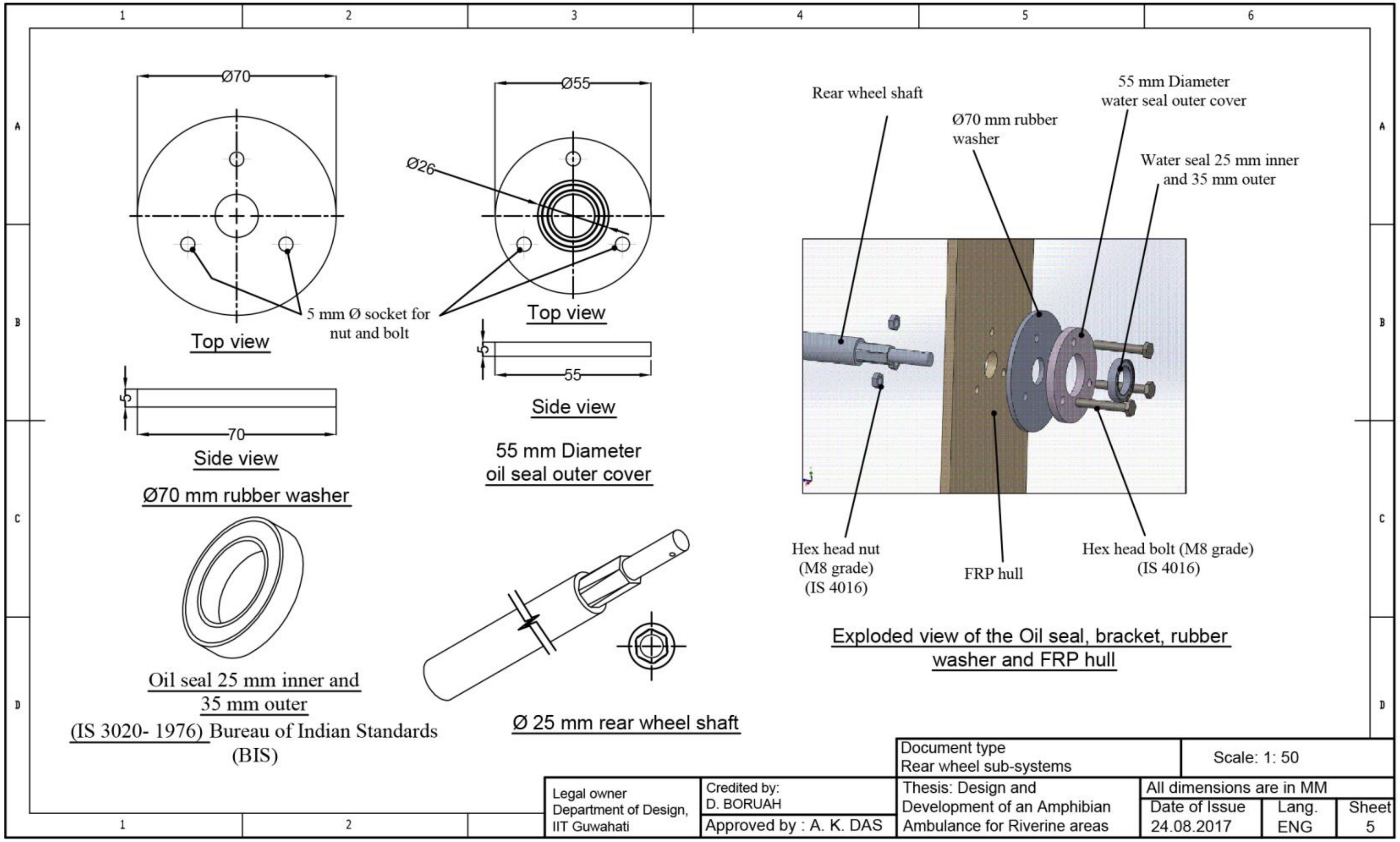


Figure App_D.6: Rear wheel sub-systems of the amphibian ambulance.

Appendix- D (continue)

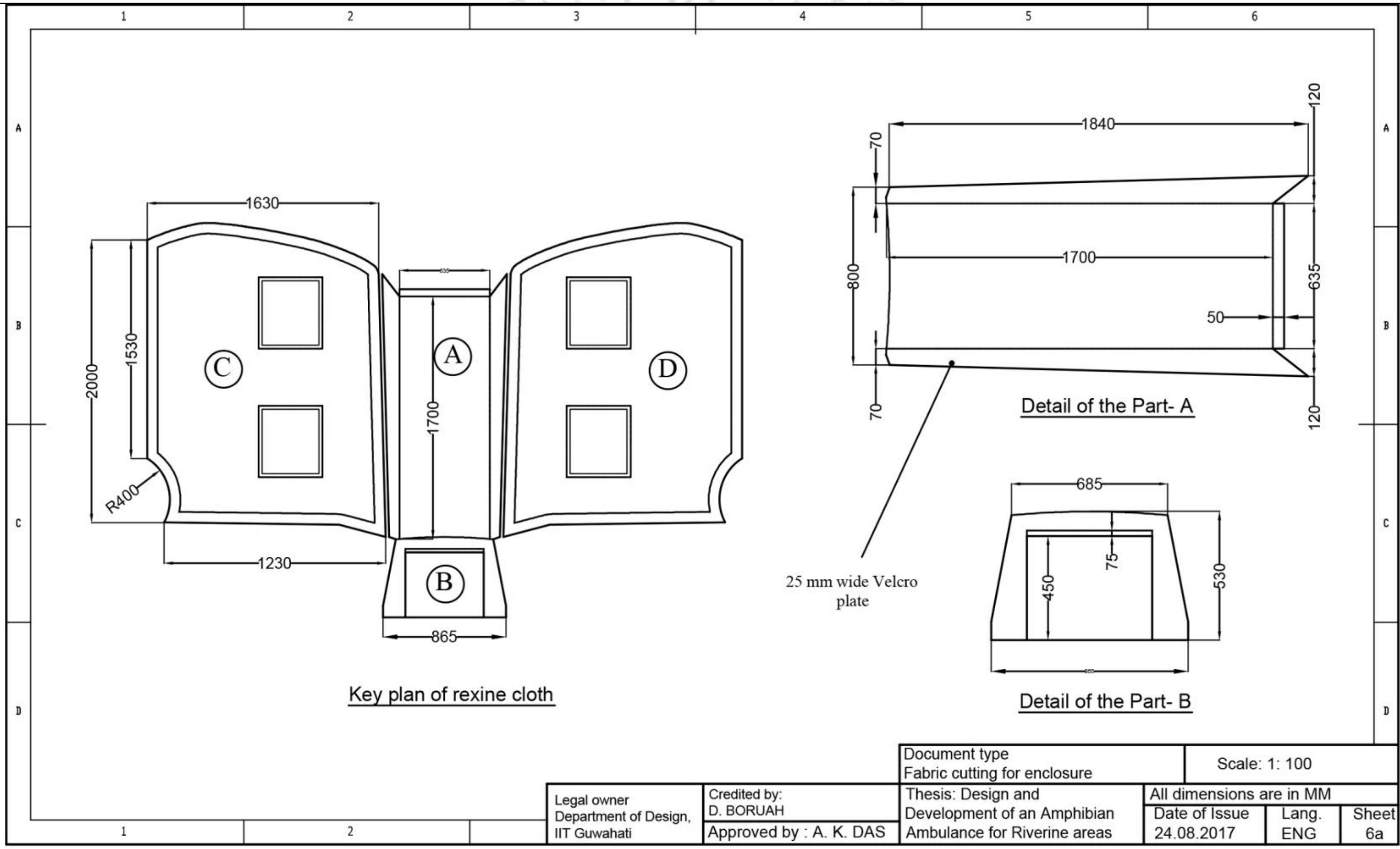


Figure App_D.7: Details of fabric cutting of the tubular enclosure.

Appendix- D (continue)

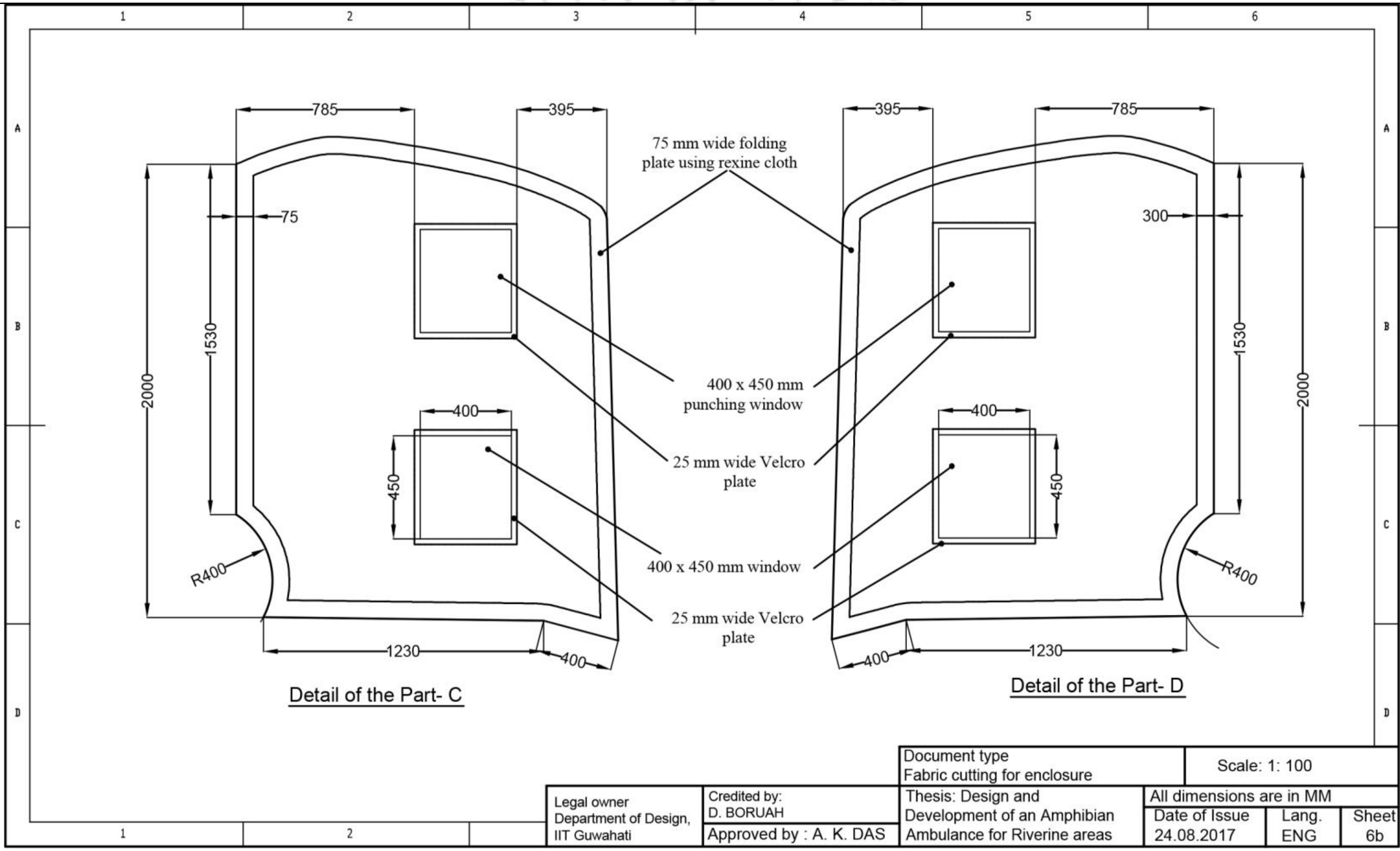
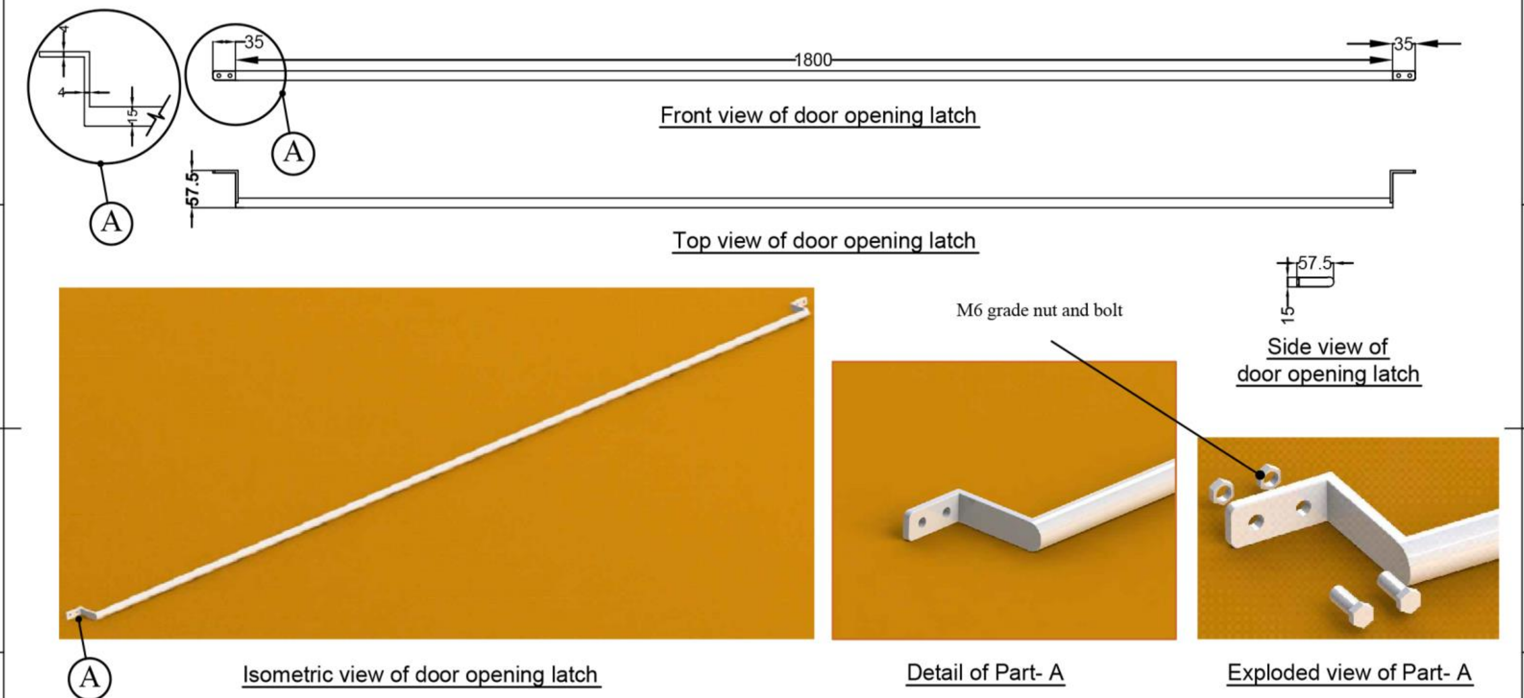


Figure App_D.8: Details of fabric cutting of the tubular enclosure.



Sl. no.	Bolt				Nut and bolt	
	Head height	Length	Diameter	Width across the flats	Grade	Quantity
1	4.37	25	6.48	10.89	M6	8 nos.

Source: IS 1363 (Part- 1): 1992, ISO 4016: 1988
Bureau of Indian Standards (BIS)

		Document type Door opening latch		Scale: 1: 100	
Legal owner Department of Design, IIT Guwahati	Credited by: D. BORUAH	Thesis: Design and Development of an Amphibian Ambulance for Riverine areas	All dimensions are in MM		
	Approved by : A. K. DAS		Date of Issue 24.08.2017	Lang. ENG	Sheet 7

Figure App_D.9: Details of door opening latch.

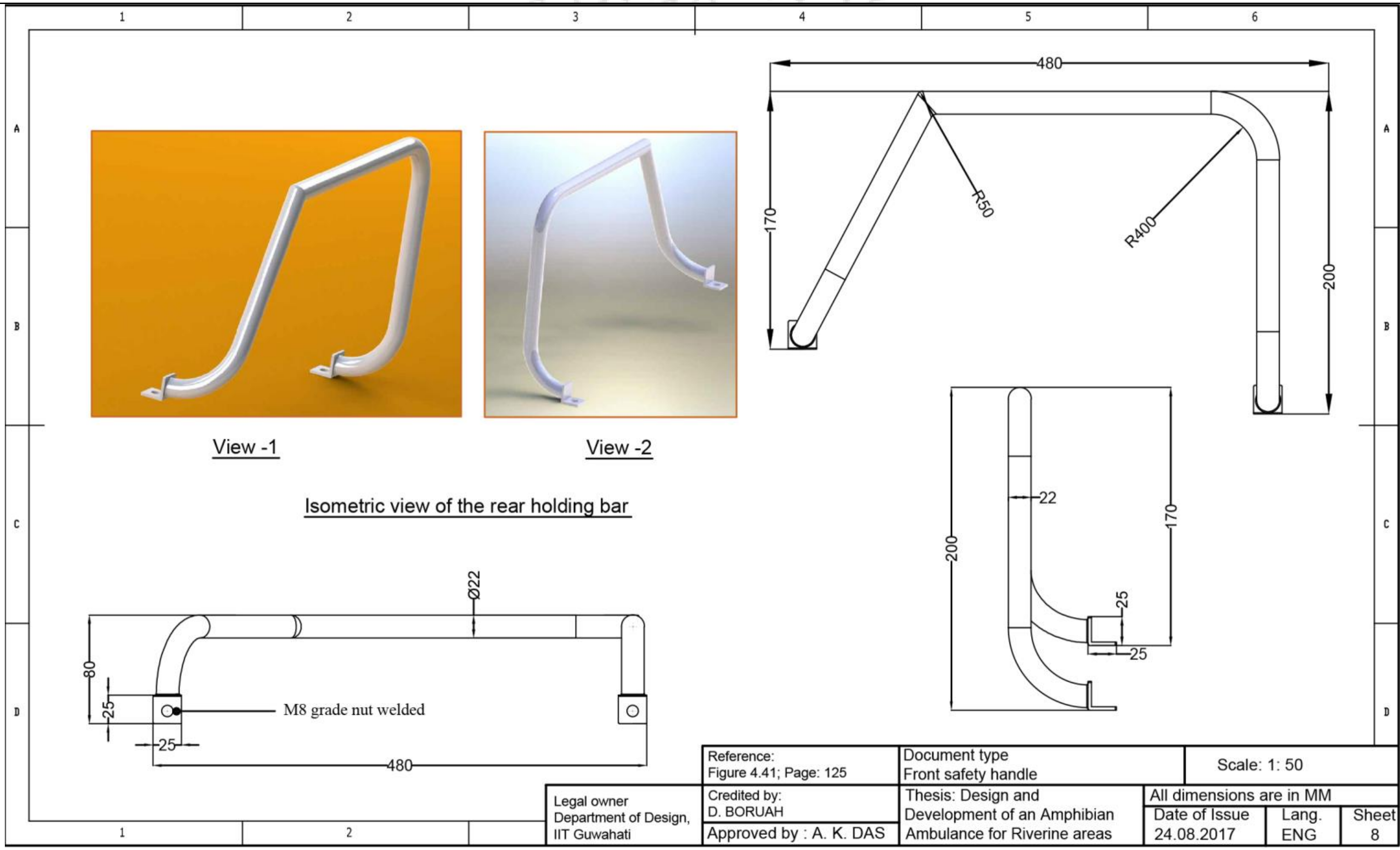


Figure App_D.10: Details of front safety handle of the amphibian ambulance.

Appendix- D (continue)

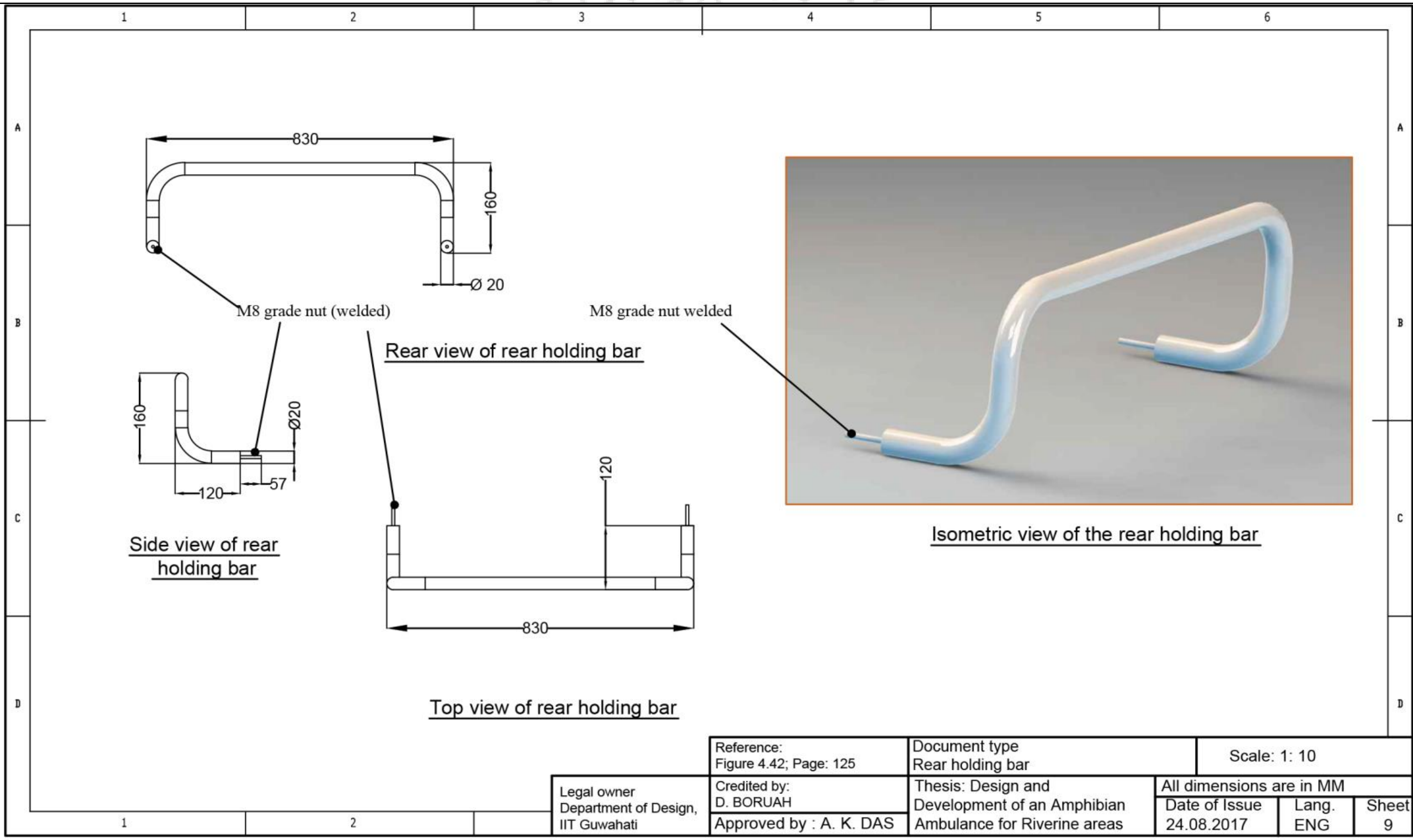


Figure App_D.11: Details of rear holding bar of the amphibian ambulance.

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